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STEAM INJECTION PRESSING–LARGE PANEL FABRICATION WITH SOUTHERN HARDWOODS

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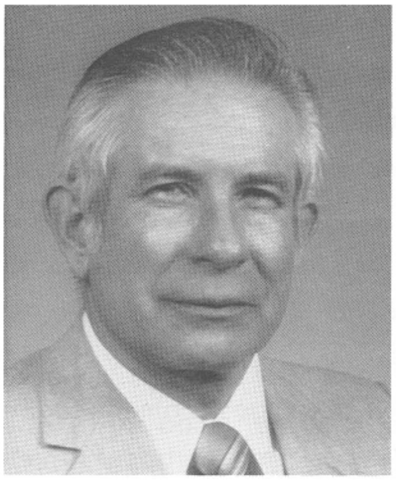

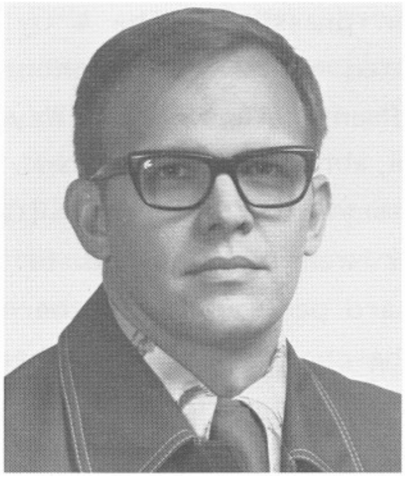

ABSTRACT

Large 4 by 8 ft (1.22 by 2.44 m) panels were made using a steam injection method of pressing. Homogenously constructed flakeboards were fabricated from southern red oak, sweet gum, and a mixture of the two species using both isocyanate and phenolic resins. Isocyanate was especially suited to the process and 1-1/2 in. (38 mm) thick panels were pressed in less than 150 seconds. Phenolics on the other hand were susceptible to dilutions by steaming and required higher temperature to cure.

INTRODUCTION

The commercial implementation of a laboratory-developed concept is in most cases technically challenging and economically dangerous. When the cost to put an idea into practice involves large sums of money, as it is with modern flakeboard plants, the potential payoff must be high. Such is the case with the development of steam injection pressing technology (Geimer, 1983). Steam injection pressing possesses the potential to lower both plant investment and operating costs while increasing production and expanding markets.

The time and capital expenditures to develop large equipment necessary for scaled-up trials, however, puts a tremendous strain on research budgets. Following a scale-up recommendation by the National Forest Products Association's Committee on Research and Evaluation, it was decided to approach Siempelkamp Corporation, an equipment manufacturer in the Federal Republic of Germany, with a proposal to use their pilot plant. This, as far as was known, was the only available equipment capable of large-scale steam injection pressing. The 4 by 8 (1.22 by 2.44 m) press had recently been retrofitted with steam injection capabilities during the course of a cooperative development effort with Weyerhaeuser Company. Although the process (Taylor, 1985) differed in several aspects from the Forest Products Laboratory (FPL) process (Geimer, 1983), the actual press design and controls were well suited to the objective of fabricating large structural flakeboard panels from southern hardwoods.

The choice of southern hardwoods for this feasibility study was prompted by a major concern of both private industries and government agencies for the increased utilization of these species. Siempelkamp, whose developmental efforts had largely been directed at steam injection of medium-density fiberboard, favorably greeted the proposal.

Even though the logistics of developing and implementing the program were massive and required the cooperation of several organizations and people on an international basis, it appeared to be the most feasible way of rapidly obtaining the required results for industrial application. The following material describes:

1. Preliminary investigations needed to establish technical details of board production
2. Large-scale panel production
3. Properties of the 4 by 8 ft panels

Preliminary Studies

The process of steam injection pressing requires saturated steam to be introduced into the mat through perforated platens at a critical time during the press cycle. When pressing is performed properly, the panel acts as a seal to permit pressure and temperature buildup. The temperature in the center of the panel rises rapidly, and residual moisture problems are minimized (Geimer, 1982; Geimer, 1985). Use of the high-density southern hardwoods at a normal panel density results in a porous panel and makes the high-temperature levels relatively difficult to obtain. Plans called for the fabrication of an all sweetgum *(Liquidambar styraciflua)* panel at 0.673 specific gravity (SC) and a 50/50 mix of sweetgum and southern red oak *(Quercus falcata)* at 0.721 SC. Later in actual plant trials, panels were fabricated with both furnishes at both SG levels. In addition, several all-oak panels were constructed.

