# BLEED-THROUGH OF GLUE IN AIRCRAFT PLYWOOD

**Information Reviewed and Reaffirmed**

**June 1960**

**No. 1541**

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

# BLEED-THROUGH OF GLUE IN AIRCRAFT PLYWOOD[1]

By

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

----

Glue deposits on the surfaces of plywood panels that result from the penetration of glue from the joints during hot pressing are commonly designated as "bleed-through." Such surface glue deposits are rather common on thin aircraft plywood, particularly on plywood with thin mahogany, khaya, or yellow birch face plies.

By carefully adjusting the moisture content of veneers, producers of aircraft plywood have found it possible to reduce bleed-through greatly; it is difficult, however, if not impossible to eliminate bleed-through entirely in material with thin faces. Consequently, plywood that shows various amounts of bleed-through but is otherwise of excellent quality often reaches aircraft fabrication plants.

Numerous inquiries regarding the suitability for aircraft of plywood showing bleed-through came to the Forest Products Laboratory during World War II. Most of these inquiries were concerned with the quality of the secondary glue bonds that could be made to plywood surfaces showing various amount of bleed-through, but the quality of the primary glue bonds of this plywood also was questioned.

The frequency of these requests for information on aircraft plywood showing bleed-through indicated a need for a general investigation of the problem and resulted in the studies described in this report. The specific problems investigated were as follows: (1) The factors contributing to the development of bleed-through; (2) the secondary gluing of plywood showing various amounts of bleed-through; and (3) the quality of primary glue bonds in plywood showing various amounts of bleed-through.

---

[1] This report is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available. Original report dated November 1944.

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

## Materials and Methods

Since aircraft plywood was commonly faced with mahogany or khaya, most of these studies were concerned with plywood having mahogany (Swietenia spp.) and khaya (African mahogany) face plies. Veneers of other species were included in those parts of the study dealing with the effect of species on the occurrence of bleed-through.

With the exception of the studies made to determine the effect of thickness of veneer on bleed-through, face veneers of 1/100- and 1/48-inch thickness were used.

Veneers were conditioned in humidity-controlled rooms before hot pressing, and when the moisture content of veneers was the variable being studied, the moisture content at the time of hot pressing was determined by ovendrying samples.

Because most aircraft plywood is made with phenolic glue film, this glue was used in most of these tests. The panels were pressed for 6 to 10 minutes at platen temperatures of 320° F. under pressures of 150 to 200 pounds per square inch, depending on the species.

Bleed-through on commercially produced aircraft plywood has usually been described as light, moderate, or heavy. Although this classification is based largely on observation and such estimates may be subject to some error, it was adopted in this study with the addition of a fourth class described as very heavy. To achieve some measure of uniformity between estimates made at widely separated intervals, a set of panels was selected and used as a standard for comparison (fig. 1). The approximate percentage of the surface area covered with glue deposits for each of these four classes was as follows:

| | |
|---|---|
| Light.......... | Less than 5 percent |
| Moderate....... | 5 to 15 percent |
| Heavy.......... | 15 to 30 percent |
| Very heavy..... | Over 30 percent |

A preliminary test also was made to determine whether all of the dark surface deposits on thin-faced mahogany and khaya panels were glue or whether they consisted partly of the dark-colored gums occurring naturally in both khaya and mahogany. Because these dark-colored gums resemble the phenol-formaldehyde glues in color and are somewhat soluble in phenol, it has been suggested that they might make up all or part of the bleed-through deposits on thin-faced mahogany plywood. In these preliminary tests no bleed-through was obtained when thin mahogany and khaya veneers having various moisture contents were laid up in the form of panels and hot pressed without glue, or when mahogany and khaya veneers soaked in phenol were laid up in the form of panels and hot pressed without glue. In a further test, typical bleed-through was obtained on panels with face plies of a wood resembling mahogany in structure, but containing none of the dark-colored gums typical of mahogany, when this material was glued with phenol-formaldehyde film glue. These preliminary tests indicated rather conclusively that bleed-through on mahogany and khaya plywood consists largely, if not entirely, of glue.

## Factors Contributing to the Development of Bleed-Through

Some of the factors contributing to the development of bleed-through are well recognized, and their importance has been reasonably well established through experience in plywood manufacture. For example, the moisture content of veneers at the time of gluing, species and thickness of face veneers, and the amount of glue spread are known to affect the amount of bleed-through that may occur in the manufacture of aircraft plywood.

In addition to the studies made to evaluate more accurately the effect of these factors on bleed-through, the effect of the following was investigated: Slope of grain in face veneers; species and kind of core (heartwood or sapwood); and hot pressing temperatures and pressures.

### Moisture Content of Veneers

The experience of aircraft plywood manufacturers has indicated that the moisture content of veneers at the time of hot pressing is one of the most important factors affecting the development of bleed-through, and that bleed-through can be minimized by reducing the moisture content of veneers to the minimum necessary to insure the production of high-quality glue bonds.

A number of tests to determine the effect of veneer moisture content on bleed-through were made during the course of these studies. The results of one test, which are quite typical, are given in table 1. These tests were made on 3-ply panels (27 by 18 inches) with 1/48-inch mahogany and khaya faces and 1/32-inch sweetgum heartwood cores, with all plies conditioned to the same moisture content. Results of tests giving additional information on the effect of moisture content of veneers on bleed-through are presented in table 2.

