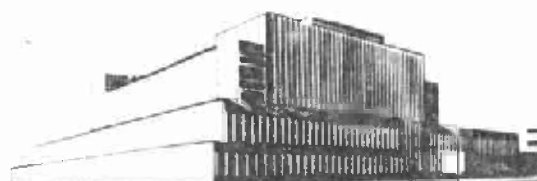


SUMMARY OF INFORMATION ON GLUING OF TREATED WOOD

Revised April 1959

Information Reviewed and Reaffirmed 1965

No. 1789



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

SUMMARY OF INFORMATION ON GLUING OF TREATED WOOD¹

By

M. L. SELBO, Chemical Engineer

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

Introduction

Production of glued laminated wood products suitable for unprotected exterior use dates back to the development of resorcinol and phenol-resorcinol glues, about 1943. Glues available before that time either lacked necessary water resistance or required very high curing temperatures, such as those used for exterior-type plywood. Because the resorcinols provided highly durable bonds when cured at moderate temperatures, interest soon shifted to the problem of making the wood as durable as the glue under conditions of service favoring decay.

An urgent need for production of preservative-treated laminated structures has been evident for some time. Research on laminating has done much to improve the design and usefulness of such structures as wood ships and boats, bridges, and many types of buildings. The need to increase the potential service life of such structures where the wood is exposed to decay justifies the use of preservative treatment.

There are essentially two methods for making preservative-treated laminated members, (1) by treating the already glued and machined laminate, or (2) by treating the lumber and then gluing members of the required size and shape. Both methods have advantages and disadvantages. Treatment of the laminated

¹This report is based on results obtained in a number of investigations at the Forest Products Laboratory, in industrial laboratories, and in commercial operations, some of which have been reported in Proceedings of the American Wood-Preservers' Association.

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

member permits application of preservative after all cutting, boring, and other framing have been done and assures a protective coating on all exposed surfaces. Handling of material at the treating plant is often simplified when the finished members rather than the lumber are treated. Probably the most serious disadvantage of this method is the necessarily limited size of treating cylinders, which precludes treatment of larger timbers and particularly of curved ones. Penetration of the preservative has been found to be blocked by the glue line to some extent, and this is, of course, an obvious disadvantage. Furthermore, when only the outer layer of a member is treated, checks that develop later in service may allow decay to start. On the other hand, bridge timbers produced by this method (pressure treated with creosote or creosote and oil mixtures after gluing) are in excellent condition after more than 14 years of service.

Wood already pressure treated with preservatives has the advantage that it can be used to produce members of practically any size and shape that are thoroughly impregnated. By proper selection of materials, thin laminations can be given complete penetration with preservative chemicals; this, as a rule, is not possible with large timbers. Laminated members produced from such treated stock can safely be shaped and bored without exposing untreated material. A disadvantage of this method is the fact that each treated lamination must be surfaced prior to gluing. This removes part of the treated wood and may expose untreated wood if complete penetration has not been obtained.

Of the two methods, treatment after gluing is, in general, the most practical and economical. When laminated members do not lend themselves to treatment because of their size or shape, however, the gluing of treated material is the only known method of producing adequately treated members.

Studies on gluing of wood treated with wood preservatives and fire-retardant chemicals have been undertaken from time to time by various workers and organizations. Gluing of this type of material has also been done to a certain extent on a commercial scale since about 1954.

The results obtained from the research, however, have varied a great deal and have not been sufficiently conclusive to furnish bases for general recommendations for many of the preservatives and species involved. The reason for the apparent lack of uniformity in results is not always clear and may be attributed to a certain extent to variations in the characteristics of woodworking adhesives, even of the same type, to the type of treating chemicals, and to the variable treating characteristics of wood, even of the same species.

In spite of variations in results by different workers, there are now adequate data to show that certain combinations of glue and preservative treatments are compatible under prescribed conditions of gluing, whereas others appear to require further study both on a laboratory and commercial scale before definite production procedures can be formulated.

The gluing of treated wood has been successfully accomplished with certain preservative, species and adhesive combinations. All preservatives and glues are not, however, equally compatible, and the conditions that lead to good, durable bonds on untreated wood are not always directly applicable to treated wood.

Certain basic principles that apply to gluing of untreated wood do hold true to a certain extent for gluing treated wood. It is well known, for example, that in gluing untreated wood there is usually considerable difference in the gluing properties of the different species, the denser woods being in general more difficult to glue than the lighter ones. The same also applies more or less to treated wood, although the bonding of treated wood is also dependent upon the concentration of preservative on the surface at the time of gluing and upon the chemical effect of the preservative on the glue. A reasonably clean joint surface is required in the bonding of untreated wood, and this appears to apply also to treated wood. There seems to be fairly good agreement among workers that where gluing of treated lumber is involved, surfacing after treating (preferably shortly before gluing) is required, and unless otherwise indicated throughout this report it may be assumed that the lumber was resurfaced after treatment.

The purpose of this report is to correlate and summarize results obtained in various studies on gluing of treated wood and to attempt to formulate recommendations that might be helpful to anyone who would have need for gluing this type of material.

No attempt has been made to analyze or comment on all of the data available. Much of the work has been done with relatively small specimens, with which the problem of avoiding contamination on the gluing surfaces would be less than in a commercial operation where larger laminations usually would be involved. Furthermore, the data often consist of results of a rather limited number of dry block shear tests, which may not necessarily be an adequate evaluation of the joints for exterior or other severe service where treated material ordinarily would be used. Most of the information in this report is concerned with tests simulating service conditions or accelerated laboratory tests. Likewise, more emphasis has been given to the gluing of treated lumber, since less information is available on the gluing of treated veneer.

The recommendations made and the curing schedules for glues shown in this report have been formulated with the expectation that the glued members should withstand exterior exposure. Where the treatment is intended mainly for resistance to termites and similar hazards and the glued members will be protected from the weather, possibly milder curing schedules would be sufficient.

Treating, Gluing, and Testing Procedures
Used in Laboratory Investigations

For the tests on the gluing of treated wood discussed in this report, the preservatives were all applied to the specimen material by pressure impregnation. Higher retentions than those normally used were employed to compensate for preservative lost in surfacing before gluing. Exceptionally high retentions were used for the water-borne copper compounds, because these preservatives are being considered for use where limited protection from marine borers is required.

All the glues used within recent years were brands that met the requirements for Specification MIL-A-397B for Class 2 adhesives (or earlier versions of this specification). Beams of untreated material were made simultaneously with those of treated material for use as controls. Both the minimum and maximum assembly times recommended by the glue manufacturer were often used in gluing beams of treated material. However, except with the poorer performing glues or where the curing temperature was not sufficiently high the results from minimum and maximum assembly times were not significantly different.

Tests for resistance to glue-joint delamination were made in accordance with ASTM Standard D1101-53 (sometimes slightly modified to conform with MIL-W-17445 (SHIPS)), and for joint strength in accordance with ASTM Standard D805-52 (Block Shear Test).

Effect of Treatments on Glue Joint Test Values

The block shear test results were often promising, and indicated that it is feasible to produce durable glue joints when laminating treated wood of several species, treatment, and glue combinations. Delamination was generally greater in treated beams than in untreated controls, but the results with some treated beams were considered well within acceptable limits. The data indicated that, in general, longer curing times or higher curing temperatures are needed for treated than for untreated wood to obtain comparable glue-bond quality in the two types of material.

High wood failures were obtained in glue-joint tests of both treated and untreated red oak, Douglas-fir, and Southern yellow pine, indicating that the glue bonds were about as strong in shear as the wood for several treatment-species combinations. In certain instances, there was some reduction in shear strength in the joints of the treated wood as compared to those in the untreated

controls. A separate study was therefore made to determine the effect of preservative treatment on the joint-shear strength of laminated red oak. The work was designed to continue the testing up to 3 years after gluing. The average reduction in joint-shear strength, as compared to that of untreated controls, based on tests made 2 weeks, 3 months, 6 months, 12 months, and 36 months after gluing is shown in table 1. A graphic presentation of the block-shear values of treated and untreated controls is given in figure 1.

