REDUCING PARTICLEBOARD PRESSING TIME:
EXPLORATORY STUDY

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ABSTRACT

Minimum presstimes depended primarily on a suitable combination of time and temperature to cure the binder and dispel sufficient moisture to avoid steam blisters. An adequate 1/2-inch-thick board was produced in as little as 1 minute presstime by proper selection of variables. Variables most effective in reducing presstimes were higher press temperatures, fast press closing, and nonuniform mat moisture contents. Data were obtained from strength tests on more than 90 boards with five replicate tests per board.
INTRODUCTION

The output of the hot press determines the quantity of particleboard produced by a manufacturing facility. The variables which control this output are size of press and time the material is in the press, both primary factors in equipment and production expenses. Any factor which would reduce press time is vitally important in particleboard economics. Time in the press will become even more important in those plants which use single-opening presses or the exceedingly thick platens typical of the newly designed, multiple-opening presses.

A review of literature reveals a considerable amount of research directed toward reducing the time required to press particleboards or studying effects of related variables. In general, these may be grouped into four classifications: (1) Moisture content and related effects, (2) pressure and related effects, (3) temperature, and (4) catalysts. Naturally, there also are interactions between the effects of the various classifications. A list of selected publications is presented at the end of the report.

In our study of factors that influence the length of the press cycle, the focus was on two sets of variables:

Part I. Process variables (using only hot platens and uncatalyzed resin).

Part II. Moisture distribution variables (using hot platens, uncatalyzed resin, and unequal moisture distribution; essentially this second part was concerned with the well-known "steam shock" effect on rate of cure of particleboard binders).

The objective was to develop basic information on the effects of several variables individually on minimum time required in the hot press using uncatalyzed binders with and without uniform moisture distribution in the particle mat.

In the future we hope to consider effects of variables using hot platens, catalysts or multiple catalyzation, and high frequency alone or in combination with hot platens.
RESEARCH PLAN

The variables were investigated in relation to those used to make the "standard" Forest Products Laboratory (FPL) board. In this work, the following factors remained constant for each panel:

Board dimensions: 1/2 by 24 by 28 inches.
Particle dimensions: 0.015- by 1-inch, random-width flakes.
Resin content: 6 percent solids based on oven-dry weight of wood.
Press closing rate: Press was closed to twice the final panel thickness in the first quarter of the closure period and to final thickness in the remaining period.

The following variables were studied using the levels shown, with the underlined element in each case being the "standard" level:

Part I: Process Variables

Board thickness (in.): 1/4, 1/2, 3/4, 1.
Time to thickness (min.): 1/4, 1/2, 1, 2.
Density (p.c.f.): 30, 40, 50, 60.
Moisture content (MC) into press (pct.): 8, 10, 12, 14.
Resin type: Urea (UF), phenol (PF), melamine (MF).
Species: Douglas-fir, aspen, southern pine.

Part II: Moisture Distribution Variables

A. Boards prepared using standard conditions, except for moisture:
   Uniform 10 percent MC distribution in mat.
   Mat MC 5 percent, with 5 percent moisture uniformly sprayed on cold cauls.
   Center half of mat 5 percent MC, with two faces at 15 percent MC.
   Center half of mat 15 percent MC, with two faces at 5 percent MC.
   Center half of mat 5 percent MC, with two faces at 25 percent MC.

B. Mat MC 5 percent, with 5 percent moisture sprayed on cauls. Also was studied at the following levels of Part I variables:
   Board thickness (in.): 1/4, 3/4.
   Board density (p.c.f.): 30, 50.
   Time to thickness (min.): 1/4, 1/2.
   Aspen flakes, Douglas-fir planer shavings.
   Phenolic resin.

Effects of these variables were determined individually with all other variables held constant at the standard level. Then, at each level, beginning at an appropriate pressing time, the prestart was shortened until boards had uncured corners or "blew" on opening the press. Prestart times were reduced as follows: At 1-minute intervals to 3 minutes prestart, 1/2-minute intervals between 2 and 3 minutes prestart, and 1/4-minute intervals below 2 minutes prestart.

Data Recorded

For each test panel, the following information was obtained:
   (1) Press pressure during entire cycle, recorded every 10 seconds until final thickness was achieved and every 30 seconds thereafter until the press was opened.
   (2) Temperature at the center of each panel throughout the entire cycle.
   (3) Moisture content directly out of press.
   (4) Thickness out of press.
   (5) Density gradient, by 0.030-inch increments after conditioning the boards at 65 percent relative humidity (one per panel).
   (6) Modulus of elasticity (MOE) and modulus of rupture (MOR) by standard test procedures on conditioned boards (five per panel).
   (7) Internal bond (IB) by standard test procedures on conditioned boards (five per panel).
RESULTS AND DISCUSSION

This experimental design provides data by which the effects of individual variables may be analyzed with regard to presstime. Each variable usually was studied at several levels, and therefore there are sufficient points to establish a trend for each variable compared to other variables. Naturally, this partial replication study gives no information on the interactions between variables studied individually. It was anticipated that information from this study would reveal where the most important interactions would be expected and these could be included in later research.