These results indicate that with a light glue spread (one sheet of phenolic glue film per glue line) bleed-through is relatively unimportant, unless the veneers are at a moisture content of 14 percent or higher at the time of hot pressing. With heavier glue spreads, obtained by using more than one sheet of phenolic glue film per glue line, bleed-through was proportionately greater.

An experiment similar to the one previously described was made with melamine glue film instead of phenolic glue film. The bleed-through obtained was light in color; little bleed-through was evident until the moisture content of the veneers was 14 percent or higher, and less occurred at higher moisture contents than with phenolic glue film.

Bleed-through was never uniform over the entire surfaces of individual panels and was always heavier over areas of short grain. For example, panels pressed at 14 percent moisture content often had heavier bleed-through over areas of the face plies where the grain was shorter than was present on panels with straight-grained face plies pressed at 18 percent moisture content. The thickness of face plies and kind of wood in the core (heartwood or sapwood) also affected the amount of bleed-through obtained when veneers were hot pressed at various moisture content values.

## Slope of Grain in Face Veneers

Examination of all of the panels made in this study and many commercially produced mahogany, khaya, and yellow birch panels showed that the slope of grain in face veneers, with respect to the plane of the sheets, is a major factor in the formation of bleed-through. In panels showing light to moderate bleed-through, these surface glue deposits were largely restricted to short-grain areas in the face plies (fig. 2). Mahogany, khaya, and yellow birch plywood panels with thin face plies, 1/48, 1/48, and 1/100 inch, respectively, may show some bleed-through over short-grain areas, even though the veneers are not at a high moisture content at the time of gluing and all gluing conditions are in accordance with good commercial practices.

## Face Veneer Thickness

The fact that bleed-through is rarely encountered in aircraft plywood when the face plies are thicker than 1/24 inch indicates that there is a relationship between bleed-through and thickness of face veneers. In these studies it was difficult to eliminate bleed-through completely on panels with 1/100-inch yellow birch and 1/48-inch mahogany and khaya faces glued at moisture contents of 10 percent and above; whereas bleed-through was rare for the same species in panels with 1/16-inch faces, even when the moisture content of the veneers was high and heavy glue spreads were used. The results of one study to establish the relationship between face veneer thickness and bleed-through are presented in table 2.

## Sapwood and Heartwood in the Core

The occurrence of heavy bleed-through over heartwood core areas and its absence over sapwood cores has been observed for many commercially produced panels with thin mahogany and khaya faces and sweetgum and yellow-poplar cores. In some of these panels it has been possible to identify the portions of the panels having sapwood or heartwood cores by the amount of glue deposits on the face plies.

To investigate the effect of sapwood and heartwood cores on bleed-through, a number of panels with 1/48-inch mahogany and khaya faces and 1/48-inch yellow-poplar, sweetgum, yellow birch, black walnut, and Sitka spruce cores were glued with phenolic film glue. The veneers were conditioned to moisture contents of 6, 10, 14, 18, and 20 percent before hot pressing; and the cores of the panels were made up of alternate strips of heartwood and sapwood (figs. 3 and 4).

The difference in the amount of bleed-through formed under these conditions was very marked for panels having yellow-poplar, sweetgum, and black walnut cores; the glue deposits over the heartwood-core areas were always much heavier than over sapwood-core areas (figs. 3 and 4). No appreciable difference in the amount of bleed-through produced was evident for the panels with yellow birch or Sitka spruce heartwood and sapwood cores.

The reason for this difference in amount of bleed-through became apparent when the panels were scarfed (figs. 3 and 4). The glue was found to penetrate deeply into the sapwood-core areas but failed to penetrate the heartwood. The resistance of the heartwoods of these species to penetration by glue apparently caused the glue to flow to the surface; whereas the glue penetrated the sapwood cores and was polymerized there during hot pressing.

These results indicate that the formation of bleed-through may be appreciably influenced by the species and penetrability of wood, whether sapwood or heartwood, used for cores.

## Sapwood and Heartwood in Face Plies

No appreciable difference was observed in the amount of bleed-through on sapwood and heartwood portions of yellow birch panels with thin face plies (1/48 and 1/100 inch). On birch panels with thicker face plies, somewhat more bleed-through was present on sapwood portions. On panels with yellow-poplar, sweetgum, or Sitka spruce face plies, considerably more bleed-through was present on sapwood areas than on heartwood, although, as is subsequently pointed out, bleed-through was not a serious factor with these species.

## Species of Face Plies

Observations on commercially produced aircraft plywood and the results of several laboratory tests indicated that under normal gluing conditions, bleed-through is a problem chiefly when mahogany, khaya, and yellow birch are used for face veneers.

The tests made indicated that for the hardwoods most commonly used in the manufacture of aircraft plywood--mahogany, khaya, yellow birch, yellow-poplar, and sweetgum--there is a direct relationship between pore size and bleed-through. The diameters of the pores in these hardwoods are as follows: Mahogany, 110 to 170 microns; khaya, 180 to 240 microns; yellow birch, 60 to 160 microns; yellow-poplar, 80 to 130 microns; and sweetgum, 60 to 95 microns.

