THE ADAPTABILITY OF WESTERN WOODS TO THE MANUFACTURE OF DRY-FORMED HARDBOARD*

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INTRODUCTION

The hardboard industry in the Pacific Northwest has developed during the past six years into a major industry of the region. Hardboard production in this region now rivals that of Sweden, although that country's industry began almost twenty years earlier.

Approximately 25 per cent of the United States' hardboard capacity is in the Northwest, and may be as high as 30 per cent by 1954. The estimated annual capacity of the Northwest is now over 340 million square feet (1/8-inch basis).

It is interesting to note that at the present time the entire production of hardboard is from sawmill and veneer mill residues, and has imposed no additional drain on the region's forest resources.

PROCESSES

Methods of hardboard manufacture can be illustrated most easily on the basis of how the mat is formed. The mat can either be formed from a water slurry or by felting dry fiber; hence the designations wet-formed and dry-formed. There are variations in each category which will be explained later. As early as 1925 hardboard was being made commercially by the wet-formed method, but not until 1952 was there a commercial plant in operation in this country using the dry-formed process.

Wet-formed process

The continuous wet-process is the oldest, and perhaps the most commonly known, method. A flow sheet of a typical plant is shown in Figure 1.

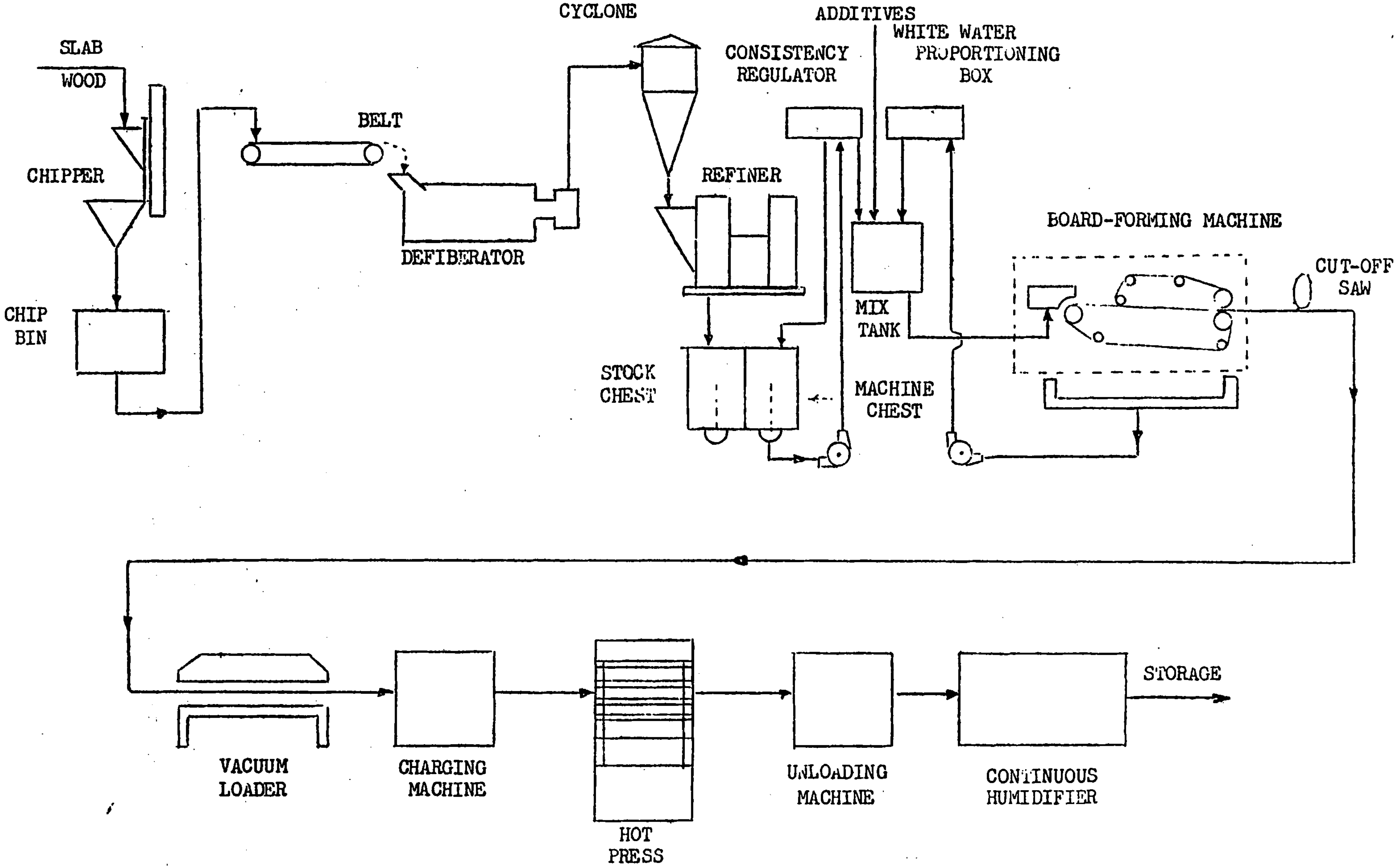

Figure 1. Continuous Wet-formed Hardboard Process.

Slab wood or other wood residue is first chipped and screened to about 5/8-inch or 3/4-inch chip size. This slab wood is usually bark-free, but not always, as satisfactory board can be made (at least with some species) with the bark included. The chips are then steamed, either in a cooker before passing through a defiberator or within the defiberator itself. Fiber is then blown or otherwise conveyed to a cyclone or similar unit where water is added, bringing the slurry to about 8 per cent consistency before going to the refiner.

From the refiner the fiber is pumped to stock chests where rapid circulatio keeps the fibers in suspension. A consistency regulator reduces the stock to about 2 per cent consistency, and as the slurry is pumped to a mixing tank white water from the Fourdrinier machine is added to bring the fiber content to about 1 per cent. Additives, such as resins and sizes, usually are added to the fiber in the mixing tank, although one company has made a satisfactory hardboard without the addition of chemicals.