In addition, the data obtained from press pressures, internal board temperatures, and density gradients provide additional valuable information about the particleboard process.

The data obtained from the board manufacturing and testing phases are shown in tables 1 and 2 for parts I and II, respectively. These tables explain

<table>
<thead>
<tr>
<th>Table 1.—Summary of factors influencing minimum presstimes (part I)</th>
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<td>Standard board</td>
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<td>Press temperature (°F.)</td>
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<td>Closing time (sec.)</td>
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<td>Moisture content (pct.)</td>
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<td>Board thickness (in.)</td>
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1 All factors held at standard levels except as shown in variable and presstime columns.
2 Final pressure was restricting pressure at end of press cycle.
3 Time above 220° F. was measured in center of board. Only minimum time was shown.
4 Face specific gravity was average of first 3 surface density determinations.
5 Core specific gravity was average of center 3 density determinations.
6 Average specific gravity of 5 bending specimens.
many of the actions and interactions occurring in the particleboard pressing operation. Essentially, particleboard properties at a given resin content are a function of board density and density gradient relationships, which in turn are controlled by the manufacturing variables that produce these density levels and gradients (assuming the resin is cured properly). Variables are species, particle geometry, board density, board thickness, amount and distribution of moisture, pretime, press temperature, and closing rate of hotpress. Each of these has been studied and direct effects of the individual variables are shown in the tables.
All variables were studied at decreasing presstimes until satisfactory boards could no longer be produced as judged from panel strength properties. Internal bond was selected as the most important property and IB strengths below 100 p.s.i. (pounds per square inch) were judged to be unsatisfactory. Figure 1 illustrates the effects produced on MOR by certain variables as presstimes were decreased. The most important trend is the decrease in strength properties with decreasing presstime. In both parts of the study, the MOR data all appeared to decrease about 250 p.s.i. for each minute decrease in presstime. While not shown in the figure, MOE data generally followed the pattern established by MOR values. The IB data showed a similar trend with a decrease of about 25 p.s.i. for each minute presstime was decreased. If the binder can be considered to be cured at the shorter presstimes, figure 2 provides a logical reason for this loss in strength. Here thickness out of the press showed an inverse relationship to IB. Board thickness out of the press increased with decreasing presstimes, and board densities and strength properties decreased.

Other important notes gained from the data tabulated in tables 1 and 2 were as follows:

Effects on final pressure.--The pressure remaining on the particleboard at the end of the press cycle was that required to hold the board at the proper thickness. This remaining pressure was higher as minimum presstime decreased and, with few exceptions, was near or below the

Figure 1.--Effects of press-related variables on modulus of rupture of particleboard.

Figure 2.--Effect of thickness out of press on internal bond strength of 1/2 inch, 40 p.c.f. particleboard. (UF--urea formaldehyde; PF--phenol formaldehyde; SYP--southern yellow pine)

Figure 3.--Pressure-time relationships for several panel types in study.

IB of panel at the completion of the minimum press cycle. Several of these pressure-time relationships are shown in figure 3. Thus, if the normal IB of a given product was known, restraining pressure would be an ideal method of determining the minimum presstime. Exceptions were the boards 1/4 in. thick, 60 p.c.f., and some boards pressed at high temperatures with nonuniform mat moisture distribution.
Effects on time-temperature relationships.-- The thermocouples in the center of each mat continuously measured the temperature during pressing. The portion of the press cycle when this temperature was above 220°F. is tabulated in tables 1 and 2 and several time-temperature curves are shown in figure 4. Normally, satisfactory panels could be produced when the core temperature was above 220°F. for 0.5 to 0.7 minute. Because of the exceptions, and the difficulty of routinely obtaining core temperatures, the final pressure was regarded as a better means of estimating minimum presstimes.

![Figure 4](image)

Figure 4.--Time-temperature relationships produced during pressing of various board types.

Effects on moisture content after pressing.-- Weighing the board after pressing provided a means of determining the moisture content of the panel at this time; these data are included in tables 1 and 2. The moisture content of the panel after pressing increased with decreasing presstime in both portions of the study. For the most part, satisfactory boards were obtained when moisture contents were at or below 7.5 percent after pressing. Again, because of the difficulty of measuring moisture contents on a commercial scale, the final pressure was the better means of estimating minimum presstimes.