No apparent difference in amount of bleed-through was observed between panels with khaya and panels with mahogany face veneers.

For the same thickness and under identical gluing conditions, less bleed-through was obtained on plywood with yellow birch faces than on plywood with khaya or mahogany faces. Although this was probably largely due to a difference in size and number of pores, straightness of grain may have influenced the results, because birch veneer usually has considerably less short grain than mahogany or khaya veneer.

Relatively little bleed-through was obtained for panels with yellow-poplar face veneers, and it was even more infrequent for panels with sweetgum faces. Although sliced sweetgum veneers may have as much sloping grain as mahogany, the small size of the pores in sweetgum appeared to retard the penetration of glue and prevented the formation of bleed-through under all except the most extreme gluing conditions.

No appreciable bleed-through was obtained on panels made with quarter-sliced Sitka spruce and Douglas-fir face veneers even when the veneers were at high moisture contents and heavy glue spreads were applied. Several panels made with 1/48- and 1/100-inch rotary-cut Douglas-fir face veneers, however, showed considerable bleed-through, and the appearance of the panels indicated that the glue penetrated to the surface through the rays and resin ducts.

## Effect of Amount of Glue Spread

Since the greater part of thin aircraft plywood is made with phenolic glue film, the amount of glue spread is rarely an important factor in determining the quantity of bleed-through present on commercially produced aircraft plywood. There is a direct relationship between the amount of glue spread and the amount of bleed-through produced, however, and in all of these tests more bleed-through was obtained when two or more sheets of phenolic film glue were used per glue line than when a single sheet was used (table 1). When liquid glues were used to glue thin mahogany, khaya, and birch veneers, it was difficult to obtain spreads that were uniform and still sufficiently light to prevent excessive bleed-through. In thin-faced aircraft plywood made with phenolic glue film, more bleed-through is usually present over areas where two sheets of glue film are overlapped.

## Effect of Other Factors

Within the limits of the temperatures required to cure adequately the glues tested, platen temperature had relatively little effect on the amount of bleed-through produced. This was true also for pressures, little difference in amount of bleed-through occurring throughout the range of pressures recommended for the production of high-quality joints.

No appreciable difference in the appearance and amount of bleed-through was noticed when waxed birch plywood or metal cauls were used.

The effect of assembly time on bleed-through was given little attention in this study because most of the work was done with phenolic film glue. It is recognized, however, that assembly time is an important factor and would probably affect the amount of bleed-through when liquid glues are used.

## The Secondary Gluing of Plywood Surfaces Showing Various Amounts of Bleed-Through

The questions most frequently raised in connection with aircraft plywood showing bleed-through are: (1) Can satisfactory secondary glue joints be made to these surfaces with cold-setting glues; and (2) can the gluing characteristics of surfaces showing bleed-through be improved by some type of treatment.

Most of the secondary gluing tests made during the course of this study were limited to mahogany and khaya plywood glued with phenolic film glue, some of which was produced during the course of the experiments previously described and some of which was produced commercially.

Two types of secondary glue joints were made: Sitka spruce cap strips (3/8 by 3/8 by 12 inches) were nail glued to strips of plywood (3 by 12 inches); and two strips of plywood (5 by 12 inches) were glued together under 150 pounds per square inch pressure. The cap strip-to-plywood joint made by nail gluing probably is more typical for the majority of the glue joints made to plywood surfaces during aircraft fabrication than is the plywood-to-plywood joint. The manner in which the cap strip-to-plywood joints were prepared and tested has been described in another publication.[3]

In an effort to improve the gluing characteristics of plywood surfaces containing bleed-through, some of the panels were lightly sanded and others were washed with ether prior to making the secondary glue joints.

---

[3] Kaufert, F. H. Preliminary Experiments to Improve the Gluing Characteristics of Refractory Plywood Surfaces by Sanding. Forest Products Laboratory Rept. No. 1351, 1943.

Light sanding of plywood surfaces showing bleed-through has been reported to improve greatly both the joint strength and the percentage of wood failure for secondary glue joints made to such surfaces with cold-setting glues.[3,4]

The results of secondary gluing studies on Laboratory and commercially produced panels are given in tables 3, 4, and 5. The surfaces of some of the Laboratory-produced panels were wetted with water as soon as they were removed from the hot press, a standard practice in commercial manufacture of aircraft plywood. Separate secondary gluing tests were made on the wetted and unwetted panels; but the results were in such close agreement that they were combined, and only the averages are presented in tables 4 and 5.

Although there are a few exceptions, the percentage of wood failure for the joints made to unsanded panels in general decreased as the amount of bleed-through increased. Shear strengths showed less variation and were fairly high in all panels. These results indicate that although heavy bleed-through does interfere with the adhesion of cold-setting glues, the extent of such interference is not as great as is often assumed.

When panels showing different amounts of bleed-through were lightly sanded before gluing, the resulting glue joints made with both casein and cold-setting urea-resin glues were of uniformly high quality (tables 3, 4, and 5). The removal of some of the surface glue deposits by this treatment appeared to be sufficient to insure good adhesion of glues. The shear strengths and wood failures for the resulting joints were as high for the sanded panels with heavy bleed-through as for the panels without bleed-through.