The slurry is pumped to the head box of a Fourdrinier board-making machine which is equipped with necessary vacuum sections and pre-press rolls. The formed wet mat is cut into 16-foot, or shorter, lengths by a flying cut-off saw and conveyed to a vacuum transfer which lifts the wet mat and places it on a screen-topped caul. The mat and caul then are transferred to a press charger. Pressing time is dependent upon several factors such as thickness, temperature and additive

After pressing, the boards are discharged from the press, and the cauls and screens are removed. The boards as they come from the press are at close to an oven-dry condition and must be placed in a humidifier to bring the average moistur content up to that which will be encountered in use.

The entire process usually is continuous, and requires only four or five men to operate the production machinery.

A variation of the conventional wet-process is the "wet-batch" process. This method is much the same as the continuous wet process; however, the mats are formed individually in a deckel box, rather than with a Fourdrinier machine.

To make a smooth-two-sides board, and stay within the limits of practicability, the fiber should have a moisture content before pressing of less than 10 per cent. At this moisture content it is not necessary to use a screen back to allow moisture to leave the board in the form of steam during the pressing cycle. A smooth-two-sides board can be made by the wet process if the formed wet mat is placed in a continuous drier and dried to a moisture content below 10 per cent before pressing. This method has been used, and is generally called the "wet-dry" process.

Dry-formed processes

The semi-dry process, as shown in Figure 2, has much the same equipment as the wet process until the actual felting of the board mat. In this process the wax or size is sometimes applied to chips as they enter the cooker, before being converted to fiber. The cooking operation is usually done in a continuous steam cooker (5-10 minutes at 20-100 psi). Steamed chips are fed to a double-disc rotating attrition mill and are defiberized without the addition of water.

Pick-up fans blow the fiber to a mixer or blender where resins are sprayed onto the fiber. Fiber leaving the mixer is picked up in a heated air stream which delivers it to the felter box at about 10 to 40 per cent moisture content (oven-dr basis). The felter box is designed to sift the fiber onto a traveling belt, in a manner similiar to a heavy snowfall. A continuous mat is formed which varies from around 10 to 12 inches in thickness for a $\frac{1}{4}$-inch board. After leaving the felter the fiber mat is treated in much the same manner as in the wet process. It is pre pressed, cut into 16-foot, or shorter, lengths, vacuum-transferred onto cauls and loaded into a multi-opening hot press. After leaving the press the two processes are again identical.

