# OREGON STATE UNIVERSITY RATE OF DEVELOPMENT OF JOINT STRENGTH BY FOUR RESIN GLUES ON EIGHT SPECIES OF WOOD

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#### RATE OF DEVELOPMENT OF JOINT STRENGTH BY

### FOUR RESIN GLUES ON EIGHT SPECIES OF WOOD

By

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In using resorcinol- and phenol-resin glues in the fabrication of wood aircraft the question arises as to whether these glues cure at the same rate on different species of wood. In an attempt to answer this question, joints were made with three room-temperature-setting glues and one intermediate-temperature-setting glue on eight species, cured for various lengths of time at two temperatures and tested in shear to follow the rate of development of the joint strength in the various species.

It was anticipated that the results would follow one of the three idealized patterns sketched in figure 1. If pattern (A) was found to be the case, in which the curves are coincident below the points where they depart from one another by virtue of differences in the strength of the woods, it could be concluded that there was no effect of species on the rate of curing. In the case of (B) and (C), on the other hand, a species effect could be inferred.

The glues employed were commercial glues and mixed according to the manufacturers' directions. The glues were designated as follows:

<sup>1</sup>This report is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available.

<sup>2</sup>-Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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Agriculture-Madison

Designation	Type
А	Room-temperature-setting resorcinol
В	Room-temperature-setting resorcinol
С	Room-temperature-setting resorcinol
D	Intermediate-temperature- setting phenol

The eight species of wood employed were: yellow birch, Douglas-fir, noble fir, sweetgum, Western hemlock, mahogany, sugar maple, and Sitka spruce. Most of these woods are in common use in aircraft, and as a group provide a wide range in density and strength as well as the characteristic differences between softwoods and hardwoods. The maple, birch, and sweetgum were in the form of rotary-cut veneer and the other species as quarter-sliced veneer.

#### Procedure

All veneer had a nominal thickness of one-sixteenth inch, but each sheet was calipered and only those measuring 0.061 inch to 0.063 inch, inclusive, were selected for use. The selected veneer was cut into small slips 1 by 2-1/8 inches in size, with the grain running lengthwise.

In preparing the joints, the slips were clamped in a special frame (not shown) so that the glue could be applied quickly by brush to each surface area to be glued. The slips were then laid together in pairs with a 1inch overlap in a special metal jig (fig. 2). After 15 minutes of closed assembly, a rubber caul was laid over the jig, and the specimens were subjected to a pressure of 150 pounds per square inch. The jig accommodated 32 lap joints, which made it possible to press one joint of each species with each of the 4 glues at the same time. Four sets were made at each gluing condition, and the results of these were averaged.

The joints for this study were cured at  $80^{\circ}$  F. and at  $120^{\circ}$  F. For curing at  $80^{\circ}$  F., the jig loaded with specimens and under pressure was kept for the curing period desired in a room maintained at  $80^{\circ}$  F. For curing at  $120^{\circ}$  F., the jig with specimens was pressed for the curing period desired between platens heated to  $120^{\circ}$  F. with hot water. At this higher temperature, approximately 3 minutes were required for the temperature in the

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glue line to rise to within 5° F. of the platen temperature. Measurement of the time of heating was begun after this initial heating interval.

Immediately after the desired curing period, at both 80° F. and 120° F., pressure was released, and the individual specimens were removed from the jig and dropped into a beaker of cold water to lower their temperature and inhibit further cure of the glue. The beaker with immersed specimens was set in a vacuum desiccator and a vacuum was drawn for 30 minutes, then released. The moisture content of the specimens wet in this way was from 100 to 300 percent, and the wood of all species appeared to become wet through to the glue line. After wetting, the specimens were tested at once in a standard plywood-joint-testing machine loading at a rate of about 750 pounds per minute.

#### Results

The averaged results of the shear tests on the joints are given in tables 1 and 2.

Any effect of species on the rate of curing of the glue could be expected to be revealed more clearly in the initial stages of the curing in which the joints break without wood failure and the shear values are less dependent on the strength of the wood. To analyze the data for the effect of species, therefore, the joint strengths given in tables 1 and 2 for those curing periods at which the wood failure percentages were usually low have been plotted in figures 3 to 6. To avoid confusion of lines, points have been connected for selected species only. In the figures it may be seen that the glues did not develop joint strength at the same rate on all species but that the curves for the several species fan out early, more like (B) and (C) of figure 1 than like figure 1 (A). From these observations it may be concluded that, aside from any effect of density and strength of the wood on the shear strengths of the joints there is an effect of the species of the wood on the rate at which these resin glues harden.

The effect of species on the development of joint strength is revealed in the data for both the phenol and the resorcinol glues. In general, the curves for the several species are in about the same order for each of the three resorcinol glues but not in the same order for the phenol glue. The resorcinol glues built up strength more slowly on Douglas-fir than on maple, whereas the reverse was true for the phenol glue. The

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influence of species was seen at both the 80° F. and 120° F. curing temperatures. The order of the curves was roughly the same at both temperatures.

The difference between the 'slowest' and the 'fastest' species may be enough to be of considerable practical importance. For example (fig. 5), glue C took about 3 hours longer at 80° F. to develop 200 pounds per square inch joint strength in Douglas-fir than it did on sugar maple. Glue A (fig. 3) required about 10 minutes more heating at 120° F. to develop 300 pounds per square inch strength on Douglas-fir than it did on sugar maple. These are, however, extreme examples and most of the species tested did not vary as widely in their effect on the curing of the glue.

The data of tables 1 and 2 were plotted in the form of graphs (not shown), and smooth curves drawn to fit as closely as possible the points for each species. From these smooth curves the estimated time for the joints to reach particular shear-strength levels has been tabulated in tables 3 and 4. The differences in the lengths of time shown in column 3 for a glue to reach 200 pounds per square inch are presumably due to the effects of the species on the rate of curing. The differences in the lengths of time to reach high joint strengths are due not only to the influence of the wood on the curing but also to differences in the strength of the wood of the different species.