These results show a consistent and statistically significant reduction in joint-shear strength value with all the treated materials, although there are considerable variations between treatments, from about 4 to about 16 percent. The salt-treated material in general developed high wood failures whereas the oil-treated material gave considerably lower wood failure values. There was, however, no significant change in wood failures throughout the test period with any of the treatments.

It can be seen in figure 1 that, after 3 months of aging, a significant reduction in block-shear strength had occurred for both treated and untreated red oak. From then on up to 3 years (end of test period) there was, in general, no great change. This would indicate that whatever weakening or lowering of block-shear strength occurs, it reaches its maximum in a few months, and thereafter there may not be any serious change under conditions similar to those used in the tests.

Gluing of Wood Treated with Oil-Soluble Preservatives

Since wood treated with oil-soluble preservatives goes, as a rule, into exterior or a similar type of service, only glues suitable for severe exposure conditions, such as phenol-resorcinol, resorcinol, and melamine resins, were considered.

Coal-Tar Creosote

It is generally known that untreated woods that exhibit a great deal of oiliness are difficult to glue. Likewise, it was found that treated wood that exuded or "bled" creosote appreciably during final surfacing and gluing was extremely difficult to bond. Glue bonds of good quality were obtained in laboratory experiments with such wood by wiping the joint surfaces with dry rags or with rags dipped in solvents, such as acetone, immediately before spreading. This, however, involves an extra operation that may not readily lend itself to production methods, and at least would increase production costs.

With woods having a tendency to bleed, a thorough steam cleaning or cleaning by other methods prior to final surfacing and gluing may be the most practical

solution. Possibly effective solvents for creosote or vapors from such solvents could be employed to remove the excess creosote from the surface of the stock. Creosote-treated wood that appeared "dry" (did not bleed) when surfaced has been glued successfully on several occasions on a laboratory scale and at least once on a semicommercial or pilot-plant scale.

Southern yellow pine and Douglas-fir beams were laminated at the Forest Products Laboratory from creosoted material and exposed to the weather for about 6 years. The Douglas-fir used was vertical-grained material that took treatment unusually well for this species. The average retention for the Douglas-fir was 16 pounds per cubic foot and that for the pine 13 pounds. Both species were treated by the Rueping, empty-cell process. The Douglas-fir was furthermore steamed at 240° F. for 45 minutes, after which vacuum was applied for 30 minutes to remove excess creosote from the material. When bleeding occurred after surfacing for gluing, the excess was wiped off with dry rags. Gluing data and test results, original and after about 6 years' exposure, are given in table 2. Figure 2 shows 3 samples of a group of Southern yellow pine beams and figure 3 shows sample Douglas-fir beams. Aside from minor checks in the end grain these beams were still in excellent condition at the end of the exposure period.

The results of the delamination test in general indicated satisfactory glue bonds except in a couple of cases at the lower curing temperature where the delamination percentages were higher than those usually considered acceptable for severe service. The block shear test values in general also indicated adequate glue bonds, and there was no appreciable difference between the original test values and those made after about 6 years of exposure. Neither was there any visible difference after the exposure period between beams glued at the two temperatures.

Railroad-bridge stringers were laminated from pressure-treated southern yellow pine in a commercial plant (3), ³ and installed in a bridge over the Palm river in Florida. Cyclic delamination tests (ASTM D1101-53) made at the Forest Products Laboratory on sections from these stringers indicated that, in general, they were well bonded, and this has now been born out by many years of service (fig. 4) (8). The creosoted stock used in these stringers appeared "dry," and there was no apparent bleeding after final surfacing.

Sections from similar stringers glued from Douglas-fir in a commercial plant (2) developed considerable delamination when exposed to accelerated tests at the Forest Products Laboratory, and did not appear to be bonded adequately for exterior service. It was reported that the material used for these

3

³—Underlined numbers in parenthesis refer to Literature Cited.

stringers showed considerable bleeding when surfaced for gluing. The curing temperatures used for the pine stringers were considerably higher than those used for the Douglas-fir, and results obtained on gluing treated wood at the Forest Products Laboratory have indicated improvement in bonding with increased curing temperatures. The effect of bleeding when the material was surfaced for gluing has been apparent, however, even when high curing temperatures have been used.

In one test at the Laboratory red oak and hard maple (sapwood) were treated to about the same retention and glued with phenol-resorcinol and resorcinol types of glues. Curing temperatures used were 150° F. for the resorcinol and 200° F. for the phenol-resorcinol glues. Excellent results were obtained in cyclic delamination tests (ASTM D1101-53) on the maple, but the results on the oak indicated inadequate bonds. The oak "bled" during final surfacing and gluing, whereas the maple was "dry."

With respect to curing temperatures required for gluing creosoted wood, adequate bonds have been obtained with some resorcinol glues on yellow pine when using temperatures as low as 80° F. Good results have been obtained more consistently, however, with curing temperatures of about 150° F. (table 1). On red oak good results have been obtained with some resorcinols when cured at 150° F. and with some phenol-resorcinols when cured at 210° F. (in both cases chamber temperatures). This work was with stock that did not show appreciable bleeding when surfaced for gluing.

No data are available on gluing wood treated with creosote mixtures containing petroleum oil or coal tar. It is expected, however, that the precautions that must be observed with creosote-treated wood would also apply to wood treated with the above mixtures; although, according to reports, more trouble with bleeding can be expected with solutions of creosote and tar and creosote and heavy fuel oil than with straight creosote.

Pentachlorophenol

The data available on gluing wood treated with oil solutions of pentachlorophenol indicate that the success of gluing wood treated with this preservative depends somewhat on the solvent or vehicle used. In a study made several years ago at the Forest Products Laboratory, where naphtha was used as solvent, practically no interference was noted in gluing of maple, red oak, southern pine, and Douglas-fir. When No. 2 fuel oil has been used for solvent, however, a certain amount of interference has often been observed, particularly when species having a tendency to bleed (red oak and Douglas-fir) were involved. In some work in which a light mineral spirit solvent was used, less interference with bonding was observed than when No. 2 fuel oil had been

used. It appears, therefore, that when wood treated with pentachlorophenol in an oily solvent is glued, the same precautions in regard to cleanliness of treatment are required, in order to consistently obtain adequate glue bonds, as were indicated for creosote. Where a highly volatile solvent is used, high-quality glue bonds might be obtainable without any particular precautions, except possibly that somewhat higher curing requirements might be necessary for gluing-treated wood (of certain species) than for untreated wood.

The results shown for pentachlorophenol-treated wood in tables 3, 4, and 5 were based on a treatment consisting of 5 percent pentachlorophenol in petroleum oil conforming to AWWA Specification P9 (light oil). The curing schedule used for red oak (table 3) produced generally satisfactory results. For Douglas-fir also (table 4) the gluing conditions used produced satisfactory results; whereas the average results with four glues on southern yellow pine (table 5) indicate that somewhat higher curing temperature might have been desirable. One of the four glues used, however, produced satisfactory results under the conditions shown in the table.

When gluing wood treated with oil-borne preservatives such as pentachlorophenol and copper naphthenate, it has sometimes been found beneficial to pass the boards through the spreader twice or even three times to obtain a uniform coverage with glue.

In gluing wood surfaces dip-treated with oil solutions of pentachlorophenols, adequate bonds were obtained unless the treating solutions contained waxes or other water-repellent and sealer ingredients in quantities that interfered with adhesion (7).

