VARIATION IN MAXIMUM ALLOWABLE
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FOR FOUR RESIN GLUES

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VARIATION IN MAXIMUM ALLOWABLE ASSEMBLY TIME

WITH AGE IN THE POT AT TIME OF SPREADING

FOR FOUR RESIN GLUES

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Introduction

As a thermosetting resin glue stands in the pot after mixing, the maximum assembly time at which strong joints can be made is considered to become shorter. It is generally assumed that the pressure should be applied well before the end of the working life when the glue in the pot becomes no longer spreadable. It is not known definitely, however, how the permissible assembly time should vary as the glue ages in the pot, or how the time of application of pressure should conform to the end of the working life of the glue. This study was undertaken, therefore, to obtain experimental information on this subject.

1This 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. Original report published in 1946.

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

3Assembly time in gluing is defined as the period between spreading the glue and applying the pressure. The assembly is called "open" if the surfaces to be joined are exposed to the air during this period or "closed" if the surfaces are together.
Two room-temperature-setting resorcinol-resin glues (designated A and B in this report), an intermediate-temperature-setting phenol-resin glue (designated P), and an acid-catalyzed intermediate-temperature-setting melamine-resin glue (designated M) were selected for study as representative of types of current importance in the fabrication of aircraft.

Joints were made with hard maple blocks, spreading each glue at various intervals between the time of mixing and the end of the working life, and allowing various periods of assembly, both open and closed, before applying the pressure and curing the glue. The quality of the joints so made was ascertained by testing specimens in shear.

**Procedure**

Hard maple blocks, 7/8 by 2-1/2 by 12 inches, were selected for straightness of grain, freedom from defects, and specific gravity ranging between 0.63 and 0.70 based on weight and volume when oven-dry. The blocks were conditioned to a moisture content of about 12 percent, surfaced on both sides to a thickness of 3/4 inch just before gluing, and glued together in sets of three laminations each.

Three assembly temperatures were chosen for this study, 70°, 90°, and 105° F., and the working lives of the glues, mixed from ingredients at 70° F., were determined at each of these temperatures; the end of the working life was considered as that time at which the glue could no longer be smoothly spread with a stiff bristle brush. When the glue was spread and the joints assembled, the gluing room was at 70°, 90°, or 105° F. The ingredients were always at 70° F. before mixing, and the mixed glue was allowed to adjust itself to the temperature of the room when the room was at 90° and 105° F. For each experiment, two duplicate batches of glue of 100 grams each were mixed according to the manufacturer's directions. One batch was observed frequently for a redetermination of the length of the working life; the other batch was used for gluing the joints. When the glue was spread, the wood was always at the gluing room temperature. The glue was applied by brushing at three intervals during the working life of the glue, namely 5 minutes after mixing the glue, when 50 percent of the working life as previously determined had elapsed, and when 75 percent of the working life had elapsed. The glue was applied to only one of the two joining surfaces. The spreading rate was about 65 pounds of wet glue per thousand square feet.
Various arbitrarily chosen periods of open and closed assembly were allowed after spreading the glue. Longer and longer assembly periods were chosen until shear tests of the cured joints showed a decided falling off in strength. At the end of each assembly period a pressure of 100 pounds per square inch was applied to the joints.

The joints made with resorcinol-resin glues were allowed to cure, under pressure, at the same temperatures as those used in assembling the joints, for 24 hours at 70°F., 16 hours at 90°F., or 6 hours at 105°F. The joints made with phenol-resin glue were cured under pressure for 24 hours in a chamber having a temperature of 180°F. The joints glued with melamine-resin glue were cured under pressure for 24 hours in a chamber having a temperature of 140°F. In each case the humidity in the curing chamber was controlled to keep the moisture content of the wood at about 12 percent. After removal of pressure, the joints were allowed to condition at 80°F. and 65 percent relative humidity at least 6 days before they were cut into specimens.

Ten specimens were cut from each glued assembly, and at least 10 specimens were tested for each assembly condition. Usually 20 or 30 specimens, from 2 or 3 glued assemblies, were tested for each assembly period.

**Results**

Both shear strengths and percentages of wood failure were recorded for each specimen tested, but attention has been given in the following presentation principally to the shear strength data. The average wood failures were reasonably high for all conditions, except those that had such long assembly time that the shear strengths fell well below 2,800 pounds per square inch. To illustrate, for those specimens that tested between 2,800 and 3,000 pounds per square inch the wood failure percentages averaged as follows: 48 for glue A, 34 for glue B, 65 for glue M in both open and closed assembly, and 47 for glue P in open assembly. For glue P in closed assembly, the average percentage wood failure of all specimens that had 5 days or less assembly time was 49 percent.