No attempt was made herein to explain why a resin glue may not cure as rapidly on one species of wood as on another; instead it is the purpose of this report merely to point out that such differences do exist and that they may be great enough to be of practical importance in commercial gluing operations. Table 1.---Averaged results<sup>1</sup> of shear tests on wet two-ply lap-joint specimens made with eight species and four reain glues cured for various periods of time at 60° F.

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<sup>L</sup>The value before the dash is averaged shear strength in pounds per square inch; the value after the dash is averaged wood failure in parcent. Each value is the average of four tests.

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$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	330-65       565-73       418-100       595-10       595-10         315-91       530-43       555-16       595-16       596-100       598-100         330-5       461-14       555-46       538-100       598-100       598-100         330-5       461-14       555-46       538-100       598-100       598-100         330-5       461-14       552-46       538-100       598-100       598-100         330-11       599-5       6672-80       780-100       598-100       598-100         2250-0       334-24       358-14       599-16       598-100       568-26         2250-0       334-24       358-14       548-14       586-26       586-26         318-0       338-10       338+70       358-20       388-10       358-20         318-0       338-10       358-13       546-13       586-26       44         318-0       358-14       356-10       358-20       178-0       586-26         318-15       358-13       1456-11       1466-13       1466-13       586-26         318-16       358-13       158-14       158-20       148-27       149         318-16       358-15       568-13       586	113-100 527-100 527-100 527-100 113-95 113-95 113-95 113-95 113-95 113-95 113-95 113-95 113-95 113-95 113-95
fir       0.0       80.0       180.0       89.13       715-91       7	315-91       330-91       335-100       338-100         330-5       441-14       555-146       538-90         330-5       441-14       555-146       538-90         330-5       441-14       555-146       538-90         330-5       441-14       555-146       538-90         330-5       441-14       548-51       555-100       540-100         230-6       334-70       555-45       760-80       780-90         230-1       334-70       556-100       540-100       540-100         2220-0       334-70       354-70       356-100       366-70         3130-0       139-13       348-61       356-100       366-70         314-0       1355-3       344-70       356-26       366-9         314-0       1355-3       546-13       586-26       447-10         319-0       356-15       546-13       586-26       447-10         319-10       356-15       1456-11       256-26       447-10         319-10       356-15       1456-11       256-26       146-10         319-10       356-15       1456-11       256-26       146-10         3190-11       259-18       1451-10 <td>587-100 587-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100</td>	587-100 587-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100 717-100
1       0-0       125-0       303-4       325-9       443-20       509-99         1       1       0-0       174-0       371-0       514-11       595-16       595-5         1       0-0       174-0       371-0       514-11       595-16       595-5       443-10         1       0-0       174-0       125-0       137-5       528-11       544-10       139-5         1       0-0       119-0       150-0       130-0       172-5       528-11       544-10         1       0-0       91-0       110-0       150-0       130-0       172-5       528-11       544-11         1       0-0       111-0       140-0       120-0       130-0       139-5       149-10       138-6       139-5       149-10       138-6       138-7       149-10       138-6       139-5       149-5	4419-20       508-19       553-100       540-100         528-111       5413-10       6672-80       780-100         528-111       5413-10       6672-80       780-100         220-11       5413-10       6672-80       780-100         220-11       5413-10       6672-80       760-80         220-11       544-14       553-100       564-100         220-11       544-14       550-100       566-10         220-11       558-14       559-100       566-10         220-1       590-12       591-20       780-20         220-1       595-14       594-10       566-26         306-1       558-14       594-10       566-26         318-0       599-0       594-10       566-26         318-10       568-53       574-10       566-26         318-1       258-15       1451-10       566-9         318-1       258-15       1566-13       566-9         318-1       258-15       1564-10       266-9         318-1       258-15       17100       140-100         219-1       2195-1       258-15       1665-19         318-1       268-11       268-13       266-9	525-100 571-100 113-195 115-100 115-100 115-100 115-100 115-100 115-100 115-100 115-100
Irch       22-0       172-0       277-0       514-11       595-5       481-14         Irch       0-0       174-0       371-0       514-11       595-5       481-14         Irch       0-0       174-0       177-0       514-11       595-15       595-5       441-10         Irch       0-0       119-0       120-0       120-0       129-0       137-5       522-11       595-11       595-11         Irch       0-0       111-0       110-0       120-0       129-0       137-5       220-0       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       137-5       295-11       1475-5       1495-5	330-5       4481-14       525-46       535-5         528-11       5413-10       687-65       760-80         229-4       329-13       384-70       365-100         229-4       329-13       384-70       365-100         229-4       329-13       384-70       365-100         229-4       329-13       384-70       365-100         229-4       329-13       384-70       365-100         239-0       394-24       394-70       365-100         219-0       299-13       384-70       365-26         319-0       495-5       544-100       366-53         319-0       495-5       544-100       450-13         319-0       495-5       544-100       450-13         319-0       495-5       544-100       440-100         319-0       495-5       544-100       440-100         319-0       495-5       544-100       440-100         319-10       366-5       350-26       456-70         319-10       366-5       456-70       456-70         319-10       366-5       456-70       456-70         319-10       366-71       266-90       466-10	511-100 175-100 175-100 175-100 175-100 175-100 175-100 175-100 175-100