Copper Naphthenate

Copper naphthenate is often used with fuel oils or heavier oils as solvents, and although no data are available at Forest Products Laboratory on gluing of wood so treated, it is expected that the same precautions as indicated for creosote and oil solutions of pentachlorophenols would apply.

Copper naphthenate preservative is also sometimes used with rather volatile solvents (Stoddard solvent). The data available on gluing wood treated with it in such solvents indicate that adequate glue bonds can be obtained with adhesives of the phenol-resorcinol or resorcinol types. Some interference with bonding was observed in tests at the Forest Products Laboratory when treated red oak was glued with a melamine resin. Again higher curing temperatures appeared to be required for treated than for untreated wood, particularly where Douglas-fir was involved. For instance, when a phenol-resorcinol glue was cured at 80° F., the bonds on treated Douglas-fir were inadequate for exterior service, but this combination developed excellent bonds when the glue was cured at 150° F.

In tables 3 and 4 glue joint test results are shown for copper naphthenate-treated red oak and Douglas-fir where the treating solution consisted of copper naphthenate (0.5 percent copper) in petroleum oil conforming to AWWA Specification P9 (light oil). The results on red oak appear entirely satisfactory. The average delamination for the four glues used on Southern yellow pine, however, is rather high. The reason for the high average delamination was the mediocre performance of two of the glues; the results for the remaining two were satisfactory.

As indicated earlier, better glue coverage and bonding have sometimes been obtained by passing oil-treated wood twice through the glue spreader rather than the usual single pass.

Gluing of Wood Treated with Water-Borne Preservatives

When treatment with water-borne chemicals is used, the moisture content of the wood is appreciably increased and redrying is necessary. Upon being redried, the lumber generally is somewhat distorted, more or less covered with deposits of chemicals, and too variable in thickness to be suitable for good gluing, and resurfacing becomes necessary. When the material is resurfaced immediately before gluing, there appears to be, as a rule, less of a problem in gluing wood treated with water-borne preservatives than in gluing wood treated with oil-borne preservatives. As in the foregoing section only the use of resorcinol, phenol-resorcinol and melamine types of glues will be discussed here.

Tanalith (Fluor chrome arsenate phenol)

Laboratory tests on laminating of hard maple, red oak, and southern yellow pine treated with Tanalith (one of the Wolman salts) showed excellent results when phenol-resorcinol and resorcinol glues were used at curing temperatures of 200° F. At the same curing temperature, melamine glue also developed high-quality bonds on treated maple and red oak.

Certain resorcinol glues cured at 150° F. developed good bonds on treated hard maple, red oak, and southern yellow pine, and some resorcinols also gave good results on treated Douglas-fir and yellow pine at a curing temperature of 80° F. Certain phenol-resorcinols cured at 80° and 150° F., however, did not produce entirely satisfactory joints on Douglas-fir and yellow pine. There were the usual indications that higher curing temperatures were sometimes required to develop adequate bonds in Tanalith-treated (Wolmanized) than in untreated lumber.

The compatibility of phenol-resorcinol and resorcinol-resin glues with Wolmanized yellow pine and Douglas-fir have been reported in the AWP A Proceedings (4). The conclusions drawn were based on dry block-shear tests.

Sections of Wolmanized Southern yellow pine and Douglas-fir railroad stringers laminated with resorcinol glues by a commercial firm (3, 5) and subjected to cyclic delamination tests (ASTM D1101-53) at the Forest Products Laboratory generally appeared to be adequately bonded for exterior use. A number of arches for a locomotive shed were glued of Wolmanized Southern yellow pine about 14 years ago (5). It has been reported that these arches have given good service (1). One highway bridge in which the arches were laminated from Wolmanized lumber has been in service for more than 10 years and has of recent date been reported to be in satisfactory condition.

Tables 3, 4, and 5 show results on gluing Tanalith treated red oak, Douglas-fir and Southern yellow pine respectively. The results appear entirely satisfactory with each species and the curing conditions indicated by the tables should be a useful guide in gluing this type of material commercially.

Celcure (Acid copper chromate)

The data available indicate that wood treated with Celcure can be adequately bonded with melamine, resorcinol, and phenol-resorcinol types of glues. Evidence indicates, further, that higher curing temperatures may be required when gluing Celcure-treated than when gluing untreated wood.

Results of some of the more recent investigations at the Forest Products Laboratory on gluing wood treated with this preservative are given in tables 3, 4, and 5. The results on red oak appear entirely satisfactory; the average delamination for the four glues used on Douglas-fir and Southern yellow pine, however, is slightly higher than that obtained on red oak, mainly because one glue performed poorer than the others. The curing conditions indicated by the tables may serve as a guide for commercial gluing, although somewhat longer curing periods or higher temperature may be necessary.

Boliden Salt (Chromated zinc arsenate)

This preservative has been used commercially in the United States since 1951 and hence the investigations on gluing wood treated with it are more limited than with some of the other preservatives. Data available, however, indicate that reasonably good joints are obtainable on wood treated with this preservative, at least with certain adhesives of the resorcinol and phenol-resorcinol types. Under the curing conditions shown for red oak (table 3) two of the four

glues used gave excellent results, whereas with the other two glues the results were somewhat poorer. With Douglas-fir (table 4) one glue gave excellent results and the other three considerably poorer. Hence for commercial gluing of Douglas-fir more curing than that shown in table 4 may be required.

Greensalt or Erdalith (Chromated copper arsenate)

Work on gluing wood treated with this preservative at the Forest Products Laboratory has involved three species, red oak, Douglas-fir, and Southern yellow pine. Test results indicated that reasonably good bonds could be obtained with resorcinol and phenol-resorcinol adhesives on these species after treatment with Greensalt (tables 3, 4, and 5). With Southern yellow pine somewhat more curing than indicated in table 5 may be needed, although two of the glues used gave good results under the conditions shown.

Zinc Meta Arsenite

Work on gluing lumber treated with zinc meta arsenite at the Forest Products Laboratory has not been as extensive as with some other preservatives, but the results were very similar to those on gluing Celcure-treated stock. As a rule, good bonds were obtained with the proper cure of the glue, but generally the curing temperatures that were satisfactory for gluing the untreated wood of certain species gave inadequate bonds on treated wood, indicating that higher curing temperatures are needed for treated than for untreated wood.

Chromated Zinc Chloride

In limited laboratory tests red oak and hard maple treated with chromated zinc chloride preservative glued well with melamine and phenol-resorcinol types of glues cured at 200° F., and with resorcinol glues cured at 150° F. Resorcinols gave good results on yellow pine when cured at 150° F., but phenol-resorcinols cured at this temperature did not give satisfactory bonds either on Southern yellow pine or Douglas-fir. With this treatment it appears that higher curing temperatures may be needed for adequate gluing than with some of the other water-borne preservatives. This preservative has not been included in studies on gluing treated wood at the Forest Products Laboratory during the last decade, so no data are available from the work of this Laboratory with the latest adhesive formulations.

Copperized Chromated Zinc Chloride

Copperized chromated zinc chloride is a more recently developed form of chromated zinc chloride. The results of gluing studies conducted at the Forest Products Laboratory on red oak and Douglas-fir, treated with it indicated that reasonably good bonds can be obtained with resorcinol and phenol-resorcinol adhesives. The curing conditions shown for red oak in table 3 appear adequate, but those for Douglas-fir in table 4 gave good results with only two of the four glues used. Higher temperature or longer curing time may be needed for the gluing of treated Douglas-fir.

Gluing of Treated Wood of Lighter Species

Essentially all the work on gluing of treated wood in this country has involved such species as red oak, Douglas-fir, and Southern yellow pine, although minor studies have included such species as hard maple, gum, and hickory. Research on the gluing of treated wood of other species has been done in Europe. Some work was carried out on the gluing of Scotch pine (Pinus sylvestris) at the Norwegian Institute of Wood Technology, Oslo, Norway, during the academic year 1955-56 (9). The preservatives used were creosote, Boliden Salt, and Celcure. Promising results were obtained with creosote-treated material when the glues were cured at temperatures as low as 95° F. and with Boliden Salt and Celcure-treated material as low as 77° F. This would indicate that milder curing schedules are adequate for treated wood of species less dense and more uniform in texture than Douglas-fir and Southern yellow pine.