Preliminary laboratory trials made at FPL used both phenolic and isocyanate resins. Fewer problems were encountered with the isocyanate, and preliminary press schedules developed for this resin indicated that total press times of 128 seconds for the 1/2 in. (12 mm) thick and 185 seconds for the 1 1/2 in. (38 mm) thick, 26 by 30 in. (66 by 72 mm) panels were adequate. Although the times were not considered minimum, they demonstrated the potential of the system if implemented on large panels.

Phenolic resin trials presented many difficulties, particularly the ability to obtain high bond strengths. Comparison of conventional pressed panels and steam-injected pressed panels indicated the problem was related to both moisture and temperature. In conventionally pressed panels, resin remains on the flakes as discrete droplets except in high-density areas where some spreading and squeezeout is exhibited. High steam flow characteristics of steam-injected panels tends to dilute the resin, spreading it evenly over the entire surface of the flakes. Penetration of the resin into the wood imparts a distinct light-brown color to the oak and a pinkish cast to the sweetgum flakes, permitting easy identification of the species.

Following trials with a variety of phenolic resins, some ranging in viscosity as high as 2,000 centipoises (cP) and others having solid contents of 78%, a laboratory modification (WS 337-122) of a highly condensed Borden Chemical Company phenolic (HB-37) was selected. The resin, supplied at 41% solids and 350 cP viscosity, resisted spreading and/or penetration better than any of the others examined. Internal bond (IB) and interlaminar shear tests indicated that bond strengths would equal those derived in conventional pressing only if temperatures in the range of 310 - 320°F (154 - 160°C) could be attained during the steam period. The laboratory press schedules were adjusted to permit a fast rise to a high temperature with a minimum amount of steam. This was accomplished by:

1. Decreasing the press closure rate and introduction of a regulated steam flow at an intermediate mat specific gravity (SG) of 0.420
2. Succession of steaming and continued closing to a mat SG of greater than 0.600
3. Reintroduction of steam to attain and hold a platen manifold temperature of 320°F (160°C).

Press times for the 1/2 and 1–1/2 in. (12 and 38 mm) thick panels were 188 and 406 seconds, respectively.

The FPL equipment and Siempelkamp's pilot plant equipment were not identical. Two major differences were the available steam pressure (200 psi [1,379 kPa] in the laboratory versus 100 psi [689 kPa] in the pilot plant), and the caul carrier system.

Whereas mats had been loaded into the laboratory press using a single, thin Fourdinier screen. (on the bottom surface), heavy screen cauls on both top and bottom surfaces were used in the pilot plant. These screen cauls were sealed around their periphery to prevent steam escape. Laboratory investigations, however, indicated that the required high temperatures needed to cure the phenolics could be obtained with 100 psi steam pressure using the screen cauls. The pilot plant also had the capability of introducing a vacuum phase in the decompression stage of the press schedule. This option was deemed unnecessary with hardwood flakeboards.

Other minor differences in programming capabilities, press and steam control capabilities, and data acquisition were also observed. Laboratory equipment options such as direct control of steam flow in addition to the pilot plant system of manifold temperature control was deemed desirable, but not absolutely necessary, for panel production. Final judgment as to system capabilities could, of course, be made only after gaining experience with the fabrication and pressing of the large panels.

LARGE SCALE PANEL PRODUCTION

Twenty tons of red oak and sweetgum logs from central Louisiana were shipped to The Federal Republic of Germany. After convincing the custom authorities that the material was free of oak wilt and destined for experimental purposes, the logs were transported to Maschinenfabrik-Bezner in Ravensburg where they were cut into 0.020 in. (0.51 mm) thick by random width by 3 in. (76.2 mm) long flakes (Figure 1). The flakes were dried by Schenkmann and Piel in Leverkussen, rebagged, and shipped to Siempeikamp's pilot plant in Krefeld. Both the oak and sweetgum flakes were screened to eliminate the fines passing through a 0.079 in. (2 mm) screen. Oversized sweetgum flakes (those retained on a 0.79 in. [20 mm] screen) were reduced in size using a drum-type flake braker and mixed back into the furnish.