Inclusion       Inclusion <thinclusion< th=""> <thinclusion< th=""> <thinclusion< th=""></thinclusion<></thinclusion<></thinclusion<>	<b>328-11 349-10 612-80 760-80 3296-16 595-5 565-65 760-80 229-4 329-11 348-61 365-100 229-4 329-11 348-61 365-100 2390-11 348-61 355-100 365-100 290-11 356-114 356-100 365-100 318-0 290-11 356-100 365-100 319-0 292-11 356-100 365-26 319-0 389-8 145-114 500-94 319-0 389-8 145-110 566-51 319-0 399-0 399-100 440-100 319-10 366-53 316-100 440-100 319-10 366-51 366-11 366-9 319-10 366-51 366-11 366-9 319-10 319-100 440-100 440-100 319-10 329-8 366-11 366-11 319-10 223-11 266-9 100-100 119-0 119-0 228-11</b>	175-100 1 175-100 1 175-100 1 196-100 1 196-10
Gine 1       229-1       329-1         fir       0-0       119-0       150-0       219-3       229-4       339-3         fir       0-0       91-0       130-0       172-5       229-4       339-3         fir       0-0       91-0       130-0       172-5       229-1       339-3         fir       0-0       111-0       130-0       215-0       235-1       339-3         fresh       0-0       130-0       215-0       215-0       235-1       339-3         lend       130-0       130-0       215-0       215-0       215-0       215-0       215-1         lend       130-0       130-0       215-0       215-0       215-0       215-1       215-1         lend       130-0       130-0       215-0       215-0       215-1       215-1       215-1         lend       0-0       140-0       130-0       215-0       215-1       215-1       215-1         lend       115-0       118-0       126-0       215-0       215-1       215-1       215-1         lend       115-0       118-0       126-0       216-2       217-1       216-4       218-5         lend <td>Glue 2         Glue 2           229-b         139-J         384-70         365-100           226-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           315-0         1395-3         544-10         365-26           318-0         1365-3         544-10         565-26           318-0         1365-3         544-10         565-26           318-0         1365-3         544-10         565-26           318-15         1365-13         1451-10         1451-29           320-0         399-0         399-0         1451-10           318-15         1265-1         1451-10         1451-19           318-16         266-11         265-19         1455-19           318-17         265-11         265-19         1451-19           318-15         1365-15         1456-10         140-10           318-16         265-11         265-15         1455-19</td> <td>1 122-100 1 1 144-100 1 1 144-</td>	Glue 2         Glue 2           229-b         139-J         384-70         365-100           226-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           255-0         1394-24         344-70         365-100           315-0         1395-3         544-10         365-26           318-0         1365-3         544-10         565-26           318-0         1365-3         544-10         565-26           318-0         1365-3         544-10         565-26           318-15         1365-13         1451-10         1451-29           320-0         399-0         399-0         1451-10           318-15         1265-1         1451-10         1451-19           318-16         266-11         265-19         1455-19           318-17         265-11         265-19         1451-19           318-15         1365-15         1456-10         140-10           318-16         265-11         265-15         1455-19	1 122-100 1 1 144-100 1 1 144-
France         Color         113-0         115-0         120-0         130-0         132-1           fire         C-O         91-0         130-0         172-5         220-0         134-1           fire         C-O         91-0         130-0         172-5         220-0         134-1           fire         C-O         111-0         130-0         135-0         234-0         234-1           fire         C-O         131-0         130-0         234-0         234-0         234-1           Liceh         C-O         131-0         130-0         234-0         234-0         234-1           Liceh         D-O         131-0         130-0         234-0         234-0         234-1           Liceh         130-0         137-0         234-0         234-0         234-1           Liceh         140-0         130-0         235-1         339-0         339-0           Liceh         145-0         200-0         145-0         234-0         235-1           Liceh         139-0         139-0         136-1         149-0           Liceh         139-0         139-0         136-1         149-0           Liceh         139-0	229-14       329-13       334-70       365-100         220-0       374-60       344-61       369-100         2215-0       292-13       344-61       369-100         2215-0       292-13       344-61       369-100         2215-0       292-13       291-100       378-60         215-0       295-13       291-100       378-60         319-0       1365-3       294-10       495-31         319-0       1365-3       544-10       495-31         319-0       1365-3       544-10       495-36         319-0       1365-3       544-100       40-100         265-6       334-36       564-10       40-100         377-10       366-31       366-36       366-36         379-10       366-13       366-36       366-36         379-10       366-13       366-36       366-36         379-14       289-13       266-9       366-9         379-15       285-13       286-13       286-3         379-16       286-13       286-3       366-3         379-16       286-13       286-9       366-3         379-16       286-13       286-3       366-3	755-100 101-100 101-100 101-100 101-100 101-100 101-100 101-100 101-100 101-100 101-100