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4In the case of the phenol-resin glue, P, it was found that periods as long as 7 days in closed assembly at 70°F. and 90°F. had not caused a decided drop in shear strength, but longer assembly periods were not investigated.
The thickness of glue line was measured with a microscope on representative joints and inspected on all joints. In general, the lines were thicker the higher the assembly temperature and the longer the assembly time; but, even of those joints with such a long assembly time that the strengths were low, the glue lines did not exceed 0.010 inch in thickness.

**Closed Assembly**

**Resorcinol-resin glues.** --In figures 1 and 2 the average shear test values of the maple block joints prepared with the resorcinol-resin glues A and B in closed assembly have been plotted against the age of the mixed glue at the time the pressure was applied to the joints. Each point in the figures represents a set of specimens made with a particular assembly time. For example, in preparing the joints represented by point a in figure 1, the glue was brushed on the blocks 5 minutes after mixing; then 315 minutes passed in closed assembly, and the pressure was applied 320 minutes after the glue was mixed.

An interesting observation from figures 1 and 2 is that joints were obtained of as high strength as can ordinarily be made from maple of the density employed, even though the pressure was applied some time after the glue in the pot could no longer be spread.

The principal conclusion from these figures is that, for joints of at least 2,800 pounds per square inch by these resorcinol glues within the conditions of the experiment, the interval between mixing the glue and pressing the joint was approximately a constant. This constant varied with the glue and the assembly temperature. The value of the constant for glue A was about 375 minutes for 70° F., assembly temperature, about 150 minutes for 90° F., and about 90 minutes for 105° F. The value of the constant for glue B was about 215 minutes for 70° F. assembly temperature, about 105 for 90° F., and about 95 minutes for 105° F. If the pressure was applied so late that the total interval between mixing and pressing exceeded these times, the joint strength fell off rapidly. These values have been plotted in figure 3.

Since the interval between mixing the glue and pressing the joints must not exceed a maximum value for a particular resorcinol glue and gluing temperature, and since it is equal to the sum of the elapsed times between mixing and spreading and between spreading and pressing, the longer the glue stands in the pot before it is applied to the wood, the shorter is the closed assembly time permissible.

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Phenol-resin glue, intermediate-temperature-setting. --In figure 4 the average shear test values of the maple block joints prepared with the phenol-resin glue P in closed assembly were plotted against the age of the mixed glue at the time the pressure was applied to the joints, as was done in the case of the resorcinol-resin glues. This figure indicates that this glue would allow a very long closed assembly period. No sharp decline in joint strength was noted, and even after 7 days closed assembly at 70° and 90° F. and 3 days at 105° F. joints were produced that averaged over 2,800 pounds per square inch. At 105° F. the fresh glue gave consistently higher joint strengths than the same glue after 30 and 45 minutes in the pot.

Melamine-resin glue. --In figure 5 the average shear test values of the maple block joints prepared with the melamine-resin glue M in closed assembly were plotted against the age of the mixed glue at the time pressure was applied to the joints as was done in the case of the resorcinol- and phenol-resin glues.

The data indicate that at 70° F., unlike the resorcinol-resin glues, the maximum allowable time between mixing the glue and applying pressure to the joint decreased somewhat as the glue aged in the pot before spreading, from about 205 minutes for freshly mixed glue to 175 minutes for glue within 25 percent of the end of its working life. This effect of the age of the glue in the pot was not apparent at 90° and 105° F. The maximum elapsed time (choosing the most conservative value at the 70° F. temperature) has been plotted in figure 3 as a function of the assembly temperature.

Open Assembly

Resorcinol-resin glues. --The strength data obtained from shear tests of joints made with the resorcinol-resin glues in open assembly have been plotted in figures 6 and 7. From the data it appears that the maximum allowable open assembly time, with which glue A produced joints on maple blocks with a shear strength of at least 2,800 pounds per square inch, was between 20 and 25 minutes at 70° F., and between 10 and 15 minutes at 90° F. and 105° F. For glue B the maximum allowable open assembly times were between 12 and 15 minutes at 70° F., between 9 and 12 minutes at 90° F., and between 6 and 9 minutes at 105° F.

Up to 75 percent of the working life, the age of the glue in the pot at which the glue was spread, seemed to have little or no influence on the maximum permissible open assembly time for these resorcinol-resin glues.

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Phenol-resin glue.--The average strength data obtained from shear tests of joints made with the phenol-resin glue P, in open assembly have been plotted in figure 8. In marked contrast to the case for the resorcinol glues, the data of figure 8 show the age of this phenol glue at the time of spreading was very important in determining the maximum allowable open assembly time. For example, at 70° F., this glue freshly mixed produced maple block joints with shear strengths of 2,800 pounds per square inch with an open assembly period of over 8 hours, but as the glue stood in the pot, the period of open assembly at which joints of this strength were made became progressively shorter and was less than 2 hours when the glue had reached 75 percent of its working life at the time of spreading. For all temperatures and open assembly periods tried with this glue, it was permissible to apply the pressure at least as long as the glue in the pot remained spreadable.