Figure 1.--*Flakes used for large-scale panel fabrication; left side is red oak flakes, right side is sweet gum flakes*

Isocyanate Trials

A series of panels were made with 3% (ovendry [OD] wood basis) of a PBA 1042 isocyanate resin supplied by Imperial Chemical industry (ICI) in Holland. This resin is equivalent to the Rubicon MF178 emulsifiable isocyanate used for laboratory experimentation. The resin was sprayed neat, and no difficulties were encountered in blending the material in a rotary drum continuous-feed blender, using air atomization.

The pilot plant equipment is designed to process numerous types and sizes of panels, therefore, certain process adaptions had to be made for each panel type. Forming of the mat (Figure 2) was done in two passes, alternating directions. The forming head and an attached, parallel-to-felting alignment device, was raised to maximum height. In the case of the 1 1/2 in. (38 mm) thick panels, the end and edge overspread was quite large, necessitating the recycling of the excess material between forming passes. To compensate for forming errors, line speed miscalculations, changing mat moisture content, and all the other errors which affect panel formation, the mats were pressed to a variable thickness, calculated from final OD weights, and based on a target panel density. Moisture content of the mat entering the press was between 5% and 8%.

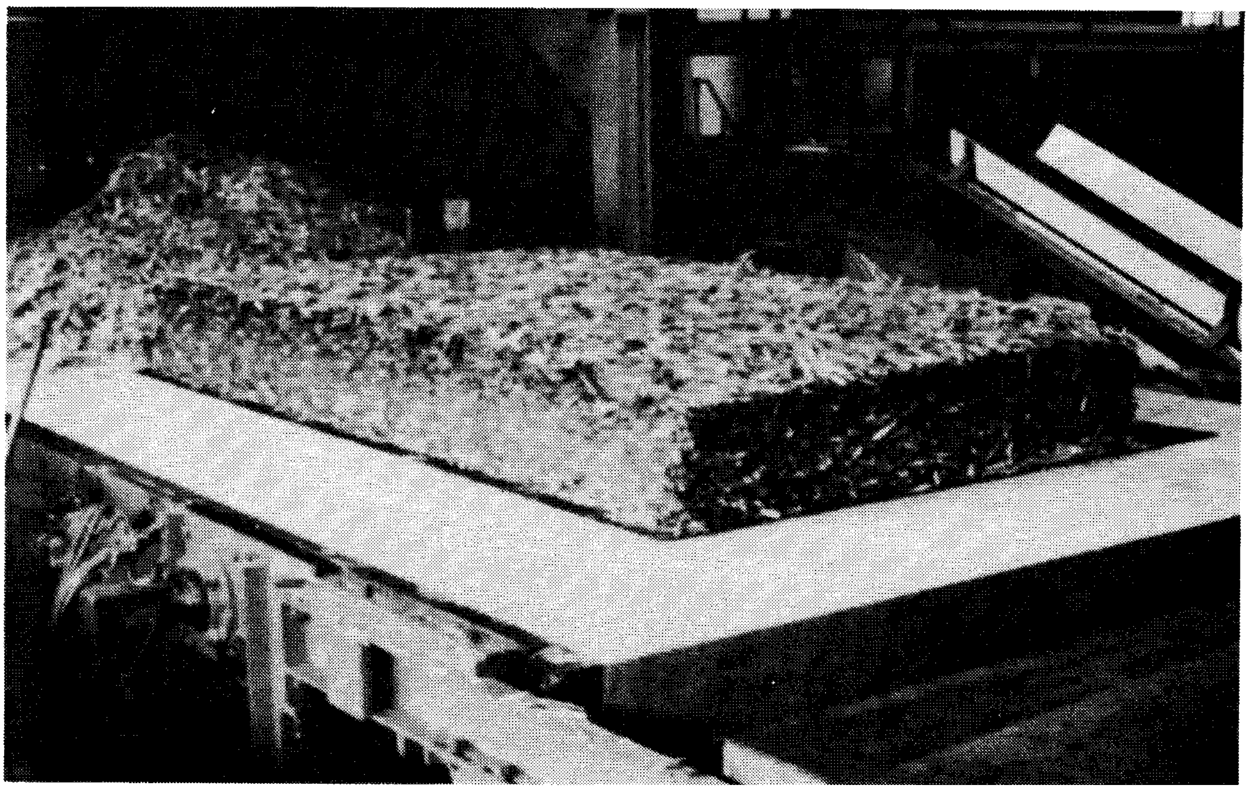

Figure 2.– –*Matbeing formed*