Treatment of the panel surfaces with ether did not appreciably improve the gluing characteristics of plywood having various amounts of bleed-through (table 3). Results similar to those obtained with ether were obtained with other solvents, such as benzene, methyl alcohol, ethyl alcohol, and acetone. These solvents have been tried by a number of aircraft fabricators in an attempt to improve the gluing characteristics of plywood showing heavy bleed-through, but the results obtained in this test indicated that such treatment is not effective.

## Effect of Bleed-Through on the Strength of Primary Glue Joints

The quality of the primary glue bonds in plywood showing heavy bleed-through has frequently been questioned. Although the amount of glue on the surface of such plywood may be deceiving, the appearance of some of

---

[4] Haskelite Manufacturing Company. Effect of Bleed-Through on Secondary Gluing. Tech. Note No. 1051, 1944.

this material does suggest that so much glue has bled to the surfaces that the primary glue joints may be starved, and consequently are not of as high a quality as the primary joints of plywood free from bleed-through.

Plywood shear tests made on commercially produced mahogany, khaya, and yellow birch plywood showing different amounts of bleed-through, from light to very heavy, have shown no indication of reduced joint strengths for panels with heavy surface glue deposits as compared to panels free from bleed-through.

In order to obtain more information on this point, plywood shear tests were made on a number of the mahogany- and khaya-faced panels produced in the Laboratory during the course of the previous studies. These panels were made from veneer of fairly uniform quality glued with phenolic film glue under known conditions, thereby affording a better comparison than could be obtained with panels from commercial production.

The results of the plywood shear tests on one set of Laboratory-made panels are summarized in table 6. Since these panels were made from veneers at different moisture contents, the results involve a moisture content as well as a bleed-through variable. In spite of this complicating factor, however, there is no consistent difference between the joint strength of the panels with different amounts of bleed-through.

In these studies on Laboratory and commercially produced plywood it was difficult to distinguish between the effect of moisture content of veneers at the time of gluing and the effect of bleed-through on joint quality. Panels of the type illustrated in figure 3, however, provided material showing different amounts of bleed-through without involving a moisture content variable. Matched plywood shear specimens, therefore, were cut from a number of panels with 1/48-inch mahogany and khaya face veneers and 1/32-inch yellow-poplar and sweetgum cores, with the cores of the panels composed of alternate strips of heartwood and sapwood as illustrated in figures 3 and 4. The results of these shear tests are summarized in table 7.

It is evident from these results that in material tested at 10 percent moisture content, the shear specimens cut from the portions of the panels showing different amounts of bleed-through were as strong as or slightly stronger than the specimens cut from portions of the panels without bleed-through. Since the failures in the shear specimens tested dry were predominately in the face plies, it is possible that this difference in shear strength was partially due to reinforcing of the face plies by glue over the heartwood cores. Shear specimens tested wet after boiling did not indicate this increase in strength with bleed-through, as the specimen failure was typically in the core.

## Summary

The amount of bleed-through produced on Laboratory-made panels of thin aircraft plywood was appreciably affected by the following: Moisture content of veneers at the time of hot pressing; slope of grain in the face veneers; thickness and species of face veneers; amount of glue spread; and species and type of wood (sapwood or heartwood) used for cores.

The presence of light to moderate bleed-through or surface glue deposits on mahogany and khaya plywood panels did not seriously interfere with adhesion of casein and cold-setting urea-resin glues in secondary gluing operations. The presence of heavy or very heavy bleed-through, on the other hand, usually caused some interference with adhesion of the cold-setting glues used for secondary gluing, unless the surfaces were sanded before gluing.

Light sanding with 3/0 or 4/0 garnet paper, or their equivalent in other abrasives, proved to be the simplest and most effective method of treating surfaces showing bleed-through in order to assure a satisfactory condition for gluing with casein and cold-setting urea-resin glues. When plywood surfaces showing heavy bleed-through were lightly sanded before gluing, the quality of the secondary glue joints made to these surfaces with cold-setting glues was as high as the quality of joints made to plywood surfaces without bleed-through.

There was no evident correlation between bleed-through and the quality of primary glue joints in plywood made within the range of conditions normally encountered in the manufacture of aircraft plywood.

Table 1.--Effect of moisture content of veneers at the time of hot pressing on the amount of bleed-through produced on mahogany-faced panels[1]

| Number of panels | Average moisture content of veneer[2] | Number of sheets of phenolic glue film per glue line | Amount of bleed-through |
|---|---|---|---|
| | Percent | | |
| 4 | 6 | 1 | None |
| 5 | 10 | 1 | None to light |
| 5 | 14 | 1 | Light to moderate |
| 1 | 18 | 1 | Heavy |
| 2 | 20 | 1 | Heavy |
| 4 | 14 | 2 | Moderate to heavy |
| 4 | 14 | 3 | Heavy |
| 5 | 20 | 3 | Very heavy |

[1]Panels pressed at a platen temperature of 320° F. and pressure of 175 pounds per square inch.

[2]Face plies 1/48-inch, cores 1/32-inch sweetgum.