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	229-0       139-3       384-70       365-100         226-0       1394-24       346-51       365-100         255-0       1394-24       346-51       365-100         215-0       295-10       295-10       365-10         319-0       1455-3       294-71       565-26         319-0       1455-3       154-11       565-26         319-0       1455-3       1545-10       40-100         319-0       1455-3       1545-10       400-100         319-0       1455-3       1545-10       400-100         319-0       1455-3       156-10       400-100         319-0       1455-3       156-10       400-10         319-0       1455-3       156-11       266-9         319-14       244-1       266-11       266-9         256-6       1495-10       410-100       420-100         266-6       1495-11       266-9       1665-19         266-6       1495-11       266-9       1665-19         266-6       1495-10       410-100       266-9         266-6       1495-10       126-0       266-9         266-6       1495-10       266-9       201-9	355-100 366-100 366-100 360-100 355-100
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	275-0     378-10     378-50       275-0     290-11     378-10       306-11     358-14     378-10       318-0     297-10     378-50       318-0     297-10     378-50       318-0     297-10     378-50       318-0     399-0     399-0       319-0     399-0     399-0       319-0     399-0     599-10       319-0     399-0     599-10       319-10     368-53     599-10       319-10     368-53     599-10       319-10     368-53     599-10       319-10     368-53     599-10       319-10     368-53     599-10       319-10     368-53     599-10       319-10     399-5     569-13       319-10     368-53     369-13       319-11     265-13     266-9       319-12     269-11     266-9       354-13     268-11     266-9       354-14     516-5     528-11       354-15     268-11     266-9       354-16     2139-19     366-9       354-16     2139-19     366-9       354-16     2139-59     360-19       354-18     340-18       354-19     354-59 <t< td=""><td>1001-545</td></t<>	1001-545
Tite       0-0       98-0       120-0       196-2       235-0       290-1         Tite       0-0       111-0       140-0       209-0       318-0       295-1         Tite       0-0       120-0       130-0       219-0       318-0       295-1         Tite       0-0       120-0       139-0       218-0       399-0       385-8         Tite       0-0       120-0       159-0       2159-0       218-0       399-0       399-0         Tite       0-0       140-0       199-0       2159-0       218-0       319-0       1455-1         Tite       69-0       165-0       201-5       225-10       379-10       365-5       399-0         Tite       69-0       1160-0       119-0       216-9       269-6       365-5       149-9       269-6         Tite       160-0       109-0       126-0       218-9       139-5       149-5         Tite       160-0       109-0       288-2       149-6       149-6       149-6         Tite       160-0       109-7       118-0       118-0       149-6       149-6         Tite       199-0       129-0       288-2       1499-6 <td< td=""><td>255-0       290-1       350-19       378-60         306-1       358-19       284-14       293-10         319-0       195-5       246-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-10       366-53       544-100       410-100         265-6       334-35       376-10       489-20         379-10       366-53       376-11       266-9         219-10       366-53       376-10       410-100         265-6       334-35       376-11       266-9         376-6       376-9       376-9       376-9         376-6       376-9       270-18       366-9         376-6       376-9       288-34       366-9         376-6       376-9       288-34       366-9         376-6       376-9       288-34       366-9         376-6       376-9       376-9       376-9         376-6       376-9       376-9       366-9         376-6       <td< td=""><td>380-100 t</td></td<></td></td<>	255-0       290-1       350-19       378-60         306-1       358-19       284-14       293-10         319-0       195-5       246-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-0       195-5       546-13       489-24         319-10       366-53       544-100       410-100         265-6       334-35       376-10       489-20         379-10       366-53       376-11       266-9         219-10       366-53       376-10       410-100         265-6       334-35       376-11       266-9         376-6       376-9       376-9       376-9         376-6       376-9       270-18       366-9         376-6       376-9       288-34       366-9         376-6       376-9       288-34       366-9         376-6       376-9       288-34       366-9         376-6       376-9       376-9       376-9         376-6       376-9       376-9       366-9         376-6 <td< td=""><td>380-100 t</td></td<>	380-100 t
Intro       111-0       110-0       100-0       205-0       255-0       255-1         Iren       0-0       111-0       110-0       209-0       319-0       355-1         Iren       0-0       120-0       179-0       215-0       319-0       355-1         Iren       0-0       120-0       179-0       275-0       319-0       355-1         Iren       0-0       155-0       201-5       225-10       379-10       355-5         Iren       165-0       201-5       225-10       379-10       355-5         Iren       165-0       109-1       216-0       139-10       145-15         Iren       165-0       201-5       225-10       379-10       356-5       1399-0         Iren       165-0       109-1       216-2       117-10       149-0       229-1         Iren       166-0       165-0       201-1       216-2       179-0       1499-5         Iren       166-0       126-0       228-11       259-1       249-5       299-5         Iren       166-0       126-0       229-1       136-5       299-5       1499-5         Iren       160-0       126-0       211-0 <td>215-0     252-19     221-14     231-10       312-0     135-5     155-5     155-24       313-0     1455-3     546-13     455-24       319-0     1455-3     546-13     455-24       319-0     1455-3     541-10     565-26       319-10     366-53     315-10     410-100       379-10     366-53     375-100     410-100       265-6     334-36     356-9     256-9       379-10     368-53     375-100     410-100       265-6     334-36     356-9     256-9       379-10     265-13     266-9     266-9       379-10     268-13     266-9     266-9       379-10     268-13     266-9     266-9       379-10     268-13     266-9     266-9       368-6     382-15     644-25     366-9       