Following mat formation and final weighing, the mats were pressed according to a computer-controlled schedule. In general, two types of schedules, designated as A and B, were followed. For successful results, it was critical that steam be introduced prior to the mat being pressed to a SG of approximately 0.448. Then the steam could be either halted until final position was reached, or continuously applied. The type A schedule called for an interruption in the steaming period, whereas the Type B schedule programmed a continuous steaming period. Press schedules for 1 1/2 in. (38 mm) 0.721 SG panels are shown in Figure 3. Both schedules incorporated a push-through stage described by Taylor (1985) wherein steam was introduced into the lower platen and exhausted to atmosphere through the top platen.

Following the final steaming period, the steam manifolds were shut off permitting the trapped steam to bleed into the panel. Excess steam was bled off from both platens during the exhaust period. This final exhaust period was shorter for the Type B schedule. Press variables such as total time, steam time, and steam pressure varied with target panel thickness and SG.

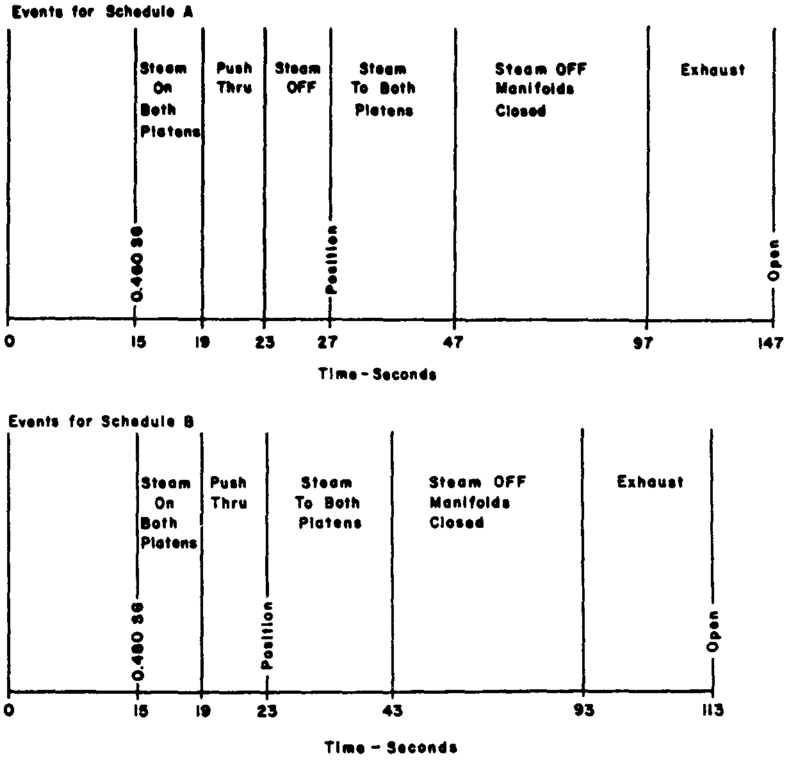

Figure 3.--*Schedule A and B press schdules*

Preliminary trials in the pilot plant indicated that the laboratory press times were conservative, and total press times were shortened. The Type A schedule for the 0.721 SG 1 1/2 in. (38 mm) isocyanate-bonded panel was reduced to 147 seconds, while the Type B schedule for the same panel was reduced to 113 seconds. Total press time for the 1/2 in. (12 mm) thick 0.721 SG panels pressed only to a Type A schedule was 81 seconds.