Table 2.--Effect of veneer thickness on the amount of bleed-through produced on mahogany-faced panels[1]

| Thickness of face veneers[2] | Moisture content of veneers at time of hot pressing | Amount of bleed-through |
|---|---|---|
| Inch | Percent | |
| 1/48 | 10 | None to light |
| 1/32 | 10 | None |
| 1/24 | 10 | None |
| 1/16 | 10 | None |
| 1/48 | 14 | Light to moderate |
| 1/32 | 14 | Light |
| 1/24 | 14 | Light |
| 1/16 | 14 | None |
| 1/48 | 18 | Heavy |
| 1/32 | 18 | Moderate |
| 1/24 | 18 | Moderate |
| 1/16 | 18 | None |
| 1/48 | 20 | Heavy |
| 1/32 | 20 | Moderate to heavy |
| 1/24 | 20 | Moderate to heavy |
| 1/16 | 20 | Very light |

[1]One sheet of phenolic glue film used per glue line.

[2]All plies of any one panel of the same thickness.

Table 3.--Relation of amount of bleed-through to strength of urea-resin glue joints between spruce cap strips and commercially made mahogany panels with surfaces treated in various ways before gluing

| Amount of bleed-through | Surface treatment | | | | | |
|---|---|---|---|---|---|---|
| | Surfaces of panels not treated before gluing | | Surfaces of panels sanded before gluing | | Surfaces of panels scrubbed with ether before gluing | |
| | Number of panels tested[1] | Joint strength and wood failure[2] | Number of panels tested[1] | Joint strength and wood failure[2] | Number of panels tested[1] | Joint strength and wood failure[2] |
| None | 4 | 556-96 | 4 | 621-99 | 4 | 611-91 |
| Light | 7 | 513-66 | 7 | 628-94 | 7 | 540-68 |
| Moderate | 3 | 499-34 | 3 | 631-98 | 3 | 561-77 |
| Heavy | 8 | 499-50 | 8 | 618-95 | 8 | 533-53 |

[1]9 shear test specimens from each panel were tested for each condition.

[2]The first value represents joint strength in pounds per square inch; the second value represents the percentage wood failure.

Table 4.--Relation of amount of bleed-through to strength of urea-resin and casein glue joints between spruce cap strips and Laboratory-made mahogany plywood with surfaces untreated or sanded before gluing

| Amount of bleed-through | Surfaces of panels not treated before gluing | | Surfaces of panels sanded before gluing | |
|---|---|---|---|---|
| | Number of test specimens | Joint strength and wood failure[1] | Number of test specimens | Joint strength and wood failure[1] |
| **UREA-RESIN GLUE** | | | | |
| None | 27 | 632-90 | 27 | 634-92 |
| Light | 21 | 666-96 | 21 | 660-97 |
| Moderate | 24 | 634-91 | 24 | 699-99 |
| Heavy | 60 | 591-69 | 60 | 680-98 |
| Very heavy | 12 | 576-55 | 8 | 585-100 |
| **CASEIN GLUE** | | | | |
| None | 27 | 627-76 | 30 | 597-92 |
| Light | 39 | 555-66 | 21 | 665-96 |
| Moderate | 33 | 578-69 | 24 | 717-98 |
| Heavy | 66 | 567-61 | 58 | 639-93 |
| Very heavy | 14 | 536-86 | 12 | 551-99 |

[1]The first value represents joint strength in pounds per square inch; the second value represents the percentage of wood failure.

Table 5.--Relation of amount of bleed-through to strength of urea-resin and casein secondary glue joints between Laboratory-made mahogany-faced plywood panels with surfaces untreated or sanded before gluing

| Amount of bleed-through | Surfaces of panels not treated before gluing | | Surfaces of panels sanded before gluing | |
|---|---|---|---|---|
| | Number of test specimens | Joint strength and wood failure[1] | Number of test specimens | Joint strength and wood failure[1] |
| UREA-RESIN GLUE | | | | |
| None | 16 | 425-99 | 26 | 427-99 |
| Light | 28 | 354-100 | 40 | 366-99 |
| Moderate | 40 | 378-100 | 39 | 350-100 |
| Heavy | 28 | 451-99 | 26 | 415-100 |
| Very heavy | 15 | 367-8 | 15 | 534-92 |
| CASEIN GLUE | | | | |
| None | 26 | 479-98 | 27 | 542-99 |
| Light | 30 | 490-97 | 30 | 405-99 |
| Moderate | 32 | 432-96 | 40 | 354-100 |
| Heavy | 24 | 437-81 | 28 | 435-99 |
| Very heavy | 30 | 525-56 | 30 | 539-93 |

[1]The first value represents joint strength in pounds per square inch; the second value represents the percentage of wood failure.