Effects on density.--Density profiles were obtained for each panel as previously described and the average face, core, and overall density are recorded in tables 1 and 2 where the face density was the average of the first three density determinations from each panel surface, and the core density was the average of the center three determinations. In general, overall density decreased slightly with decreasing presstime. Core and face density depended upon the specific variables under consideration for each panel, but a general relationship developed among most panels and is shown in figures 5 and 6. In these figures, MOR and IB were plotted against face and core layer density, respectively, and were found to be directly related to one another. The differences between regressions from the two portions of the study will be discussed later.

Effects of moisture content and distribution.-- Mat moisture contents of 8, 10, 12, and 14 percent were studied and 10 to 12 percent MC was found to be the optimum range of moisture content. Lower moisture contents produced problems such as insufficient moisture for proper bonding and need for higher pressures to consolidate the mat. Boards made at 8 percent MC had greater thicknesses out of the press and thus lower densities, which resulted in lower strength properties. The boards pressed at 14 percent MC had lower internal bond strengths, which resulted from the density gradient and a concentration of moisture in the center of the board at the end of
the press cycle. High moisture contents require longer press times to allow sufficient moisture to escape so desired level of internal bond can be attained.

Moisture distribution formed the basis of differentiation between parts I and II. Boards in part I were manufactured using uniform mat moisture contents and in part II the effects of unequal moisture distribution in the mat were studied.

Figure 6.---Effect of density of core layer (average of center three density measurements) on internal bond in particleboard.

The effects of moisture distribution are most readily demonstrated by the density gradients shown in figures 7 and 8. The characteristic density profile of a board pressed from a mat of uniform MC was that of lower density near the surface, rising rapidly to a maximum within 3/32 inch from the surface and then declining to a lower density in the central core of the board. Maximum density variation across the board profile was 0.20 gram per cubic centimeter (g. per cc.). If the mat contained only 5 percent MC, with the remaining 5 percent MC applied to the cauls, a similar but less variable profile was produced where the range of variation was only 0.10 g. per cc. If, however, the core of the mat contained 5 percent MC and each face contained 15 percent MC, an extremely variable profile resulted (fig. 8), where a density range of 0.33 g. per cc. resulted.

Reversing the core and face moisture contents to 15 and 5 percent, respectively, produced a much more uniform gradient as shown in figure 7, but the minimum density of 0.56 g. per cc. was at the surface and the maximum of 0.67 g. per cc. was near the core. Bending strength decreased as a result, because the surface density was closely related to this strength property and internal bond strength was related to core density. These relationships are shown in figures 5 and 6 where face and core layer density are plotted against MOR and IB, respectively.

Inspection of these figures showed a higher slope of strength versus density with uniform mat MC (part I) than where half of the moisture...
was added to the cauls (part 11). This would be expected in MOR since higher density gradients were produced with the uniform mat MC than when moisture was added to the cauls. Internal bond strengths generally were lower with the nonuniform MC treatment, probably because the lower MC conditions in the core of the mat lead to poorer bonding and more springback out of the press. This resultant increased thickness out of the press and decreased density resulted in decreased internal bond strength (fig. 2). Figure 2 also shows that the effects of thickness out of press were more pronounced in mats of uniform MC than in mats of nonuniform MC.

Presstimes were reduced by 1 to 2 minutes using the technique of nonuniform mat MC (tables 1 and 2), but strengths also were reduced because of the thickness increase out of press. Further research should indicate whether equivalent thicknesses and strengths could be attained at the shorter presstimes by judiciously selecting face and core MC levels or press cycle adjustments.

Effects of press closing time.--The rate of press closure during hot pressing had an extremely important influence on the resultant board properties. This influence was primarily a function of the density profile produced by the closing cycle (tables 1 and 2 and fig. 7) where various closing rates were compared. Essentially, as the closing time was increased, the face density decreased and the core density increased. This resulted in lower bending strengths and higher internal bond strengths.

Naturally, other factors interacted with press closing rate; one was that of mat moisture distribution. The effects on density profiles by the moisture distribution-closure time interaction are shown in figure 6. Use of nonuniform mat MC with fast closure times (15 to 30 sec.) permitted the production of 1/2-inch particleboards at 1–1/2 minutes presstime. Another example using 15 seconds closing time nonuniform MC, and a press temperature of 375° F. showed that satisfactory 1/2-inch panels could be produced with only 1 minute presstime.

Effects of press temperature.--The effects of the temperature of the hot press are shown in tables 1 and 2. These effects were caused by the increased temperature and faster heat transfer which accompanied the higher temperatures. Using uniform MC, presstimes were decreased by 1 to 2 minutes when press temperatures increased to 375° to 475° F. Bending strengths decreased slightly while internal bond increased, again as a result of shifts in the density gradient produced by the higher temperatures.

When one-half of the moisture was added on the cauls, presstimes were reduced to 1–1/2 to 1–1/4 minutes, but both bending and internal bond strengths were reduced.