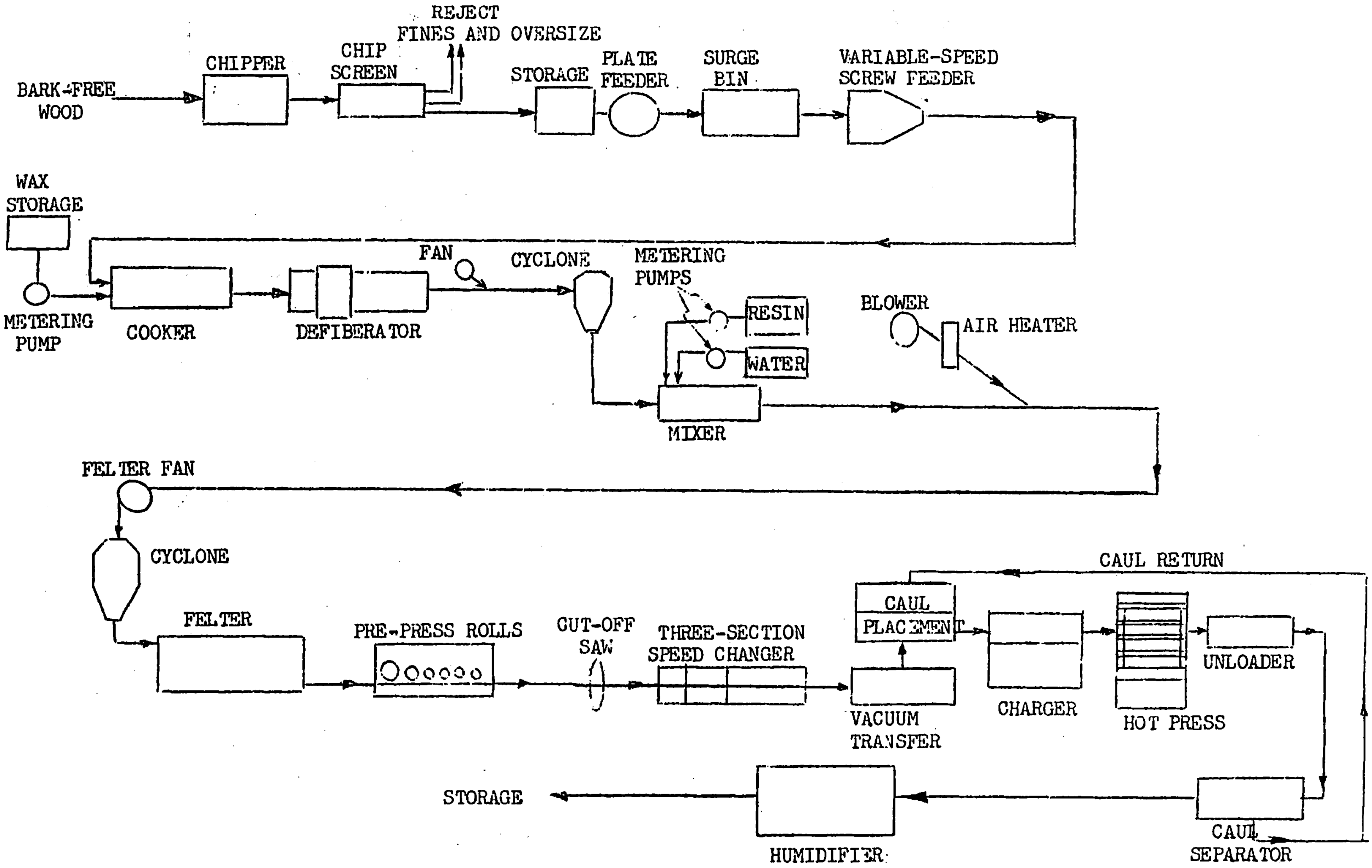

Figure 2. Continuous Dry-formed Hardboard Process.