Laminating of Treated Wood on a Commercial Scale

Until the last few years, commercial laminating of treated wood has been very limited. Since the fall of 1954, however, an appreciable amount of Tanalith-treated red oak has been laminated for ship and boat use to obtain greater decay protection. Block shear and cyclic-delamination tests on much of this laminated material have been made at the Forest Products Laboratory (on samples taken from production), and the results in general have been excellent.

Figure 5 shows a typical section of this treated and laminated red oak after completion of two cycles of a delamination test similar to ASTM D1101-53. The wood was checked appreciably, which indicates the severity of the test, but the glue joints were almost entirely intact.

Of 90 sections taken from the production of one plant over a period of about a year, the maximum delamination for any sample was 4.1 percent. The highest average block-shear strength was 3,004 pounds per square inch, and the lowest was 1,812 pounds. Highest average wood failures were 100 percent and lowest 76 percent. The curing schedule for the phenol-resorcinol glue used on the treated red oak at this plant was about 160° F. (glue-line temperature) for 10 hours.

From another plant, 127 sections were taken over a period of nearly 2 years. The average block-shear strength in this group varied from a high of 2,780 to a low of 1,839 pounds per square inch, and average wood failure varied from 100 to 76 percent.

Sections from this group were run through only 2 of the regular 3 cycles of the delamination test (similar to ASTM D1101-53). The maximum delamination developed by any of the sections was 2.4 percent. The curing schedule used at this plant to glue treated red oak with a phenol-resorcinol glue was 10 hours at 150° F. or 9 hours at 155° F. The minimum net retention of preservatives in the laminated red oak from the 2 plants was 0.75 pound per cubic foot.

These results have established that laminating of Tanalith-treated red oak on a commercial scale is entirely feasible.

Gluing of Wood Treated with Fire-retardant Chemicals

Since fire-retardant-treated wood is often used in relatively dry exposures for such purposes as veneered doors and partitions, data on gluing of treated veneers and on the use of glues other than the phenol, resorcinol, and melamine types will also be considered in discussing the effects on gluing of these chemicals. For maximum fire resistance (as far as the glue is concerned) it probably would be necessary, however, to use glues of the phenol, resorcinol, and melamine-resin types that do not permit the veneers to delaminate or separate when the wood is charred. It is also known that many of the fire-retardant salts are hygroscopic and that wood treated with them has higher equilibrium moisture content than untreated wood. This might be another reason for using glues of good water-resistance.

Fire-retardant formulas usually employ various chemicals in mixture, so that a desired combination of properties is obtained. Those in more or less common use at present are monoammonium phosphate, diammonium phosphate, ammonium sulphate, borax, boric acid, zinc chloride, and chromated zinc chloride.

The data available on gluing fire-retardant-treated wood are very limited, and the work done has been with the more commonly used formulations; consequently, any conclusions drawn or recommendations made are tentative and limited in application.

Monoammonium Phosphate

In some of the earliest work at the Forest Products Laboratory on gluing fire-retardant-treated wood several types of glues were tried for bonding veneers treated with monoammonium phosphate. Successful gluing was reported for hot-press blood glue and phenol-resin film glue. Soybean, starch, casein, and liquid phenol resin glues gave generally unsatisfactory results.

Good success in gluing veneers treated with monoammonium phosphate with phenol-resin film glue and bag-molding phenol resin was also reported in another study (6) at the Forest Products Laboratory. In the same study liquid hot-press phenol and room-temperature-setting urea gave fair results, hot-setting urea and bag-molding urea gave poor results, and room-temperature-setting phenol gave very poor results.

Diammonium Phosphate

In gluing veneers treated with diammonium phosphate, (6) good results were obtained with phenol-resin film glue, fair results with hot-press phenol-resin glue and room-temperature-setting urea, and poor results with hot-press urea, bag-molding urea, and bag-molding phenol-resin glue.

In general, considerable difficulty has been encountered when using casein for gluing wood treated with salts containing ammonium ions or salts of acid reaction.

Diammonium Phosphate-

Monoammonium Phosphate (2:1)

Veneers treated with a mixture (2:1) of diammonium phosphate and monoammonium phosphate⁴ also glued well with phenol-resin film glues. With hot-press phenol and room-temperature-setting urea the results were fair; and with bag-molding phenol, bag-molding urea, and hot-press urea resin they were poor.

⁴-Navy Department Specification 51C38 (Chemicals, Fire-retardant for lumber and timber).

Ammonium Sulfate

In gluing veneers treated with ammonium sulfate (6), fair results were obtained with phenol-resin film glue, room-temperature-setting urea, and hot-press urea. With bag-molding urea, room-temperature-setting phenol, hot-press phenol, and bag-molding phenol-resin glues the results were poor.

Boric Acid

Room-temperature-setting urea-resin glue developed fair bonds on veneers treated with boric acid (6). Poor or very poor results were obtained with hot-press urea, bag-molding urea, room-temperature-setting phenol, hot-press phenol, and bag-molding phenol-resin glues and with phenol-resin film glue.

Borax

Gluing of veneers treated with borax (6) resulted in development of poor bonds with phenol-resin film glue and hot-press urea-resin glue; and from very poor to practically no bonds with hot-press phenol, bag-molding phenol, room-temperature-setting phenol, bag-molding urea, and room-temperature-setting urea-resin glues.

Borax-boric Acid (60:40)

No interference with bonding was observed when veneers treated with borax-boric acid mixture (60:40)⁴ were glued with room-temperature-setting urea, phenol-resorcinol, resorcinol, and melamine-resin glues, and with fortified urea-resin glue. Slight interference was observed when hot-press phenol-resin glue was used, and with phenol-resin film, casein, and soybean glues there was considerable interference.

On hard maple treated with borax-boric acid no interference with bonding was observed when the glue used was casein, phenol-resorcinol, resorcinol cured at 160° F., and melamine resin. When the glue was cured at room temperature, slight interference was noted with resorcinol and considerable interference with urea resin. No interference was observed when Douglas-fir lumber blocks treated with this mixture were glued with the same glues.

Results obtained at an industrial laboratory on wood treated with borax-boric acid (5) indicated good bonds with urea and casein on hardwood and softwood blocks, fair results with resorcinol on hardwood blocks and good results on softwood blocks, and good results with phenol-resorcinol on both softwood and hardwood blocks.

Difficulties in gluing with starch glues were experienced in experiments at the Forest Products Laboratory when boron salts were present in the treating chemical.

Ammonium Sulfate-diammonium Phosphate-
borax-boric Acid (60:10:10:20)

In a study at the Forest Products Laboratory in which maple, red oak, Southern yellow pine, and Douglas-fir lumber were treated with an ammonium sulfate-diammonium phosphate-borax-boric acid mixture (60:10:10:20), ⁴ satisfactory glue bonds were obtained with resorcinol-resin glue on the pine and fir, and with melamine-resin glue on the oak. Unsatisfactory results were obtained with resorcinol and phenol-resorcinol on maple and on oak, with melamine on maple, and with phenol-resorcinol on fir and pine. Where the same phenol-resorcinol glue was cured at 80° F. in one case and at 150° F. in another the results were improved at the higher temperature.

In another study at the Forest Products Laboratory, Douglas-fir treated with formula 2⁴ glued well with urea, resorcinol, and melamine-resin glues; but when casein and phenol-resorcinol types of glues were used, some interference was observed. Similarly treated hard maple glued well with urea resin; but when casein, phenol-resorcinol, resorcinol, and melamine resin were used, moderate interference with bonding was observed.