Laboratory trials revealed that minor modifications of the press schedule were beneficial in pressing different species. However, no changes were made when pressing sweetgum or a 50/50 mixture of sweetgum and oak in the pilot plant. The rationale in not making schedule changes was to determine the relative sensitivity of the steam injection system to a change in furnish mixture.

In a small 30 by 30 in. (760 by 760 mm) panel, lateral steam movement occurs easily. It was expected that the large panels would behave similarly and anticipated problems included excessive loss of steam through the edges, thus reducing maximum internal pressures and temperatures. During the initial large-scale trials, 1/4 in. (0.64 mm) thick hardboard strips were placed around the periphery of the mat to densify the edges. Later when the press schedules had been refined, this procedure was deemed unnecessary. Large panels definitely exhibited more resistance to lateral steam movement than small laboratory panels. The phenomenon was determined readily by observations of steam escaping through the edges of the panel during the steaming cycle (Figure 4) and a much slower rate of steam pressure and temperature drop when steaming was stopped. The latter, however, may have been due partially to the larger reservoir of steam in the platens and manifolds, as evidenced when the excess steam was vented at the beginning of the exhaust period (Figure 5).

The "push through" step where steam was injected from one platen and exhausted to the atmosphere through the other platen, was deemed to be necessary when steaming large panels. As illustrated in Figure 6 (A and B), without the "push through" step, a low-density area of unbonded flakes occurred in the central portion of the board. This low-density area differs from one caused by a moisture blow because there is no definite centerline separation present. Apparently, air is entrapped in the central portion of the panel during the initial two-sided steaming.

Although the large panels exhibited only slight leakage during the steaming cycle, the internal structure of the hardwood flakeboard is such that the panels were degassed sufficiently during the allotted exhaust period. Therefore, no vacuum step at the end of the press cycle was used. The vacuum step may be beneficial or, in fact, necessary, when pressing panels to a higher compaction ratio. It would also be useful in shortening press times when the degassing period is marginal.

Phenolic Trials

The phenolic resin, patterned after that furnished by the U.S. Borden Corporation for FPL laboratory trials, was supplied from Borden's Great Britain laboratory. Differences in equipment and batch size, however, produced a resin which was slightly higher in solids, somewhat lower in pH, and considerably higher in viscosity. The resin arrived at the plant at a viscosity of 2,700 cP, and had to be diluted to 38% solids to pass through the spray equipment. This brought the mat furnish to a high moisture content that was between 11% and 12%.

The first panels constructed during the plant trials were bonded with phenolic resin. A major press-related problem encountered during this stage of the fabrication trials resulted in a lengthy delay between the initial and secondary steaming phases. This was later corrected by adjusting accumulator controls and modifying the computerized press schedule. Unfortunately, this discrepancy, along with other forming- and pressing-related problems, resulted in panels that were bonded inadequately. Onsite shear tests showed that the large steam-injected panels had only 50% - 70% of the strength of the small panels made from the same blended furnish, but conventionally-pressed in Siemplekamp's laboratory press.

Later, after the isocyanate panels had been fabricated, panels were made using a mixture of 25% oak and 75% sweetgum which had been dried to 2% moisture content after blending with 6% phenolic resin. These panels had IB strengths comparable to the isocyanate panels and actually were better than conventionally-pressed laboratory panels made with the same material.

Panel Properties

Interruption of steaming in the initial closing portions of the press cycle allows the mat a chance to "reseal" itself and promotes higher internal pressures. The process is more beneficial in the small laboratory panels than in the large panels, as reflected by the similarity of IB strength values for the panels pressed with both Schedules A and B (Table 1). With the exception of the low-density 100% gum panels, the IB of panels pressed with the two schedules was similar.