Table 6.--Effect of amount of bleed-through on the shear strength of thin-faced mahogany panels tested after conditioning to about 10 percent moisture content or boiling in water for 3 hours

| Amount of bleed-through | Moisture content of veneers at time of gluing | Number of sheets of glue film per glue line | Tested after conditioning to about 10 percent moisture content | | | Tested wet after boiling in water for 3 hours | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number of specimens | Average shear strength | Average wood failure | Number of specimens | Average shear strength | Average wood failure |
| | Percent | | | Pounds per square inch | Percent | | Pounds per square inch | Percent |
| None | 6 | 1 | 20 | 292 | 91 | 20 | 321 | 86 |
| None | 10 | 1 | 20 | 314 | 99 | 20 | 374 | 97 |
| Light | 10 | 1 | 29 | 297 | 97 | 29 | 338 | 99 |
| Moderate | 14 | 1 | 28 | 288 | 99 | 28 | 328 | 98 |
| Heavy | 18 | 1 | 18 | 324 | 95 | 18 | 309 | 71 |
| Heavy | 20 | 1 | 17 | 281 | 63 | 17 | 281 | 50 |
| Heavy | 14 | 2 | 31 | 316 | 99 | 31 | 362 | 96 |
| Heavy | 18 | 2 | 5 | 436 | 100 | 5 | 344 | 100 |
| Heavy | 14 | 3 | 7 | 401 | 97 | 7 | 363 | 97 |

Table 7.--Effect of amount of bleed-through on the shear strength of mahogany-faced plywood with yellow-poplar and sweetgum sapwood and heartwood cores, conditioned to 10 percent moisture content or tested wet after boiling for 3 hours

| Species of core stock | Amount of bleed-through over cores | | Moisture content of veneers at time of gluing | | Shear strength of specimens conditioned to about 10 percent moisture content[1] | | Wet shear strength of specimens after boiling for 3 hours[1] | |
|---|---|---|---|---|---|---|---|---|
| | Heartwood | Sapwood | Faces | Cores | Heartwood core | Sapwood core | Heartwood core | Sapwood core |
| | | | Percent | Percent | | | | |
| Sweetgum | Light | Light | 10 | 14 | 319-100 | 256-97 | 344-92 | 342-98 |
| Yellow-poplar | Light | None | 10 | 14 | 324-99 | 290-98 | 340-96 | 274-98 |
| Sweetgum | Moderate | Light | 10 | 10 | 353-94 | 335-97 | 367-98 | 396-90 |
| Sweetgum | Moderate | Light | 10 | 18 | 326-98 | 306-97 | 320-68 | 346-100 |
| Sweetgum | Heavy | Light | 10 | 18 | 362-93 | 283-97 | 358-97 | 376-100 |
| Yellow-poplar | Heavy | Light | 14 | 14 | 351-99 | 297-100 | 375-100 | 354-100 |
| Yellow-poplar | Heavy[2] | Light[2] | 14 | 14 | 436-100 | 326-100 | 344-100 | 380-99 |
| Sweetgum | Heavy | Moderate | 18 | 18 | 304-98 | 346-100 | 356-99 | 292-96 |
| Sweetgum | Very heavy | Moderate | 18 | 18 | 347-100 | 274-99 | 304-99 | 349-100 |

[1] The first value represents joint strength in pounds per square inch; the second value represents the percentage of wood failure. Each figure is an average for 5 shear specimens.

[2] 2 sheets of phenolic glue film per glue line were used for this panel.