Birch veneers treated with formula 2⁴ were adequately glued with urea, phenol-resorcinol, resorcinol, and hot-press phenol; with fortified urea and melamine-resin glues there was slight interference, and with casein, soybean, and phenol-resin film glues there was considerable interference with bonding. Douglas-fir veneers similarly treated glued well with phenol-resorcinol and resorcinol-resin glues; when fortified urea and hot-press phenol were used, there was slight interference with bonding; with urea there was moderate interference; and with casein and soybean glues, and with phenol-resin film glue there was considerable interference.

Work reported by an industrial laboratory (5) on gluing wood treated with type 2⁴ fire retardant indicated good results with urea resin on hardwood blocks and excellent results with the same glue on softwood blocks. With resorcinol the results were fair, and with phenol-resorcinol they were good on softwood blocks.

Chromated Zinc Chloride

Chromated zinc chloride is used both as a preservative and as a fire retardant, but in the latter case the treatment is heavier.

Work on gluing wood treated with chromated zinc chloride fire retardant reported by an industrial laboratory (5) indicated fair to poor results when casein glue was used on hardwood and softwood blocks and hardwood and softwood veneers. Room-temperature-setting urea resin gave excellent results on hardwood and softwood blocks and good results on softwood plywood, but poor results on hardwood plywood. Resorcinol-resin glue gave good results on hardwood blocks and excellent results on softwood blocks. Phenol-resorcinol developed fair bonds on hardwood blocks and hardwood and softwood plywood, and good bonds on softwood blocks. Hot-press phenol developed good bonds on both hardwood and softwood veneers.

Zinc Chloride

Zinc chloride is also used both as a preservative and as a fire retardant, but in higher concentrations or absorptions when intended for the latter purpose.

Fair results were reported (5) with casein glue on hardwood and softwood blocks, and poor results on hardwood and softwood veneers treated with zinc chloride. Urea resin gave excellent results on hardwood and softwood blocks and good results on hardwood and softwood veneers. Resorcinol resin gave good results on hardwood and softwood blocks, and hot-press phenol gave fair results on softwood veneer, but poor results on hardwood veneers. Phenol-resorcinol gave poor results on hardwood blocks and plywood, fair results on softwood plywood, and good results on softwood blocks.

Tests made at the Forest Products Laboratory indicate that veneers treated to a high retention of zinc chloride are weakened when exposed to the high temperatures used for hot-press phenol-resin glues.

Tentative Recommendations for Gluing Preservative-treated Wood

As indicated earlier, the data on gluing treated wood are in many cases far from conclusive; therefore the following recommendations are tentative and offered merely with the idea that they might be of some guidance to anyone attempting to glue such material. For certain treatments, however, such as with Tanalith, adequate data and experience are available and the directions can be followed with some confidence.

Coal-tar Creosote

Stock treated with coal-tar creosote that bleeds should be steamed or otherwise cleaned until no more bleeding occurs. The treating conditions that lead to a minimum amount of bleeding should be used, and the choice of low-residue creosote seems advisable. Resorcinol and phenol-resorcinol glues are suitable adhesives for bonding creosoted wood. For dense hardwoods, curing at 150° F. or a higher glue line temperature is suggested. The optimum assembly time for creosoted wood has not been determined but a closed assembly period of 30 to 60 minutes at temperatures from 70° to 80° F. would be expected to be satisfactory. On softwoods curing temperatures of 120° to 150° F. are suggested and the higher temperature would be expected to be the safer procedure. Adequate bonds on light softwoods might also be obtained with certain of these glues cured at 80° F. if this temperature is maintained for several days.

Passing the material twice through the glue spreader instead of the usual one time is sometimes helpful in getting more uniform spread on oil-treated stock. Table 1 gives results of glue joint tests on creosote treated wood.

Pentachlorophenol and Copper Napthenate

Where oily solvents such as number 2 fuel oil are used in treating wood with pentachlorophenol and copper naphthenate, a steam and vacuum cleaning treatment is suggested for species having a tendency to bleed. The same types of glues and curing conditions as suggested for creosote are indicated. Less difficulty in bonding wood treated with these chemicals can be expected when a rather volatile solvent such as naphtha or light mineral spirits is used. The suggestion about repeated spreading given for creosote has sometimes been found beneficial when spreading copper naphthenate and pentachlorophenol-treated wood.

Tanalith, Boliden Salt, Celcure, Copperized Chromated Zinc Chloride, Greensalt, and Zinc Meta Arsenite

Phenol-resorcinol and resorcinol-resin glues are suitable for gluing wood treated with Tanalith, Boliden salt, Celcure, copperized chromated zinc chloride, Greensalt, and zinc meta arsenite. When dense hardwoods are glued, curing at a glue line temperature of 150° to 170° F. is suggested. For gluing softwoods, curing at 120° to 150° F. may be satisfactory, although with certain glues 80° F. might be adequate. Results of glue joint tests on wood treated with these chemicals are given in tables 2, 3, and 4.

Tentative Recommendations for
Gluing Fire-retardant-treated Wood

In the case of gluing fire-retardant-treated wood the data are inadequate to serve as bases for definite recommendations. Certain precautions and suggestions, however, might be offered.

Monoammonium Phosphate, Diammonium
Phosphate, or a Mixture of the Two

Based on available data phenol-resin film glue appears to be the best choice for gluing veneers treated with monoammonium phosphate, diammonium phosphate, or a mixture of the two, but liquid hot-press phenol may also be found satisfactory. Possibly resorcinol and phenol-resorcinol might do well on such treated veneers, but so far as is known no test results are available.

Interference with bonding can be expected when using casein glue on wood treated with salts containing ammonium ions or salts of acid reaction.

Ammonium Sulfate

Fair results have been obtained using phenol-resin film glue on veneers treated with ammonium sulfate.

Borax-boric Acid (60:40)

Melamine, fortified urea, and urea glues may be used for gluing veneer treated with borax-boric acid (60:40); resorcinol and phenol-resorcinol are probably also adequate, but more expensive.

Resorcinol or phenol-resorcinol glue would probably be the best choice for gluing treated lumber.

Ammonium Sulfate-Diammonium Phosphate
borax-boric Acid (60:10:10:20)

Resorcinol-resin glue has produced good bonds on softwoods treated with a 60:10:10:20 mixture of ammonium sulfate, diammonium phosphate, borax, and boric acid. Melamine-resin or urea-resin glues may be satisfactory on hardwoods, including oak, although melamine resin has given unsatisfactory

results on hard maple. Urea resin, in general, has developed good bonds on wood treated with this combination of chemicals.

Chromated Zinc Chloride

Hot-press phenol glue appears to be the best choice for gluing veneer treated with chromated zinc chloride fire retardant; and on lumber, phenol-resorcinol or resorcinol probably would be satisfactory.

Zinc Chloride

Good results have been obtained with resorcinol glue on hardwood and softwood lumber and on softwood veneers treated with zinc chloride. For hardwood veneers no entirely satisfactory results have been reported for any of the glues tried.

Literature Cited

- (1) American Wood-Preservers' Association
1950. AWPA Proc. 46:349-350.
- (2) _____
1948. AWPA Proc. 44:381-382.
- (3) _____
1947. AWPA Proc. 43:232-235.
- (4) _____
1946. AWPA Proc. 42:336-340.
- (5) _____
1945. AWPA Proc. 41:103-106.
- (6) Black, John M.
1943. The effect of fire-retardant chemicals on glues used in plywood manufacture. Forest Products Laboratory Report R1427.
- (7) Kaufert, F. H., and Hutchins, W. F.
1945. Experiments on the gluing of wood treated with oil solutions of chlorophenols. Forest Products Laboratory Report R1484.
- (8) Selbo, M. L., and Angell, H. W.
1955. Performance of laminated preservative-treated railroad bridge stringers. Forest Products Journal 5(1):84-88.
- (9) _____, and Grönvold, O.
1956. Laminating of preservative-treated Scotch pine. Norsk Skogindustri 10(9):304-311.