Table 1.--Properties of 4 by 8 ft panels[1]

Species	Press Schedule	Press Time sec	Number of Panels	Internal Bond: Specific Gravity	Internal Bond: psi (kPa)	Bending: Specific Gravity	Bending: Modulus of Rupture psi (MPa)	Bending: Modulus of Elasticity psi (MPa)	Dimensional Stability[2]: Thickness Swell %	Dimensional Stability[2]: Linear Expansion %
1 1/2 in. 0.721 Target Specific Gravity 3% ICI ISO										
Gum	A	147	3	0.702	60 (413)	0.696	3,830 (26.4)	621 (4.3)	34.4	0.37
	B	113	1	0.698	60 (413)	0.710	4,450 (30.7)	704 (4.9)	32.9	0.43
Gum/oak[3]	A	147	3	0.703	62 (427)	0.699	4,020 (27.7)	600 (4.1)	30.9	0.42
	B	113	2	0.713	59 (407)	0.710	4,330 (29.9)	627 (4.3)	31.0	0.40
Oak	A	147	3	0.726	83 (572)	0.721	4,470 (30.8)	685 (4.7)	27.3	0.41
Average				0.709	66 (455)	0.706	4,170 (28.3)	639 (4.4)	31.0	0.40
1 1/2 in. 0.673 Target Specific Gravity 3% ICI ISO										
Gum	A	107	2	0.661	51 (352)	0.671	3,640 (25.1)	601 (4.1)	32.1	0.38
	B	113	2	0.653	36 (248)	0.663	3,070 (21.2)	572 (3.9)	38.1	0.45
Gum/oak[3]	A	107	3	0.655	45 (310)	0.652	3,080 (21.2)	525 (3.6)	29.0	0.45
Average				0.656	44 (304)	0.660	3,240 (22.3)	560 (3.9)	32.4	0.43

Table 1. --continued

				Internal Bond		Bending			Dimensional Stability[2]	
Species	Press Schedule	Press Time sec	Number Of Panels	Specific Gravity	psi (kPa)	Specific Gravity	Modulus of Rupture psi (MPa)	Modulus of Elasticity psi (MPa)	Thickness Swell %	Linear Expansion %
1/2 in. 0.721 Target Specific Gravity 3% ICI IS0										
Gum	A	81	2	0.717	56 (386)	0.724	4,760 (32.8)	672 (4.6)	40.9	0.42
Gum/oak[3]	A	81	3	0.668	47 (324)	0.687	3,870 (26.7)	588 (4.1)	32.5	0.40
Oak	A	81	3	0.676	68 (468)	0.662	3,600 (24.8)	544 (3.8)	25.9	0.41
Average				0.686	57 (393)	0.686	3,990 (27.5)	592 (4.1)	32.1	0.41
1/2 in. 0.721 Target Specific Gravity 6% Phenolic										
Gum/oak[3]	A	133	3	0.710	60 (414)	0.703	3,990 (27.5)	617 (4.3)	31.6	0.50

[1]Values are the average of six samples for internal bond, four samples for bending, and four samples for dimensional stability per panel.

[2]Thickness swell and linear expansion from oven dry to vacuum pressure soak conditions.

[3]Mixture of species was 50/50 for isocyanate-bonded panels and 25% oak, 75% gum for phenolic-bonded panels.

The push through steam period of four seconds proved marginal. Delamination spots due to the presence of air pockets showed up in eight of the thicker boards. This was more prevalent with the B-type schedule where closure time from the point of initial steam injection to final thickness was four seconds shorter than in the A schedule. The 34-second reduction in total press time of the B press schedule had little effect on panel properties.

In general, the higher density 1 1/2 in. (38 mm) panels had acceptable IB properties (66 psi average) and good bending modulus of rupture (MOR) (4,170 psi) and modulus of elasticity (MOE) (639 kpsi) values. The average thickness swelling value of 31% normally can be expected in a flakeboard subjected to an OD vacuum pressure (OD-VPS) treatment. Linear expansion values averaging 0.41% are somewhat marginal. Mechanical properties were reduced of course when target SG was lowered by 6%. Bond, MOR, and MOE values of the low density panels averaged 67%, 78%, and 88%, respectively, of those values attained in the heavier panels.