Effects of board thickness.--Board thickness was a major factor in determining minimum possible presstimes. Minimum presstimes for mats of uniform moisture content were 1 minute for each 1/8 inch of board thickness (table 1), a mild exception being 7 minutes for the 1-inch-thick board. Table 2 shows that with half of the moisture applied to the cauls, minimum presstimes were about 1 minute for each 1/4 inch of board thickness or about half of the time required for mats of uniform moisture distribution. However, as with other variables leading to reduced presstimes, the strength properties were reduced because of the changes in thickness and density.

Effect of board density.--Density of the board also had a definite effect on the minimum press-time. This was due to two factors. First, more heat had to be transferred to the higher density panels to attain a given temperature, thus resulting in a lower rate of temperature rise within the panel. Second, a larger quantity of moisture had to be removed from the higher density panels. This, coupled with a lower permeability of the higher density panels, resulted in longer presstimes with increasing density. Applying half of the mat moisture to the cauls did not reduce the presstime with 50-p.c.f. boards, but did reduce the presstime from 4 to 2 minutes with the 30-p.c.f. board. However, presstimes for the 30-p.c.f. board were not shorter than those obtained with 40-p.c.f. boards.

Effect of resin type.--Urea (UF), melamine (MF), and phenolic (PF) resins were used as binders. Board properties with UF and MF resins were similar at the same presstimes. However, boards bound with PF resins, which were pressed at 350° F., had lower strength properties in both MOR and IB than UF-bound boards even though density profiles of the two board types were almost identical. This strength difference occurred when using either uniform or nonuniform mat moisture distribution. When half of the mat moisture was applied to the cauls, the presstime with PF binder was reduced to 3 minutes as compared
to 4 minutes with uniform mat moisture distribution.

Effect of species. -- In addition to Douglas-fir, both southern pine and aspen were used as raw materials in the study. Using uniform mat moisture distribution, 6 minutes was the minimum presstime for both of the alternate species; this was reduced to 3 minutes for aspen when half of the moisture was applied to the caulns. The alternate species required presstimes 1 to 2 minutes longer than Douglas-fir. The reason can be considered in large measure to be due to the relative effects of the natural acidity and buffering capacities of the three species upon the cure rate of the resin.

Effects of particle type. -- In addition to the standard flake raw material, hammer milled Douglas-fir planer shavings were used as furnish. Bending strengths of the shavings boards with uniform mat moisture content were only about one-third of the flakeboards while internal bonds were almost equivalent (table 2). When one-half of the moisture was applied to the caulns, the shavings boards could be pressed in 1–1/2 to 2 minutes, but suffered a sharp loss in bending strength, again due to the increased thickness and thus lower density out of the press. This illustrated that the effects of board density were more pronounced with a milled shaving base than with a flake base.

CONCLUSIONS

Based on the data gathered in this study, the following conclusions are presented:

(1) Minimum presstimes primarily depended upon two factors: A suitable combination of time-temperature to cure the binder, and loss of sufficient moisture to avoid steam blisters.

(2) The combination of nonuniform mat moisture distribution, fast press closing time, and higher press temperature produced a satisfactory one-half inch board in 1 minute total presstime— one-third the time required under standard conditions.

(3) Generally the minimum presstime could be determined as the point when the pressure required to hold the board to nominal thickness fell below the level of the internal bond strength of the board.

(4) Moisture content and moisture distribution within the mat were most important in determining density gradients, followed by press closing time and temperature. Variables such as density, thickness, resin type, and species had secondary effects.

(5) Strength properties were strongly related to the density gradients of the panels.

(6) While presstimes could be reduced by proper selection of manufacturing variables, decreased presstime also produced a proportional reduction in board strength.
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APPENDIX I

"Standard" FPL Particleboard
(Revised April 1968)

The "standard" FPL particleboards are prepared using the following materials and procedures. Thus, in research work, panels may be prepared using modifications of these materials or procedures and deviations may be simply stated as "aspen," "35 p.c.f.," "10 percent resin," etc.

"Standard" Particleboard

Species: Douglas-fir heartwood.
Particle type and size: Flakes, 0.015 inch by 1 inch by random width.
Panel size: Rough--1/2 x 24 x 28 inches.
           Trimmed--1/2 x 22 x 26 inches.
Density: 40 p.c.f.
Resin solids content: 6 percent resin solids (based on ovendry weight of wood).
Resin: 65 percent solids liquid urea-formaldehyde (UF) or 44 percent solids liquid phenol-formaldehyde (PF).
Catalyst: None.
Additive: 1 percent wax emulsion (solids basis) (PF boards only).
Mat moisture content: 10 percent (ovendry basis).
Press cycle: UF--5 minutes at 325° F.
            PF--10 minutes at 350° F.
Press closing time: 1 minute to thickness.