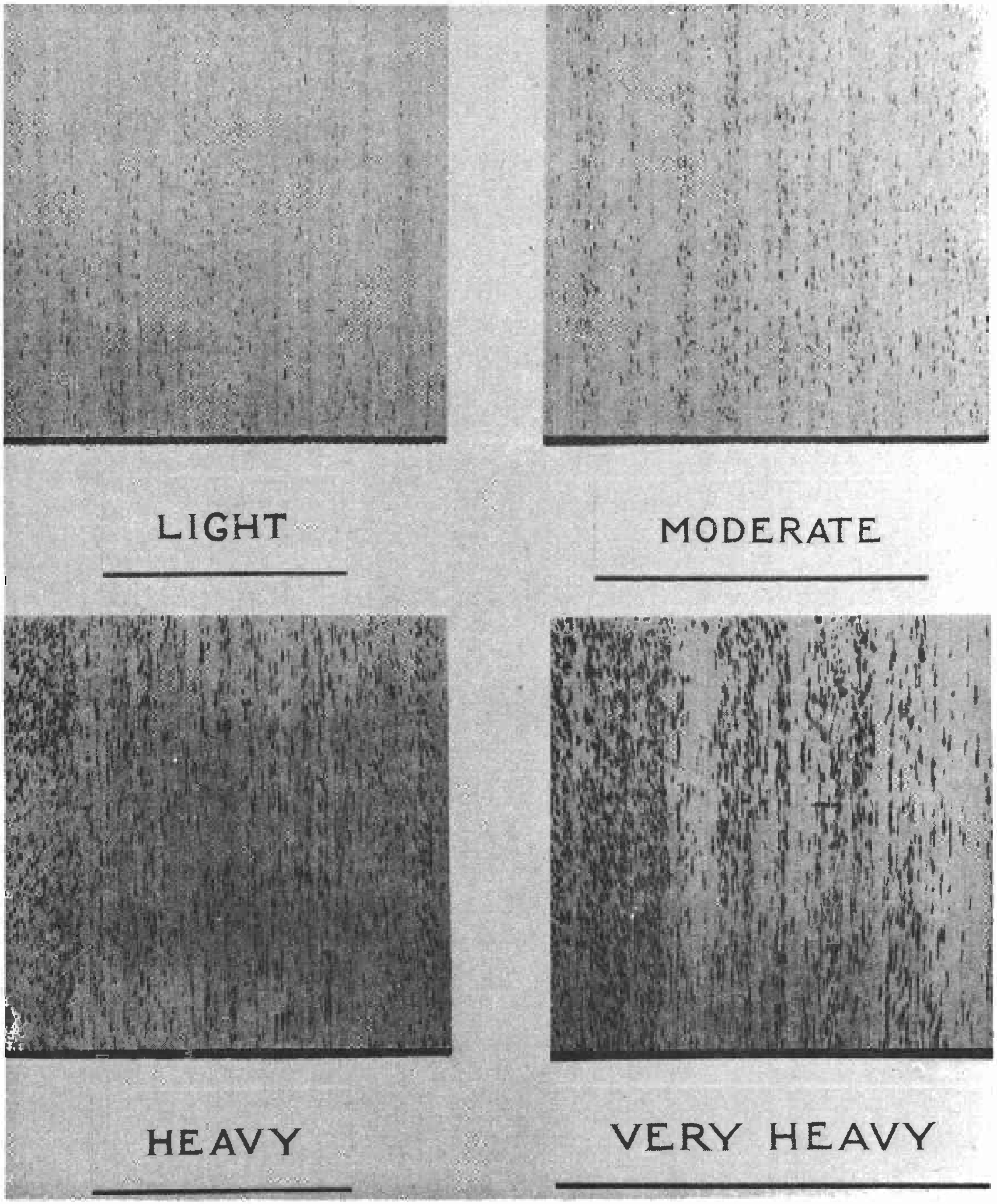


Figure 1.--Bleed-through on thin mahogany plywood panels. These panels are representative for the four classes of bleed-through recognized in this study.

Z M 58Q10 F

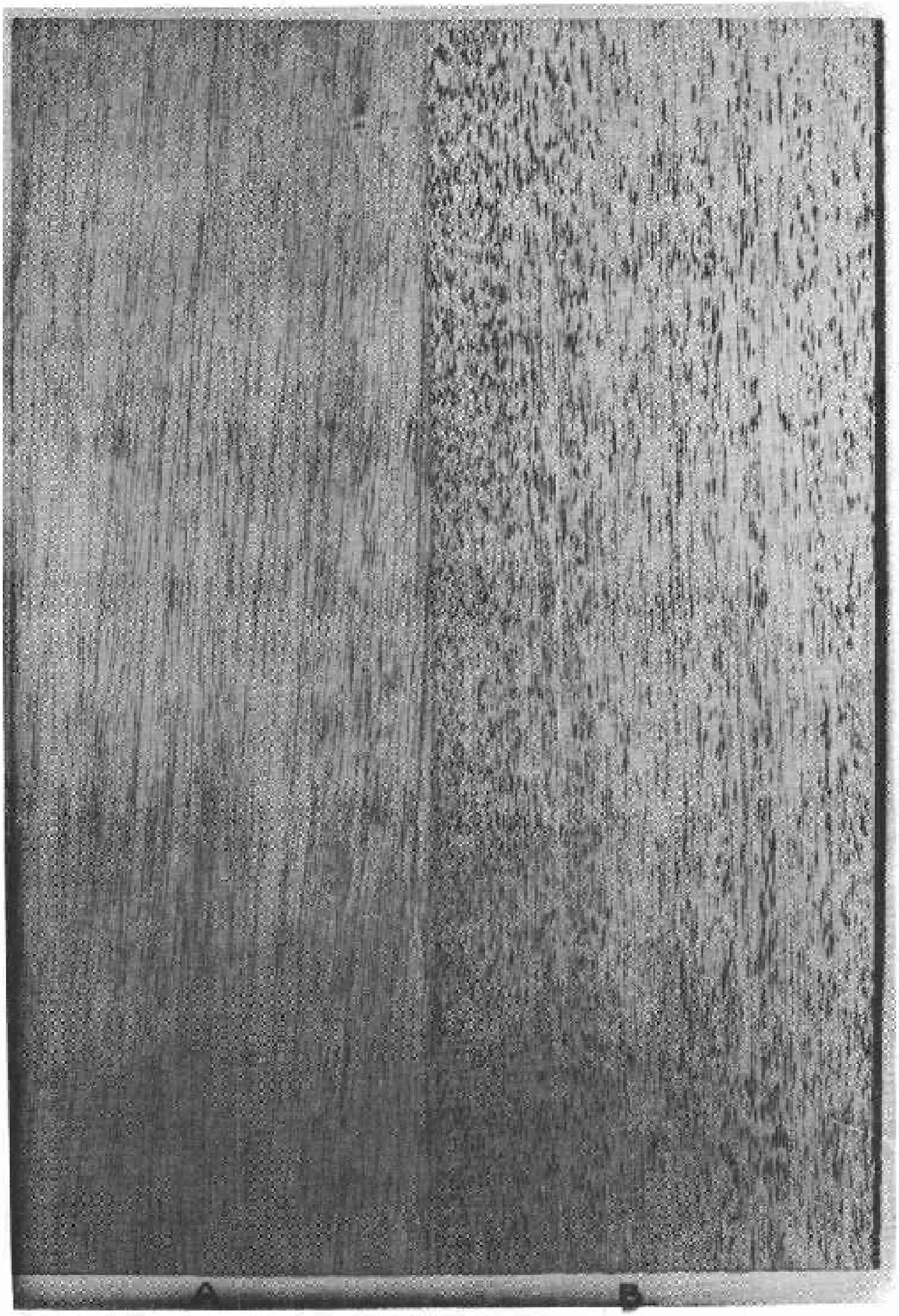


Figure 2.--Effect of slope of grain in face veneers on the formation of bleed-through on a plywood panel with 1/48-inch mahogany faces. Veneers A and B edge-glued. A, No bleed-through on straight-grained face veneer. B, Moderate bleed-through on short-grained face veneer.