Table 1.--Average reduction in block-shear strength of red oak treated with different preservatives as compared to results of untreated controls aged for the same periods

Preservative	Retention	Comparative percentage reduction in shear strength after various periods of aging					Average for all test periods
		2 weeks	3 months	6 months	12 months	36 months	
	Lb. per cu. ft.	Percent	Percent	Percent	Percent	Percent	Percent
Tanalith	1.19	3.8	3.2	3.1	5.6	3.0	3.7
Pentachlorophenol	14.00	5.6	3.6	8.6	7.2	8.2	6.6
Copper naphthenate	12.70	9.7	6.8	8.5	8.6	17.0	10.3
Celcure A ¹	1.57	7.5	9.0	12.9	11.3	14.4	11.0
Celcure B ¹	2.22	7.3	8.9	9.8	10.1	16.2	10.5
Chemonite	1.50	15.8	16.2	14.9	16.7	15.9	15.9

¹A and B indicate different retentions of the preservative.

Table 2.--Results of delamination and block-shear tests (original and after 6 years' exposure to the weather) on Douglas-fir and Southern yellow pine beams glued from creosote-treated wood¹

Beam No.:	Glue type ²	Curing temperature °F.	Delamination ³ Percent	Block-shear results ⁴	
				Original P.s.i.-Percent	After 6 years P.s.i.-Percent

DOUGLAS-FIR

59	:Phenol-resorcinol	: 150	: 3.8	: 1,163 - 93	: 1,152 - 90
61	:Resorcinol	: 150	: 7.3	: 1,064 - 58	: 1,202 - 63
63	:.....do.....	: 150	: 4.5	: 1,054 - 99	: 1,178 - 75
64	:.....do.....	: 80	: 4.9	: 1,310 - 96	: 1,376 - 80
65	:.....do.....	: 80	: 10.7	: 1,157 - 88	: 1,258 - 63

SOUTHERN YELLOW PINE

67	:Phenol-resorcinol	: 150	:.....	: 1,824 - 81	: 1,786 - 85
69	:Resorcinol	: 150	: 6.6	: 1,549 - 80	: 1,555 - 75
71	:.....do.....	: 150	: 5.7	: 1,262 - 90	: 1,619 - 83
72	:.....do.....	: 80	: 22.7	: 1,760 - 85	: 1,595 - 70
73	:.....do.....	: 80	: 3.3	: 1,744 - 80	: 1,683 - 65

¹The average retention for the Douglas-fir was about 16 pounds per cubic foot and for the southern yellow pine about 13 pounds per cubic foot.

²A closed assembly period of about 40 minutes was used with all glues and the periods in clamps were about 16 hours at the curing temperature indicated.

³Made according to ASTM D1101-53.

⁴Made according to ASTM 905-49. The figure before the dash is the shear strength. The figure after the dash is the percentage of estimated wood failure. Each value is the average of 14 tests.

Table 3.--Results of block-shear and delamination tests on laminated red oak beams made of preservative-treated lumber with resorcinol and phenol-resorcinol glues

Preservative	Average retention		Curing time		Specific gravity of wood	Block-shear values		Delamination
	Lb. per cu. ft.	Hrs.	Hrs.	°F.		Control beams	Treated beams	
Tanalith	0.70	9	150	0.68	0.67	2,636 - 80	2,584 - 87	0.1
Celcure	2.31	8	170	.68	.67	2,370 - 77	2,101 - 83	.0
Greensalt	2.10	9	150	.68	.68	2,636 - 80	2,523 - 78	.1
Pentachlorophenol	11.0	8	170	.67	.68	2,275 - 80	2,302 - 77	.0
Copper naphthenate	9.8	8	170	.67	.63	2,275 - 80	2,184 - 84	.0
Copperized chromated zinc chloride	2.45	9	150	.63	.64	2,479 - 83	2,214 - 86	.2
Boliden salt	1.16	9	150	.63	.63	2,479 - 83	2,225 - 83	.2

¹Temperature at the innermost glue line.

²Specific gravity of untreated wood based on oven-dry weight and volume.

³Made according to ASTM 905-49. The first figure in each column is shear strength; the second is percentage estimated wood failure. Each value is the average of results obtained with four different glues. Two 4-1/2 by 6 by 14 inch beams of treated and one of untreated material were made with each glue at the curing condition shown.

⁴Made according to ASTM D1101-53.

Table 4.--Results of block-shear and delamination tests on laminated Douglas-fir beams made of preservative-treated lumber with resorcinol and phenol-resorcinol glues¹

Preservative	Average: Specific grav- : retention of wood ²	Block-shear values ²	Delamination ⁴					
	Control: Treated: : beams : beams :	Control beams : Treated beams	Control: Treated : beams : beams :					
		P.s.i.-Percent: P.s.i.-Percent:	Percent: Percent:					
	Lb. per : cu. ft.:							
Tanalith	0.62	0.54	0.52	1,458 - 76	1,469 - 79	2.0	2.0	3.3
Celcure	2.31	.54	.52	1,458 - 76	1,219 - 90	2.0	2.0	5.8
Greensalt	2.17	.54	.53	1,458 - 76	1,437 - 85	2.0	2.0	2.9
Pentachlorophenol	13.4	.54	.53	1,458 - 76	1,469 - 83	2.0	2.0	3.5
Copper naphthenate	12.2	.54	.54	1,458 - 76	1,569 - 77	2.0	2.0	8.3
Copperized chromated zinc chloride	2.23	.54	.53	1,458 - 76	1,139 - 91	2.0	2.0	7.2
Boliden salt	1.10	.54	.52	1,458 - 76	1,382 - 82	2.0	2.0	7.2

¹Cured 8 hours at 120° F. at the innermost glue line.

²Specific gravity of untreated wood based on oven-dry weight and volume.

³Made according to ASTM 905-49. The first figure in each column is shear strength; the second is percentage estimated wood failure. Each value is the average obtained with four different glues.

⁴Made according to ASTM D1101-53.

Table 5.--Results of block-shear and delamination tests on laminated southern yellow pine beams made of preservative-treated lumber with resorcinol and phenol-resorcinol glues

Preservative	Average curing		Specific gravity of wood ²	Block-shear values ³		Delamination ⁴	
	Retention	Time		Control beams	Treated beams		Control beams
	per cu. ft.	Hrs.	°F.	P.s.i.	Percent	P.s.i.	Percent
Tanalith	0.56	8	120	1,800 - 77	1,833 - 79	0.8	1.2
Celcure	2.05	6	150	1,858 - 73	1,797 - 73	2.1	6.7
Greensalt	2.04	8	120	1,550 - 64	1,761 - 74	3.8	7.6
Pentachlorophenol	10.0	8	120	1,550 - 64	1,666 - 66	3.8	6.7

¹Temperature at innermost glue line.

²Specific gravity of untreated wood based on oven-dry weight and volume.

³Made according to ASTM 905-49. The first figure in each column is shear strength; the second is percentage estimated wood failure. Each value is the average obtained with four different glues.

⁴Made according to ASTM D1101-53.