265-15     143-50     1465-19     266-9       364-10     223-15     264-13     266-9       368-6     382-15     644-25     364-26       156-0     171-0     228-15     644-25       160-0     171-0     288-74     370-18       160-0     171-0     288-74     370-18       160-0     177-0     289-9     252</td> <td>380-100 555-100</td>	215-0     252-19     221-14     231-10       312-0     135-5     155-5     155-24       313-0     1455-3     546-13     455-24       319-0     1455-3     546-13     455-24       319-0     1455-3     541-10     565-26       319-10     366-53     315-10     410-100       379-10     366-53     375-100     410-100       265-6     334-36     356-9     256-9       379-10     368-53     375-100     410-100       265-6     334-36     356-9     256-9       379-10     265-13     266-9     266-9       379-10     268-13     266-9     266-9       379-10     268-13     266-9     266-9       379-10     268-13     266-9     266-9       368-6     382-15     644-25     366-9       265-15     143-50     1465-19     266-9       364-10     223-15     264-13     266-9       368-6     382-15     644-25     364-26       156-0     171-0     228-15     644-25       160-0     171-0     288-74     370-18       160-0     171-0     288-74     370-18       160-0     177-0     289-9     252	380-100 555-100
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(1r       16-0       99-0       105-0       118-0       145	155-0 1145-0 223-1 266-9 223-4 243-3 132-28 366-13 356-6 1363-15 154-8 366-13 354-6 1363-15 154-8 165-49 1554-5 155-6 155-0 465-49 1554-0 1174-0 528-15 644-25 1140-0 1174-0 288-34 354-18 1160-0 1174-0 288-34 354-18 1160-0 1174-0 288-34 354-18	341-16
rtch 1 20-0 1 115-0 1 143-0 200-1 213-4 243-3 1 73-0 1 135-0 1 228-0 1 335-5 1 358-15 1 499-5 1 63-0 1 135-0 1 228-0 1 338-2 1 459-5 1 499-5 1 155-0 1 135-0 1 228-2 1 554-5 1 195-5 1 195-5 1 115-0 1 195-0 1 115-0 1 195-0 1 195-5 1 115-0 1 195-0 1 115-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-0 1 195-5 1 115-0 1 195-0 195-0 195-0	219-4 : 245-3 : 324-8 : 366-13 368-6 : 382-15 : 438-50 : 465-49 354-5 : 499-5 : 615-29 : 701-33 454-4 : 516-5 : 528-15 : 644-25 156-0 : 171-0 : 528-15 : 644-25 160-0 : 171-0 : 288-34 : 340-18 160-0 : 179-0 : 288-34 : 340-18 180-0 : 179-0 : 288-34 : 340-18	320-24
Irch 1 79-0 1 196-0 1 228-0 3 335-9 368-6 3 383-15 1 1 45-0 1 200-0 1 206-0 1 297-1 1 354-5 1 499-5 1 63-0 1 198-0 1 209-0 1 228-2 45444 1 516-5 muce 1 0-0 49-0 1 85-0 1 131-0 1 156-0 1 196-4 muce 1 0-0 1 0-0 1 44-0 1 115-0 1 156-0 1 171-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 85-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 48-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 1 105-0 1 170-0 muce 1 0-0 1 0-0 1 0 0-0 0 0 0	368-6   382-15   438-50   465-49   154-5   199-5   644-25   149-1   156-6   528-15   644-25   144-25   156-0   171-0   228-14   140-0   171-0   288-14   140-0   171-0   288-14   140-18   120-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   179-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   196-0   288-14   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   170-0   196-0   288-14   170-0   170-0   170-0   170-0   196-0   170-0   170-0   170-0   170-0   170-0   196-0   170-	1 395-31
LTCh 1 45-0 1 200-0 1 205-0 1 297-1 1 354-5 1 499-5 1. 1 63-0 1 198-0 : 249-0 1 328-2 1 454-4 1 516-5 bamlock 1 0-0 1 49-0 1 85-0 1 131-0 1 156-0 1 196-4 bamlock 1 0-0 1 0-0 1 44-0 1 115-0 1 156-0 1 170-0 cut 1 0-0 1 0-0 1 85-0 1 115-0 1 160-0 1 170-0 cut 1 0-0 1 0-0 1 85-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 85-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 85-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 85-0 1 199-0 cut 1 0-0 1 0-0 1 85-0 1 199-0 cut 1 0-0 1 0-0 1 85-0 1 199-0 cut 1 0-0 1 0-0 1 0-0 1 85-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 85-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 85-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 105-0 1 179-0 cut 1 0-0 1 0-0 1 0-0 1 0 0-0 1 0 0-0 1 0 0-0 1 0 0-0 1 0 0-0 1 0 0-0 1 0 0-0 1 0 0-0 0 0 0	1       354-5       1499-5       615-29       701-33         1       151-6       1528-15       644-25       1         1       156-0       196-4       351-59       351-59         1       160-0       171-0       288-34       340-18         1       160-0       171-0       288-34       340-18         1       160-0       179-0       288-34       340-28         1       160-0       179-0       288-34       340-28	1 531-74 1
1     0-0     19-0     55-0     131-0     156-0     196-4       hemlock     0-0     19-0     55-0     131-0     156-0     196-4       hemlock     0-0     0-0     10-0     115-0     171-0       ruce     1     0-0     1     10-0     171-0       ruce     1     0-0     105-0     179-0       ruce     1     199-0     185-0     119-0       ruce     1     199-0     185-0     179-0       ruce     1     199-0     199-0     179-0		23-78 1 691-95 1 500-100
Mail och     Mail	@1ue D         156-0       196-4       305-9       351-59         1140-0       171-0       288-74       340-18         1160-0       170-0       196-0       288-40         120-0       179-0       223-0       298-28	: 035-66 1
T         0-0         49-0         85-0         131-0         156-0         196-4           hemilock         0-0         0-0         85-0         115-0         176-0         171-0           rus         0-0         0-0         85-0         115-0         170-0         170-0           rus         0-0         0-0         85-0         110-0         170-0         170-0           rus         0-0         105-0         120-0         170-0         179-0         179-0           rus         0-0         199-0         199-0         168-0         179-0         179-0	156-0 196-4 305-9 351-59 140-0 171-0 288-34 340-18 160-0 170-0 196-0 288-40 180-0 179-0 288-40	
Mail ock     Model	120-0 170-0 196-0 288-04 340-18 160-0 170-0 196-0 288-40 120-0 170-0 199-0 288-40	
Tire 100 100 1100 1100 11000	120-0 170-0 1950 239-10 120-0 170-0 1950 239-10	1/-096 1
tir 1 0-01 0-01 18-01 105-0 1 120-0 1 179-0 199-01 99-01 149-0 1 168-0 1 179-0 10-01 0-01 0-01 83-0 1 75-0 1 75-0	120-0 179-0 : 223-0 : 295-28	ont-o/2 i ont-t/2 ont-oc
1 0-0 1 49-0 1 94-0 1 149-0 1 168-0 1 199-0 1		
1 0-0 1 0-0 1 0-0 1 83-0 1 79-0 1 75-0		La La
	174-0 75-0 188-0 587-0	
	110-0 184-0 194-0 172-0	
1 0-0 1 0-0 1 0-0 1 70-0 1 73-0 1 139-0 1	: 73-0 : 139-0 : 200-0 : 284-0	125-2