The most surprising results for the 1 1/2 in. thick (38 mm) 0.721 SG panels was the performance of the oak. Panels made from the oak/gum mixture had mechanical properties comparable to those of the all-gum panels. The all-oak 0.721 SG 1 1/2 in. (38 mm) thick panels actually outperformed their all-gum counterparts. The good properties of the all-oak panels may have resulted from a difference in interior mat temperatures. These all-oak panels were made late in the trials and for some unexplained reason, maximum core temperatures of 330°F (165°C) were higher than the 293°F (145°C) temperatures reached in the all-gum and oak/gum panels made earlier.

Eight 1/2 in. (12 mm) thick panels, made with the different furnishes were pressed in 81 seconds (Table 1). Here again, the all-oak panel had superior IBs. Bending properties, however, reacted in a normal fashion, increasing with an increase in compaction ratio. Dimensional stability of the 1/2 in. (12 mm) thick panels following an OD-VPS treatment was very similar to that of the 1 1/2 in. (38 mm) thick panels. Thickness swell and linear expansion averaged 30.8% and 0.43%, respectively, for all of the panels made with ICI resin.

Problems encountered with the phenolic resin dictated that more isocyanate panels be fabricated than originally anticipated. Consequently, there was a shortage of ICI isocyanate. In order to produce three replicates of each panel type, a number of panels were constructed with other isocyanate resins available at the pilot plant. The mechanical properties of panels made from these resins were, in most cases, so superior to those panels bonded with the originally supplied ICI resin that they obviously could not serve as representative replicate samples (Table 2). This accounts for the sample size discrepancies (Table 1).

Data for the panels made using the alternate isocyanate is given in Table 2. Outstanding was a twofold increase in IB properties. The difference may not be entirely attributable to the resin. The same increase in maximum interior panel temperature as measured in the all-oak ICI-bonded panels occurred with these panels. Conventionally pressed laboratory panels, however, made with the alternate resin also showed a two-fold increase in IB over their ICI counterparts. The higher temperatures coupled with slightly higher average board SGs tended to create higher pressure pockets and a few blisters appeared in the all-gum and oak/gum large-scale panels made at these conditions. A reduction in thickness swell to 24.4% for the panels made with alternate isocyanate resin was offset by increased linear expansion to 0.51%.

To compare steam injection pressing with conventional pressing, blended material used in the large-scale production was used to fabricate small 0.5 by 18 by 18 in. (1.27 by 45.7 by 45.7 cm) panels in Siempelkamp's laboratory press. The panels were pressed for 5 1/2 minutes at 350°F (176°C). These panels averaged approximately 15% higher in IB and bending MOE, and 25% higher in MOR than the pilot plant panels (Table 3). Part of this difference can be attributed to the 5% higher SG measured for the laboratory panels.

Many of the phenolic-bonded panels made early in the trials exhibited good bending properties, but the IB value ranged between 25 - 40 psi (172 to 276 kPa). One series composed of three 1/2 in. (12 mm) thick panels, bonded with phenolic and made at the very end of the plant trial, had properties comparable to many of the isocyanate panels. The panels were made with 25% red oak and 75% sweetgum and pressed for 133 seconds. The IBs averaged 60 psi (414 kPa), while bending MOR and MOE were 3,990 psi (27.5 mPa) and 617 kpsi (4250 kPa), respectively. Mat moisture content had been lowered to 2% by drying the blended furnish. Internal temperatures in these phenolic-bonded panels were over 330°F (165°C). Conventionally-pressed laboratory panels made with the same material had an IB of only 30 psi (206 kPa). This could have been the result of the resin having advanced to a viscosity of over 3,200 cP.

Table 2.--Properties of 4 by 8 ft panels bonded with alternate isocyanate[1]