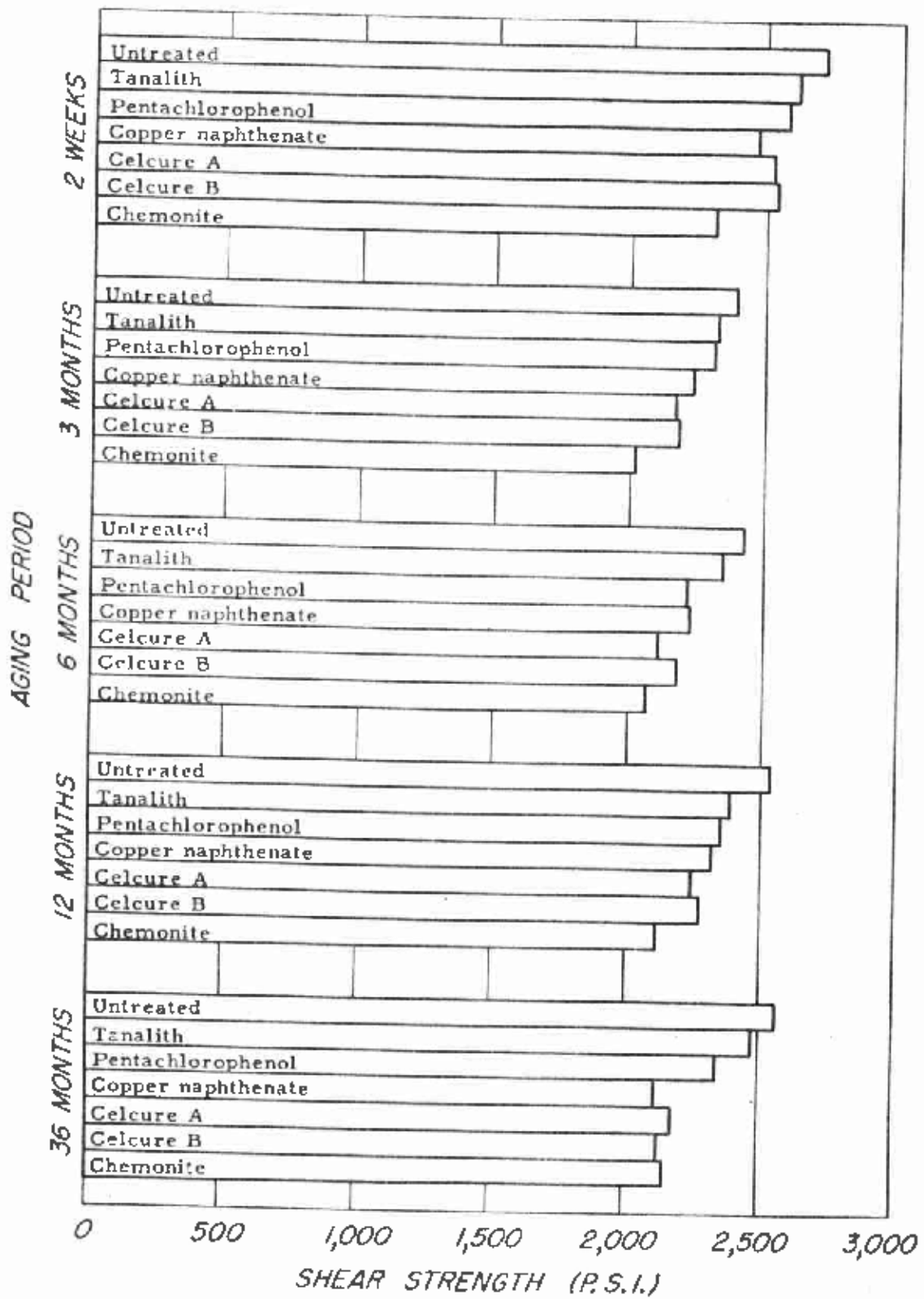
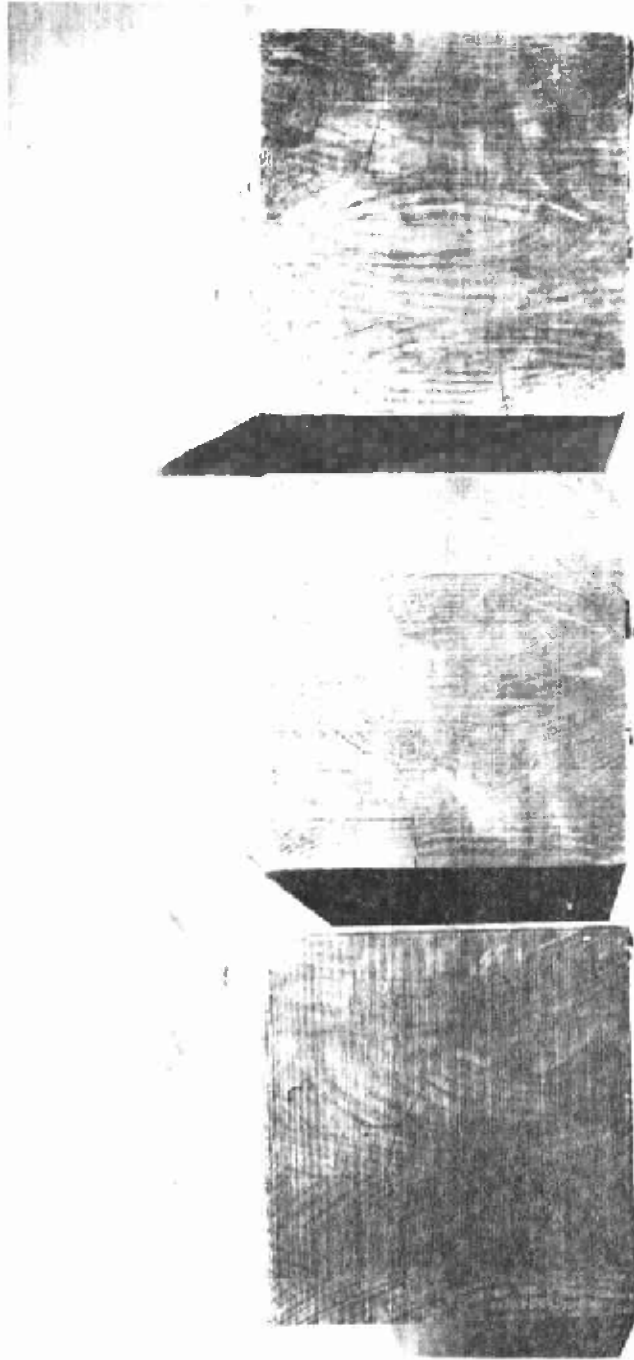


Figure 1. -- Effect of preservative treatment and aging on block-shear strength of laminated red oak.



M 109 521

Figure 2. -- Laminated southern yellow pine glued from creosote-treated material and exposed for about 6 years to the weather. The retention of creosote in this material was about 13 pounds per cubic foot.

Z M 109 521



Figure 3. -- Laminated beams glued from creosote-treated Douglas-fir and exposed for about 6 years to the weather. The material was quarter-sawn and treated to a retention of about 16 pounds per cubic foot.