<sup>A</sup>The value before the dash is averaged shear strength in pounds per square inch; the value after the dash is averaged wood failure in percent. Each value is the average of four tests.

Species	Approximate : ultimate : shear				~ ~		-	-		trength of		
	: strength	:		p.s.i. :		p.s.i.		p.s.1.		p.s.1. :		p. s. 1.
	: <u>P.s.i</u> . Gl	: ] : ] Lus /	lours	: <u>Minutes</u> :	Hours	: <u>Minut</u>	es: Hours		: Hours	: <u>Minutes</u> :		: <u>Minutes</u>
Noble fir Western hemlock Sitha spruce Douglas-fir Mahogany Sweetgum Yellow birch Hard maple			2 3 3 3 2 2	: 45 : 10 : 40 : 50 : 30 : 45 : 35	3445333	1 55 1 30 1 25 1 30 1 30 1 40 1 5 1 15	1 1 2	. t	: : : : : : : : : : : : : : : : : : :		7	
Terd mapre	• (=)	. <b>.</b>	_			2012/12/2017	1977 - 1 <b>9</b> 5	20 <b>- 1</b> - 1	S 18			
	GI	lue ]	B: Ro	om-temper	rature-	setting	resorcin	ol formal	dehyde			
Noble fir Western hemlock Sitka spruce Douglas-fir Mahogany Sweetgum Yellow birch Hard maple	380         385         425         380         535         535         720         725	2 1 2 1 2 1 2 2 2	4464 M4	20 45 35 130 15 125 125 125 125 125 125 125	10 10 5 5	1 40 1 45 1 30 1 30 1 25 1 15 1 15	: 10 : 6	. 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	14	. 1 . 1 . 1
	G	lue (	C: Ro	om-tempe	rature-	setting	resorcin	ol formal	dehyde			
Noble fir Western hemlock Sitka spruce Douglas-fir Mahogany Sweetgum Yellow birch Hard maple	* 380 * 385 * <sup>1</sup> +25 * 380 * 535 * 545 * 720 * 725	1 1 1 1 1 1	2 2 3 4 5 4 2 2	1 40 1 40	3 3 7 12 7 3	: 50 : 50 : 15 : 15 : 15 : 30 :	: : : : : : : : :	* ***** * **** * 45 * 55	*******	· · · · · · · · · · · · · · · · · · ·	11	
	Glue	D:	Inte	rmediate-	temper	ature-s	tting ph	enol form	aldehyd	9		
Noble fir Western hemlock Sitka sprace Douglas-fir Mahogany Sweetgum Yellow birch Hard maple	380       385       425       380       535       535       545       720       725	1	10 11 10 9 9 11	1 55 1 50 1 30 -	16 17 16 15 15	: 25 : 25 : 10 : 30 : 40 : 10 :						