The semi-dry process has the advantages of greater recovery of fiber from a given volume of chips, less pressing time, a smooth-two-sides board if so desired, somewhat simpler and less expensive machinery, and does not require huge volumes o water. This process does, however, require larger percentages of resin binder to obtain a given strength.

The dry-process method of hardboard manufacture is the same as the semi-dry with the exception that the fiber is dried to from 5 to 10 per cent moisture content before pressing. This process, like the wet-dry process, does not require a screened back because of the low moisture content of the fiber as it enters the press.

INVESTIGATION OF SECONDARY SPECIES

The Laboratory has completed the first in a series of studies on the suitability of some of our western species of wood for the manufacture of semi-dry process hardboard. Efforts are being concentrated on so-called secondary species because of the diminishing supplies of major sawtimber species in some areas. The semi-dry process was used in this study because of the apparent advantages of lower capital investment, greatly reduced use of water and lower operating costs. Also, since most present plants use the wet process, investigations of species suitability for this method are more likely to be undertaken by operating compani

Species to be investigated are lodgepole pine, Sierra juniper, ponderosa pine, western hemlock, white fir and red alder. Of these, lodgepole pine has been studied (complete report available upon request), and juniper and hemlock are being investigated at the present time. An estimated plant cost analysis by the Laboratory for lodgepole pine semi-dry process hardboard will be available soon.

Lodgepole Pine

Lodgepole pine stands in Oregon include some 620 million fbm of saw-timber Since only about 1/5 of the trees in mature stands reach saw-timber size, the total volume would be several times this amount. Much of this timber is concentrated in Klamath, Deschutes and Lake counties.

Preparation of material

Four-foot bolts of lodgepole pine were chipped and screened to obtain uniform 5/8-inch chips. The chips were then cooked for 1/2 hour under 25 pounds steam pressure (a preliminary investigation showed that fiber from steamed chips produced stronger boards than did fiber from unsteamed chips). After steaming, the chips were ground in a 24-inch double-disk attrition mill at a plate setting of 25 mils. The ground fiber was then allowed to dry prior to formation and pressing of the individual mats.

Preparation of the boards

The calculated percentages of additives (resins and waxes) were added as a spray while the fiber was being agitated in a propeller-type mixer. The prepared fiber was weighed, and felted into 12- by 12-inch mats. These mats then were pressed in a 24- by 24-inch steam-heated press at either 320 deg F or 400 deg F with a ten-minute press cycle at an initial pressure of 1,000 psi. The initial pressure was maintained for 45 seconds, after which time the pressure was released to 100 psi for the remainder of the press cycle. The pressed boards then were cut into test samples and placed in a constant humidity room until tested.

Testing the boards

All the boards were tested for modulus of rupture, water absorption, specif gravity and moisture content values.

The modulus of rupture tests were performed in accordance with the Federal Hardboard Specification LLL-F-311, except that the length of the sample was 11 inches (instead of 12 inches) and the breaking loads were read to the nearest 0.5 pound instead of the nearest five pounds.

After the modulus of rupture tests, a 3- by 3-inch water-absorption sample was cut from each broken bending sample. The samples were immersed for 24 hours under 1 inch of water maintained at 70 deg F.

Specific gravity values were obtained by mercury immersion of 1- by 3-inch coupons cut from the bending samples.

Analysis and discussion of results

In order to detect important differences in board properties caused by various treatments, the test data were subjected to the common statistical method of analysis of variance. Only test values for modulus of rupture, per cent water absorption and specific gravity were analyzed because of time limitations.

The work presented represents the results of testing 114 screen-backed boards, one-quarter inch in thickness.

From an analysis of the first phase of this study it was found that by the addition of 2-1/2 per cent of phenolic resin a satisfactory board with regards to modulus of rupture could be made. Water-absorption values were well above acceptable limits and because of this, the remainder of the study was an attempt to improve water resistance. The improvement of water resistance was accomplishe by using various sizes in conjunction with a 50-50 mixture of 1N sulphuric acid and 1N alum solution for pH control (4.0-5.0 pH).