Z M 58011 F


Figure 3.--Effect of heartwood and sapwood in the core on bleed-through. A, Yellow-poplar heartwood core. Note the absence of glue penetration into the core and heavy bleed-through on the surfaces. B, Yellow-poplar sapwood core. The deep penetration of phenolic glue has darkened the core, but there is little evidence of bleed-through on the faces.

Z M 58012 F

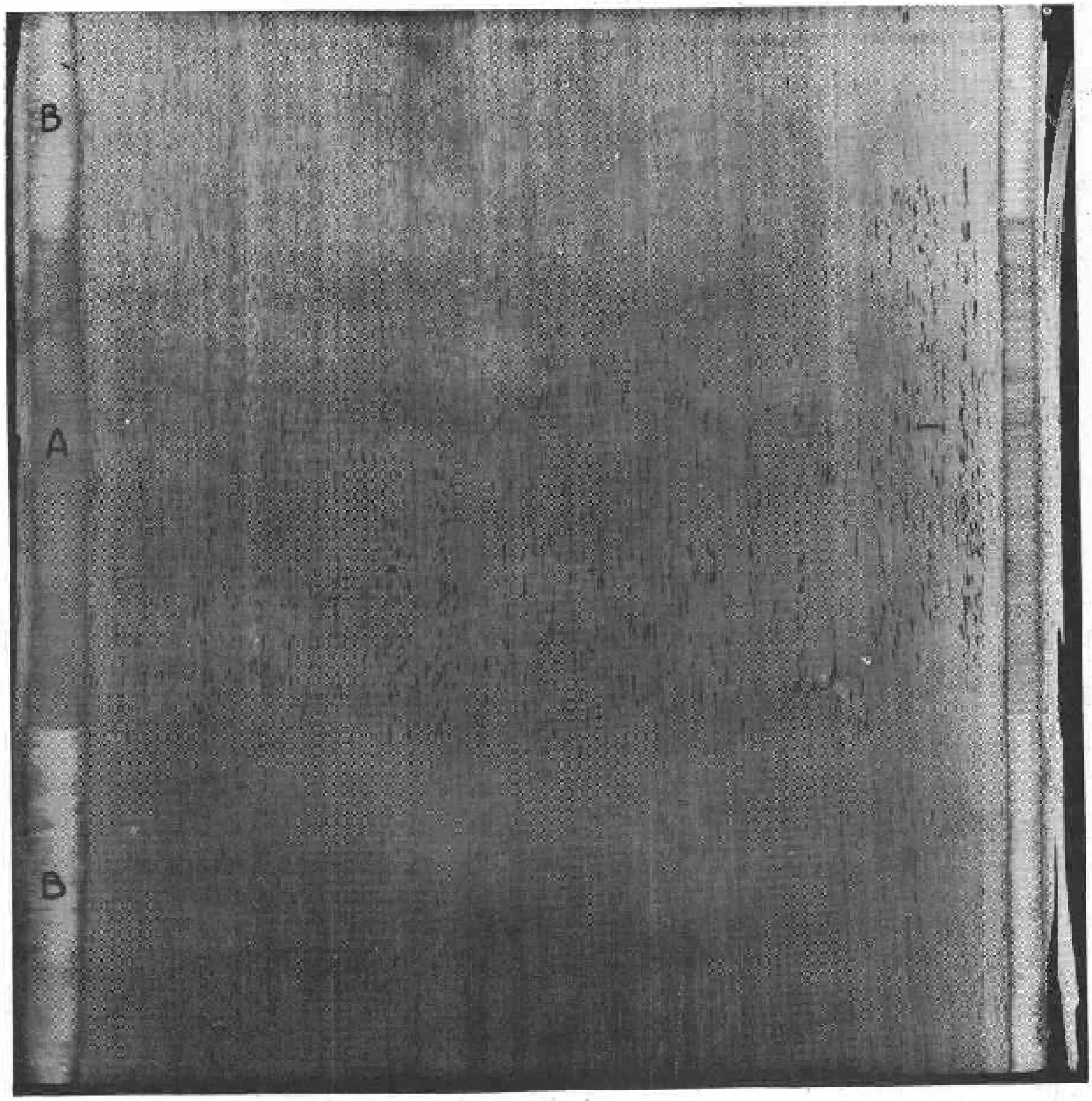


Figure 4.--Effect of heartwood and sapwood in the core on bleed-through. A, Sweetgum heartwood core. Moderate bleed-through on surfaces. B, Sweetgum sapwood core. Deep penetration of glue into the core with no appreciable bleed-through on the surfaces.

Z M 58013 F

# SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

# FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen
- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.