## Table 3.--Estimated curing periods at 80° F. to develop shear strength of several levels in lap-joints of 1/16-inch veneer of eight species glued with four resin glues

4 M 67983 F

	: Approximate : ultimate		uring per	iod required	to develop	shear	strength le	vel	óf:
Species	: shear : strength	: 200 p.			1 400 p. s. i.		500 pi.	1	600 p.s.1.
	: <u>P. s. i</u> .	s Minu	tes 1	Minutes	: <u>Minutes</u>		Minutes	- 1 8	Minutes
	Glu	A: Room	-temperat	are-setting	resorcinol r	sin			
Noble fir	: 380	i 11		19			**********		
Western hemlock		1 12	1	19				é tina	
Sitha spruce	: 425	¥ 11		20	: 47	8			**********
Douglas-fir	: 380	1 15	1	26		er e kine			**********
aho gany	\$ 535	1 12		16	: 22		32	1	
Sweetzun	545	11		16	: 25	1	38	1	
	1 720	1 11		14	: 19		26	- 8	38
	1 725	i 11		13	17		22		31
	Glu	B: Room	-temperat	are-setting	resorcinol r	esin .			
Woble fir	: 380	1 15	1	30	E.V.2.				
lestern hemlock		1 22		36	Inchesenation			2.222 - 1	
	425	2 20		34	: 39		*********		
	: 380	1 24		20			*********		*********
	535	1 18		39 26	1		60	* ***	**********
	545	1 16		24	± 37	8		- ###	• • • • • • • • • • • • •
	1 720	1 16		22	35	(#)	56 40	1.4	********
	1 725	1 17		25	1 35 1 30 1 34	1	717	i i	5I 56
	<u>61 w</u>	C: Boom	-temperatu	are-setting	resorcipol re	<u>șin</u>			
Noble fir	: 350	1 15		28					
Western hemlock		: 15 : 16		30	2		***********		***********
AAAAAA	E	27		52	1 130		**********		*********
Atta antion					1 130			****	*********
				76					
Douglas-fir	: 380	: 38	-	75	1		*********	- 1	
Douglas-fir ishogany	1 380 1 535	: 38 ; 21		38	65	1++	**********		
Douglas-fir Shogany Sweetgum	: 380 : 535 : 545	: 38 : 21 : 11	1	38 20	1 65 1 34	1	50	-	
Couglas-fir ishogany Sweetgum fellow birch	1 380 1 535 1 545 1 720	: 38 ; 21 : 11 : 13	8	38 20 20	1 65 1 34 1 27	1 8 8	80 35	1++ 1	
Douglas-fir Mahogany Sweetgum fellow birch	2 380 2 535 2 545 2 720 2 725	: 38 : 21 : 11 : 13 : 11	8 8 8	38 20 20 19	1 65 1 34 27 1 27	8 8 8 8	50	-	yta Yty
Douglas-fir Mahogany Sweetgum Tellow birch	2 380 2 535 2 545 2 720 2 725	: 38 : 21 : 11 : 13 : 11	8 8 8	38 20 20 19	1 65 1 34 1 27	8 8 8 8	80 35	1++ 1	
Douglas-fir ishogany Sweetgum Kellow birch Mard maple Noble fir	2 380 2 535 2 545 2 720 2 725 <u>Glue D</u> 2 380	: 38 : 21 : 11 : 13 : 11 : 11 : 11	i i i diato-tomy	38 20 20 19 perature-set 46	1 65 2 34 2 27 1 27 1 27 1 1 27	s s s s s s s s s s s s s s s s s s s	80 35 37	8	
Douglas-fir ishogany Sweetgum Fellow birch Mard maple Noble fir Western hemlock	2 380 2 535 2 545 2 720 2 725 01 up D: 3 380 2 385	: 38 : 21 : 11 : 13 : 11 : 11 : 11	i i i i diato-toug	38 20 20 19 99 99 90 19 46 49	1 65 2 34 2 27 4 27 4 27 ting phenol 3	s s s s s s s s s s s s s s s s s s s	80 35 37	8 8 8	չկկ 148
Douglas-fir ishogany Neestgim fellow birch lard maple Noble fir lestern hemlock litha spruce	2 380 2 535 2 545 2 720 2 725 01 up D: 3 380 2 385 2 425	: 38 : 21 : 11 : 13 : 11 : 13 : 11 : 13 : 11 : 31 : 3	i i i diato-tomy	38 20 20 19 99 99 99 46 49 67	1 65 2 34 2 27 1 27 1 27 1 1 27	1	80 35 37	1 1 1 1	եր հե
Douglas-fir ishogany Sweetgim fellow birch iard maple Noble fir festern hemlock hitha spruce Douglas-fir	2 380 2 535 2 545 2 720 2 725 01 we D: 3 80 2 380 2 385 2 425 2 380	: 38 : 21 : 11 : 13 : 11 : 13 : 11 : 13 : 11 : 31 : 3	i i i i diato-toug	38 20 20 19 <b>perature-set</b> 46 49 67 60	<pre>1 65 2 34 2 27 4 27 4 27 ting phenol 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2</pre>	1 2 3 8 *********************************	80 35 37	1	եր հեն
Douglas-fir ishogany Weetgim fellow birch lard maple Noble fir Mestern hemlock litha spruce Douglas-fir ishogany	2 380 2 535 2 545 2 720 2 725 01 we D: 3 80 2 380 2 385 2 425 2 380	: 38 : 21 : 11 : 13 : 11 : 13 : 11 : 13 : 11 : 31 : 3	i i i i diato-tomy i i i	38 20 20 19 <b>perature-set</b> 46 49 67 60	1 65 2 34 2 27 3 27 4 27 4 27 4 27 4 27 5 5 110	1 2 3 8 *********************************	80 35 37	1	եր հե
Douglas-fir ishogany Sweetgim fellow birch lard maple Noble fir Nestern hemlock sitka spruce Douglas-fir ishogany	1     380       1     535       2     545       1     725       01 we D:     01       2     380       1     385       2     425       2     380       2     535       2     535       2     545	: 38 : 21 : 11 : 13 : 11 : 13 : 11 : 13 : 11 : 35 : 42 : 39 : 36 : 42 : 42 : 42 : 44 : 47	1 3 5 5 618.to-toug 1 1 1 1	38 20 20 19 9 9 9 9 46 49 67 67 67 60 52 76	<pre>1 65 2 34 2 27 4 27 4 27 ting phenol 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2</pre>	1 2 3 8 *********************************	80 35 37		44 45
Douglas-fir ishogany Sweetgum fellow birch Hard maple Noble fir Nestern hemlock Sitha spruce Douglas-fir ishogany Sweetgum	2 380 2 535 2 545 2 720 2 725 01 we D: 3 380 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3	: 38 : 21 : 11 : 13 : 11 : 13 : 11 : 13 : 11 : 31 : 3	1 3 5 5 618.to-toug 1 1 1 1	38 20 20 19 <b>perature-set</b> 46 49 67 60	<pre># 65 # 34 # 27 # 27 # 27 # 27 # 27 # 10 # 10 # 73</pre>	8 8 8 8 8 700122  8 8 8 8	80 35 37		եր հեն

#### Table 4.--Istimated curing periods at 120° F. to develop shear strengths of several levels in lap-joints of 1/15-inch weneer of eight species glued with four resin glues

67984 1

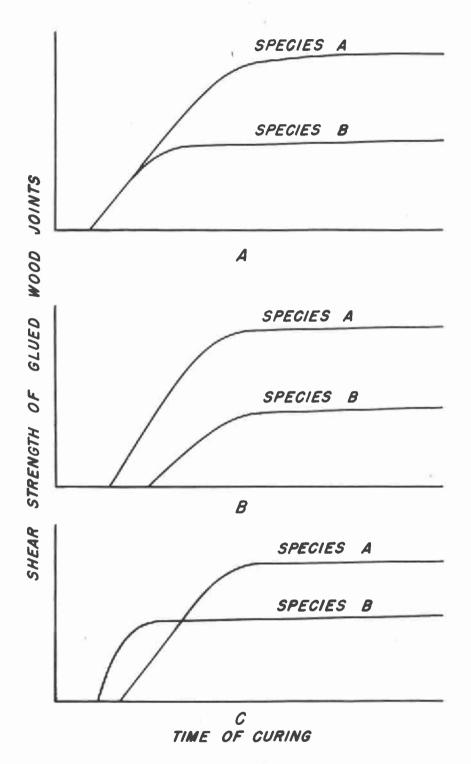


Figure 1.--Idealized rate of development of joint strength by a resin glue in two species of wood: (A) without, and (B) and (C) with species effect on the rate of curing of the glue. Z M 68842 F