The effect of pH control on water resistance of the boards is shown in Tables 1 and 2. The analysis of water-absorption values revealed that pH control appreciably increased the water resistance of all boards, regardless of the additives or press temperatures used. Table 2 shows that the additive combinati affected the degree of improvement caused by pH control. The increase in press

Table 1. Average Test Values Obtained from Lodgepole Pine Hardboard, at Two Temperatures; With and Without pH Control.

Additive treatment	Temperature							
	320° F				400° F			
	No pH Contol		pH Control		No pH Control		pH Control	
	Modulus of Rupture	Water Absorption	Modulus of Rupture	Water Absorption	Modulus of Rupture	Water Absorption	Modulus of Rupture	Water Absorption
	Psi	Per cent	Psi	Per cent	Psi	Per cent	Psi	Per cent
Control	3090	257.5	2900	251.5	3590	91.5	4180	72.2
Resin (2-1/2%)	8500	63.4	7280	51.8	8620	54.5	8680	38.2
Resin + 1-1/2% of Wax A	6820	32.8	6430	23.6	8130	47.7	6630	18.8
Resin + 1-1/2% of Wax B	5940	57.0	4420	18.3	6350	53.2	5640	15.3
Resin + 1-1/2% of Wax C	6950	59.3	5790	21.5	7160	41.0	5830	17.5
Resin + Rosin A	6260	41.4	5230	27.4	7590	35.5	6170	22.7
Resin + Rosin B	6690	61.9	5420	45.3	7340	53.6	6390	43.4
Resin + Rosin C	6610	73.5	4020	44.3	7450	54.8	4730	25.9

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Additive treatment	Decrease in water absorption percentages
Wax B - Wax emulsion (non-precipitating type)	38.3
Rosin C - Powder	29.1
Wax C - Solid type added to chips	28.1
Wax A - Wax emulsion (precipitating type)	19.1
Resin - Phenolic	13.8
Rosin A - Powder	13.4
Rosin B - Paste	13.4
Control	12.6

temperature from 320 deg F to 400 deg F decreased water absorption for some, but not all, of the additive treatments.

In summary, the following relationships were established from the analysis of water-absorption values:

a. Control of pH is an important factor in the improvement of water resistance regardless of additive treatment or press temperature used in this study.

b. An increase of press temperature may or may not improve water resistance depending on the particular additives concerned.

Modulus of Rupture

All of the major variables had a significant general effect on the modulus of rupture values of the boards. The addition of supplementary additives reduced the strength of boards compared to those made with resin only (Table 1). In general, pH control lowered the strength of the boards. Increased press temperature generally improved the modulus of rupture.

Conclusions and Recommendations

Lodgepole pine chips which had been steamed prior to grinding produced a fiber which made stronger boards than did fiber ground from raw chips. Furthermore, the steamed fiber appeared to make more efficient use of a wax emulsion added to improve water resistance.

From the water-resistance study on steamed fiber, it was apparent that pH control of the fiber-additive mixture had a definitely beneficial effect on water absorption, but usually reduced the strength of the boards, depending on the additives used (Table 1).

An increase of press temperature from 320 deg F to 400 deg F generally improved board strength, but any increase in water resistance was dependent on the additives used.

Although results of laboratory-scale experiments cannot be directly translated into expected results from a commercial-size operation without further study, the results presented here show that lodgepole pine can be a promising new source of raw material for dry-formed hardboard.

A more complete report titled "The Suitability of Lodgepole Pine for Dry-formed Hardboard", can be obtained by writing for Report L-3, Oregon Forest Products Laboratory, Corvallis, Oregon.

Western Hemlock

Procedure for this work was based on results of the lodgepole pine study. The combination of additives which produced the most satisfactory hardboard from lodgepole pine was used as a starting point for this study. Results were compared on the basis of what was known of lodgepole pine and Douglas-fir fiberboard.. A summary of the hemlock test data is shown in Table 3.