Z M 109 520

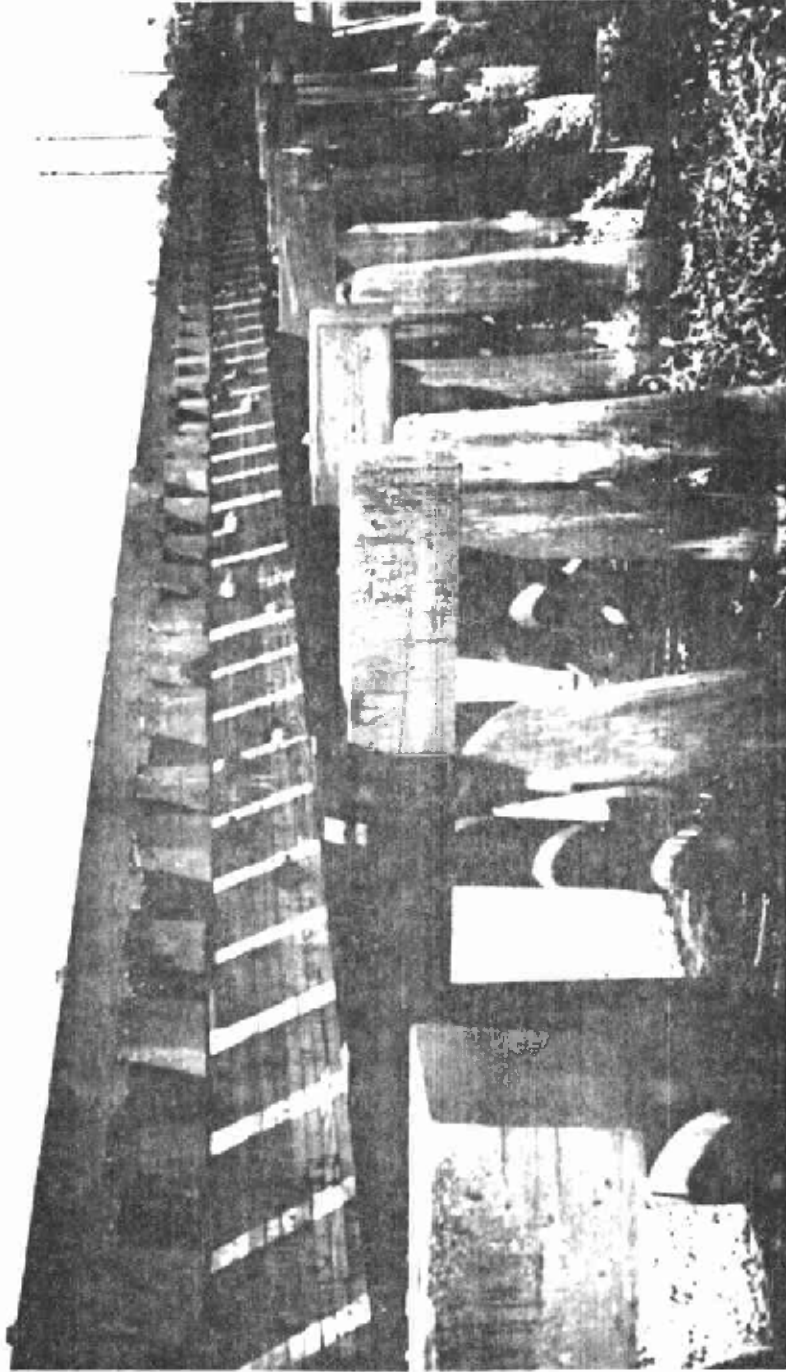


Figure 4. --Side view of railroad bridge over Palm River, Tampa, Fla., built with stringers laminated from creosote-treated southern yellow pine.

Z M 96188 F

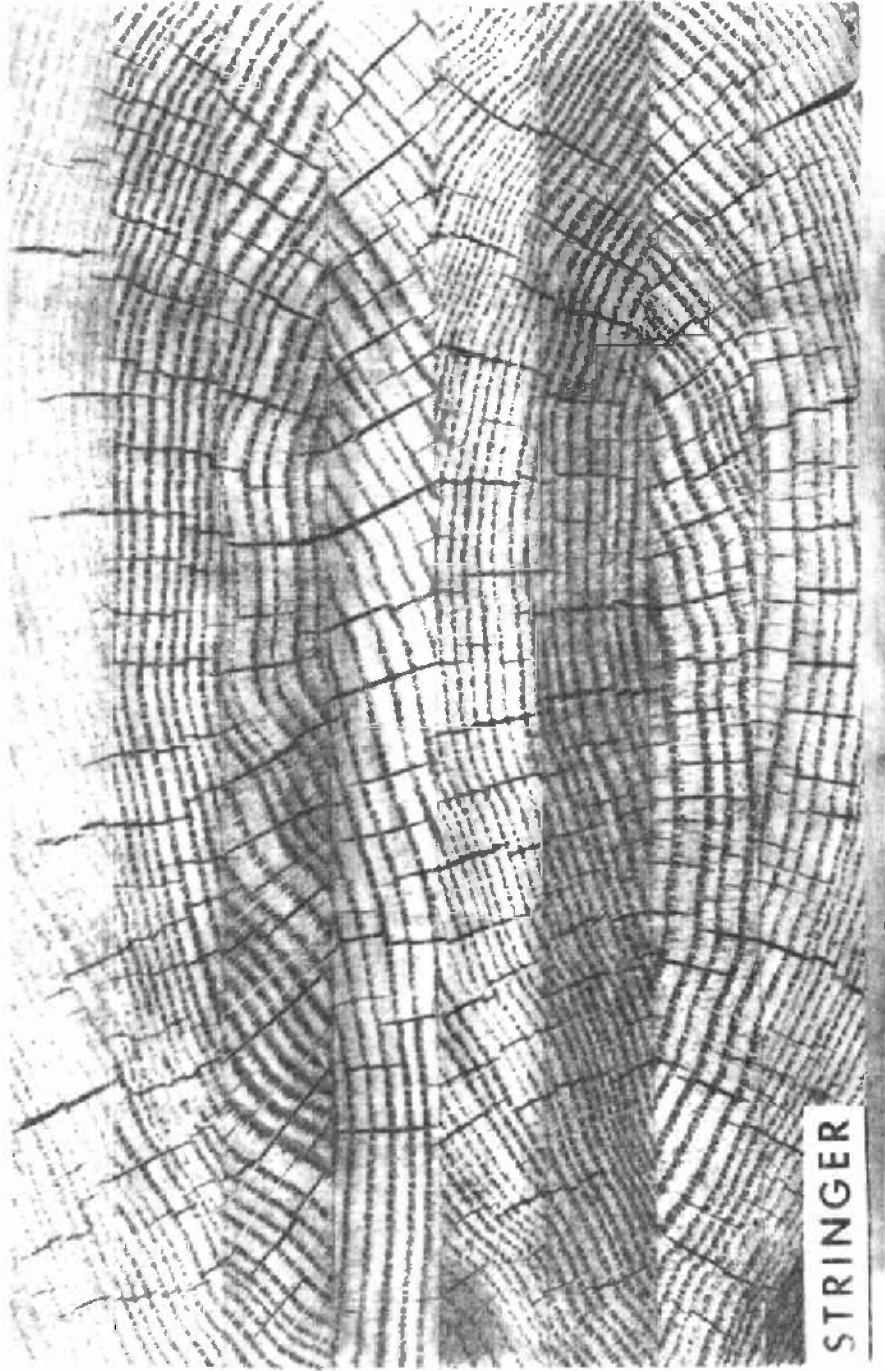


Figure 5. --Section of minesweeper stringer laminated from Tanalith-treated red oak and exposed to two cycles of the ASTM delamination test D1101-53. Note excellent performance of glue joints.

Z M 97446 F

PUBLICATION LISTS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following lists of publications deal with investigative projects of the Forest Products Laboratory or relate to special interest groups and are available upon request:

Architects, Builders, Engineers,
and Retail Lumbermen

Growth, Structure, and
Identification of Wood

Box, Crate, and Packaging Data

Logging, Milling, and Utilization
of Timber Products

Chemistry of Wood

Mechanical Properties of Timber

Drying of Wood

Structural Sandwich, Plastic
Laminates, and Wood-Base
Components

Fire Protection

Fungus and Insect Defects in
Forest Products

Thermal Properties of Wood

Furniture Manufacturers,
Woodworkers, and Teachers
of Woodshop Practice

Wood Fiber Products

Wood Finishing Subjects

Glue and Plywood

Wood Preservation

Note: Since Forest Products Laboratory publications are so varied in subject matter, no single catalog of titles is issued. Instead, a listing is made for each area of Laboratory research. Twice a year, December 31 and June 30, a list is compiled showing new reports for the previous 6 months. This is the only item sent regularly to the Laboratory's mailing roster, and it serves to keep current the various subject matter listings. Names may be added to the mailing roster upon request.