Melamine-resin glue.--The average strength data obtained from shear tests of joints made with the melamine-resin glue M in open assembly have been plotted in figure 9. Except possibly at 70° F. near the end of the working life, the data of this figure indicate that the age of the glue in the pot at the time of spreading had little effect on the maximum permissible open assembly time for this acid-catalyzed intermediate-temperature-setting melamine-resin glue. In all cases the pressure had to be applied appreciably before the glue in the pot reached the end of its working life.

Conclusions

For the single-surface spreading, species of wood, curing temperatures, and assembly conditions employed in these experiments, the following conclusions seem valid.

Resorcinol-Resin Glues A and B, Room-Temperature-Setting

The two commercial resorcinol glues varied considerably in the maximum length of assembly time, closed and open, with which strong maple block joints could be made.

When the resorcinol glues were used in closed assembly, the maximum allowable closed assembly time was shorter the longer the mixed glue had been standing in the pot at the time it was spread, and it was
necessary to apply the pressure to the joints within a certain time after the glue was mixed irrespective of the length of the closed assembly period. The maximum allowable closed assembly time was at least as long as the working life (fig. 1 to 3).

The age of the mixed glue in the pot at the time the glue was spread had no effect on the maximum allowable open assembly time for these resorcinol glues. The maximum allowable open assembly time was always much shorter than the working life of the glue (figs. 6 and 7).

**Phenol-Resin Glue P, Intermediate-Temperature-Setting**

With the glue of this type selected for study, strong joints were made after several days of closed assembly time. The age of the glue in the pot at the time of spreading was more important at 105° F. than at 70° and 90° F. (fig. 4).

When this phenol glue was employed in open assembly, the age of the glue in the pot since mixing had an important effect on the maximum allowable open assembly time (fig. 8). The older the glue mixture the shorter was the open assembly time at which strong joints could be made.

**Melamine-Resin M, Acid-Catalyzed, Intermediate-Temperature-Setting**

For this melamine glue employed in closed assembly, the age of the mixed glue in the pot at time of spreading was important at the assembly temperature of 70° F., but negligible at 90° and 105° F. (fig. 5). In open assembly, the effect was negligible except possibly at 70° F. near the end of the working life (fig. 9).

It is important to call attention to the fact that the glues in this study were spread on only one of the two surfaces to be joined. Double spreading might have given quite different results.

Also, the air movement over the surface of the spread glue during open assembly has an important effect on the maximum allowable open assembly time. In this study the glue was applied to the surfaces to be glued in a room in which the air was being circulated by fans, but the surfaces were shielded from any strong direct draft.

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Figure 1.--Average shear strengths of joints in maple blocks spread with resorcinol-resin glue A at three different times during the working life of the glue and put under pressure after various periods of closed assembly at 70°, 90°, and 105° F.
Figure 2.—Average shear strengths of joints in maple blocks spread with resorcinol-resin glue B at three different times during the working life of the glue and put under pressure after various periods of closed assembly at 70°, 90°, and 105° F.
Figure 3.—Maximum elapsed time, between mixing glue and applying pressure, within which strong joints in hard maple blocks were made with three resin glues in closed assembly.

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Figure 4.—Average shear strengths of joints in maple blocks spread with phenol-resin glue P at three different times during the working life of the glue and put under pressure after various periods of closed assembly at 70°, 90°, and 105° F.
Figure 5.—Average shear strengths of joints in maple blocks spread with melamine-resin glue M at three different times during the working life of the glue and put under pressure after various periods of closed assembly at 70°, 90°, and 105° F.
Figure 6.—Average shear strengths of joints in maple blocks made at different room temperatures with resorcinol-resin glue A applied at three different times during the working life of the glue and pressed after various periods of open assembly at temperatures of 70°, 90°, and 105° F. Working life of the glue was as follows: upper curves, 300 minutes; middle curves, 105 minutes; and bottom curves, 60 minutes.
Figure 7.—Average shear strengths of joints in maple blocks made at different room temperatures with resorcinol-resin glue "B" applied at three different times during the working life of the glue and pressed after various periods of open assembly at 70°F, 90°F, and 105°F. Working life of the glue was as follows: upper curves, 210 minutes; middle curves, 90 minutes; and bottom curves, 60 minutes.
Figure 8.—Average shear strengths of joints in maple blocks made at different room temperatures with phenol-resin glue P applied at three different times during the working life of the glue, and pressed after various periods of open assembly at 70°, 90°, and 105° F. Curing temperature was 180° F. Working life of the glue was as follows: upper curves, 300 minutes; middle curves, 120 minutes; and bottom curves, 60 minutes.
Figure 9.--Average shear strength of joints in maple blocks made at different room temperatures with melamine-resin glue M applied at three different times during the working life of the glue and pressed after various periods of open assembly time at 70°, 90°, and 105° F. The curing temperature was 140° F. Working life of the glue was as follows: upper curves, 160 minutes; middle curves, 80 minutes; bottom curves, 60 minutes.