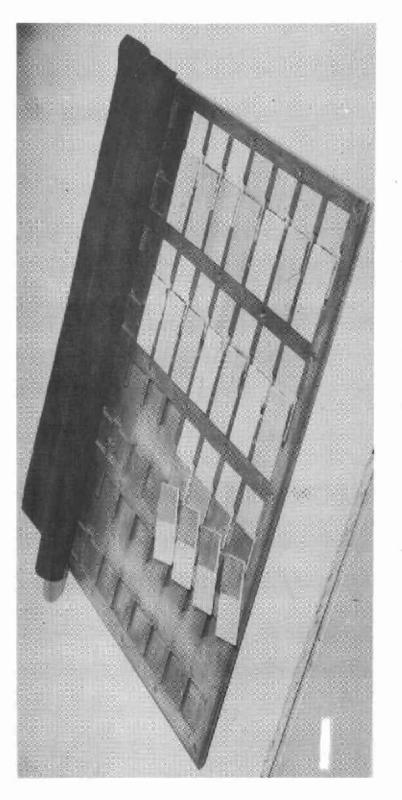
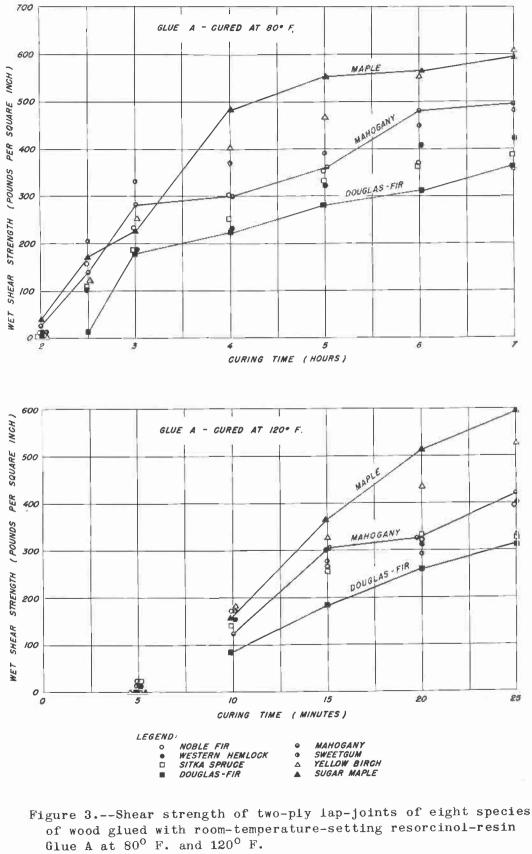


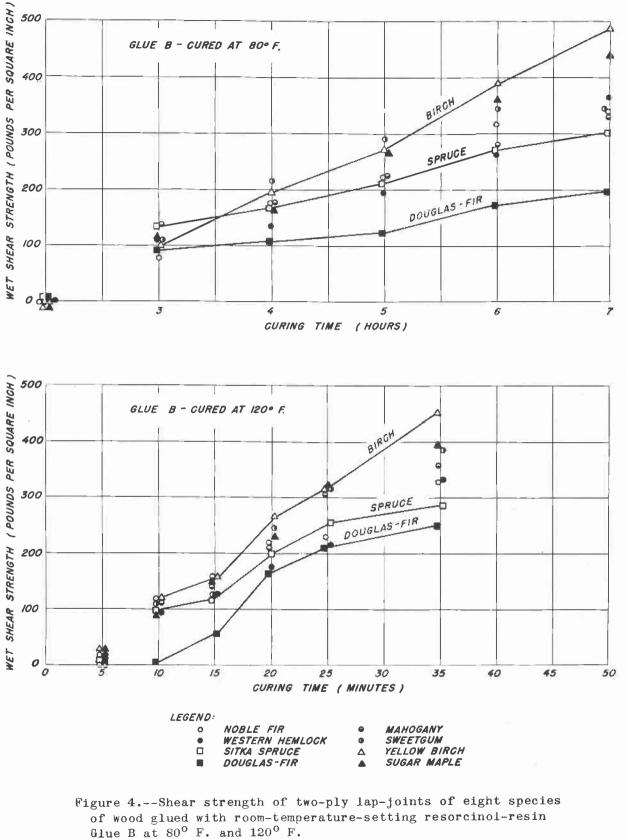
Figure 2.--Metal jig, with rubber caul, in which lap-joint specimens were prepared, 32 at a time.

Z M 64532 F





ZM 68843 F



Z M 68844 F

2.4

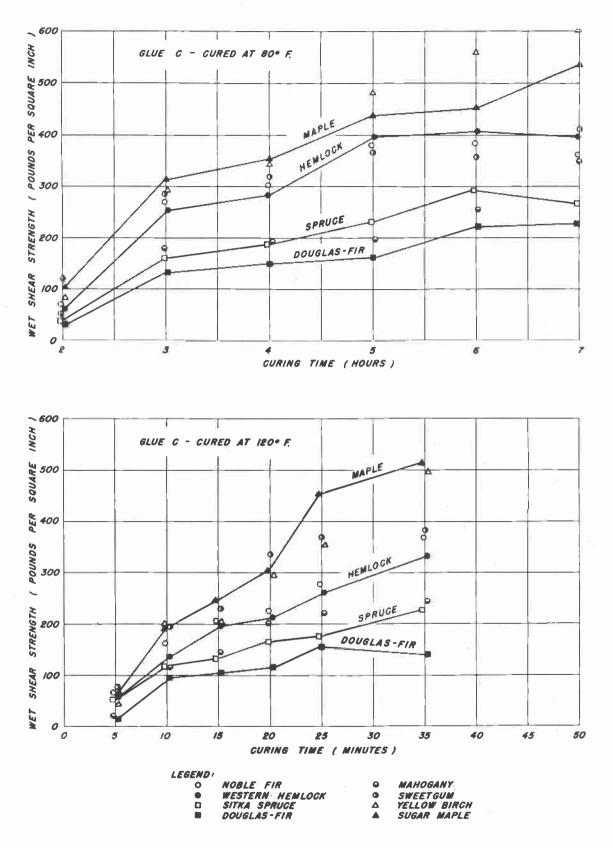


Figure 5.--Shear strength of two-ply lap-joints of eight species of wood glued with room-temperature-setting resorcinol-resin z M 68845 F Giue C at  $80^{\circ}$  F. and  $120^{\circ}$  F.