Species	Press Schedule	Press Time sec	Number of Panels	Internal Bond: Specific Gravity	Internal Bond: psi (kPa)	Bending: Specific Gravity	Bending: Modulus of Rupture psi (MPa)	Bending: Modulus of Elasticity psi (MPa)	Dimensional Stability[2]: Thickness Swell %	Dimensional Stability[2]: Linear Expansion %
1 1/2 in. 0.721 Specific Gravity 3% ISO										
Gum	B	143	2	0.726	124 (854)	0.723	5,370 (37.0)	700 (4.8)	26.3	0.47
Gum/oak[3]	B	143	2	0.725	130 (896)	0.719	5,450 (37.6)	674 (4.7)	22.5	0.50
1 1/2 in. 0.673 Specific Gravity 3% ISO										
Gum	A	143	1	0.669	109 (751)	0.658	4,450 (30.7)	553 (3.8)	25.4	0.53
	B	143	1	0.673	105 (723)	0.643	4,240 (29.2)	559 (3.9)	24.0	0.51
1/2 in. 0.721 Specific Gravity 3% ISO										
Gum/oak[3]	A	81	1	0.722	111 765	0.673	4,830 (33.3)	638 (4.4)	24.3	0.59

[1]Values are the average of six samples for internal bond, four samples for bending, and four samples for dimensional stability per panel.

[2]Thickness swell and linear expansion from oven dry to vacuum pressure soak conditions.

[3]Mixture of species was 50/50 for isocyanate-bonded panels and 25% oak, 75% gum for phenolic-bonded panels.

Table 3. --Properties of conventionally-pressed laboratory panels[1]

Species[2]	Press Time sec	Number of Panels[2]	Internal Bond: Specific Gravity	Internal Bond: psi (kPa)	Bending: Specific Gravity	Bending: Modulus of Rupture psi (MPa)	Bending: Modulus of Elasticity psi (MPa)	Dimensional Stability[2]: Thickness Swell %	Dimensional Stability[2]: Linear Expansion %
<u>ICI 1S0</u>									
Gum	330	2	0.714	90 (620)	--	5,460 (37.5)	731 (5.0)	48	0.44
Gum/oak[3]	330	4	0.745	72 (496)	--	5,520 (38.1)	758 (5.2)	52	0.48
Oak	330	3	0.736	84 (579)	--	5,630 (38.8)	753 (5.2)	44	0.53
<u>Alternate ISO</u>									
Gum	330	2	0.737	155 (1068)	--	6,750 (46.5)	869 (6.0)	40	0.36
Gum/oak[3]	330	2	0.703	162 (1117)	--	5,530 (38.1)	709 (4.9)	30	0.35
<u>Phenolic</u>									
Gum/oak[3]	480	4	0.699	30 (207)	--	3,100 (21.4)	55 1 (3.8)	64	0.49

'Values and average of three samples for internal bond, three samples for bending, and three samples for dimensional stability per panel. All panels were 0.5 by 18 by 18 in. (1.27 by 45.7 by 45.7 cm)

'Thickness swell and linear expansion from oven dry to vacuum pressure soak conditions.

'Mixture of species was 50/50 for isocyanate-bonded panels and 25% oak, 75% sweetgum for phenolic-bonded panels.

SUMMARY

A pilot plant trial proved that large-scale flakeboard panels could be made using the steam injection pressing method. Flakeboard panels were constructed from red oak, sweet gum, and a mixture of these species. Both isocyanate and phenolic resins were used. Isocyanates proved exceptionally adaptable to the steam injection method. Phenolics on the other hand were susceptible to dilution by steaming. High mat temperatures and low moisture content resulted in improved phenolic-bonded panel properties. Isocyanate-bonded panels 1 1/2 in. (38 mm) thick were pressed in less than 150 seconds. Press time was reduced to 81 seconds for 1 1/2 in.(12 mm) thick panels.

Lateral steam escape in the large panels was less than that experienced with the laboratory-sized panels. Consequently, higher internal pressures and temperatures were easier to obtain. Decompression on the other hand proved to be no problem with the hardwoods, except when very high internal temperatures were attained. The large panel size did allow pockets of air to be entrapped and necessitated a "push through" period wherein steam was injected from one platen and exhausted to atmosphere through the opposing platen. No difference in isocyanate panel properties were attributed to a difference in press schedules wherein steam injection was interrupted during the closing period.

Discrepancies in press schedules, press controls, and resin modifications prohibit conclusions being drawn in regard to the use of phenolics. Although a few acceptable panels were produced using phenolics and southern hardwoods, more research is necessary to determine the conditions wherein this combination is feasible with steam injection pressing.

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