Boards containing 2-1/2 per cent of resin and 1-1/2 per cent of a wax emulsion pressed at 400 deg F with controlled pH met the proposed commercial and federal specifications for 1/4-inch standard smooth-one-side hardboard. Strength values of hemlock were found to be superior to those of both lodgepole pine and Douglas-fir boards. Boards pressed with the same additives without pH control at 400 deg F or with pH control at 320 deg F came very close to meeting the standards, considering the small size of the water-absorption samples.

Sierra Juniper

It was suggested that juniper chips from which extractives had been removed might be a suitable material for the manufacture of hardboard. As a result, a short-term investigation of juniper fiber for hardboard making was initiated.

Juniper chips, screened to a uniform 5/8-inch size, were fiberized hot in the Bauer mill after steam distillation for volatile oil recovery was completed (5 to 8 hours at either 267 deg F or 300 deg F). It was discovered that a wider plate clearance was required to produce a fiber comparable with fiber from other species. Three different plate settings were used during the grinding of the juniper chips, each batch being segregated.

Boards of juniper fiber were made in the same manner as previously with lodgepole pine and hemlock boards. The same combinations of additives that proved most successful with lodgepole pine were used with juniper. No pH control was attempted on this fiber. The boards were tested in an identical manner to those of lodgepole pine and hemlock (Table 4).

All of the juniper boards regardless of pressing temperature used were characterized by a glossy, uniformly colored surface on the smooth side. Because of the extended steaming times, somewhat more water solubles than previously experienced with other species were deposited on the screen back. In commercial operation, it would be desirable to brush off this material because it is sticky to the touch.

A comparison of the modulus of rupture values revealed that the juniper boards were somewhat stronger than those from lodgepole pine, but weaker than hemlock boards, when pressed under the same conditions. The water resistance of juniper boards was superior to that of either lodgepole pine or hemlock boards.

There were no significant differences between grinds, although three plate spacings were used in order to grind fiber similar to that from lodgepole pine and western hemlock.

Increased press temperatures generally caused an increase in bending strength and water resistance in juniper boards, as with boards from the other two species studied.

Table 3. Summary of Results from Testing of Hardboards from Western Hemlock Fiber.

Press temp.	pH control	Additives	Modulus of Rupture	Water absorption*	Specific gravity	pH at pressing
			psi	Per cent		
320	No	2½% Resin	7,770	57.5	0.96	7.9
320	Yes	2½% Resin	7,580	47.7	0.97	3.8
400	No	2½% Resin	8,930	43.3	1.00	7.9
400	Yes	2½% Resin	7,610	25.9	1.01	3.7
320	No	2½% Resin + 1½% Wax	6,800	24.0	0.98	7.9
320	Yes	2½% Resin + 1½% Wax	8,380	18.5	1.04	4.2
400	No	2½% Resin + 1½% Wax	9,130	18.4	1.03	7.9
400	Yes	2½% Resin + 1½% Wax	8,510	15.0	1.02	4.0

* Least significant difference in water absorption values: 3.5

Table 4. Summary of Results from Testing of Hardboards from Sierra Juniper Fiber.

Press temperature	Additives	Property	Grinding run		
			1[a]	2[b]	3[c]
Degrees F					
320	None (Control)	Modulus of rupture; psi	3740	3730	3880
		Water absorption; per cent	52.4	61.5	51.7
		Specific gravity	0.98	0.96	0.98
		pH	4.0	3.9	4.2
320	Resin, 2½% Wax, 1½%	Modulus of rupture; psi	6840	7020	6170
		Water absorption, per cent	17.7	18.9	17.7
		Specific gravity	1.04	1.04	1.00
		pH	5.4	5.1	5.5
400	None (Control)	Modulus of rupture; psi	5060	5400	5380
		Water absorption; per cent	40.4	44.3	38.1
		Specific gravity	1.00	0.98	0.99
		pH	4.0	3.9	4.1
400	Resin, 2½% Wax, 1½%	Modulus of rupture; psi	7310	7270	7270
		Water absorption; per cent	13.7	13.7	13.6
		Specific gravity	1.03	1.00	1.02
		pH	5.4	5.2	5.3

[a] Attrition mill plate clearance: 23 mils.
[b] Attrition mill plate clearance: 35 mils.
[c] Attrition mill plate clearance: 40 mils.

The inclusion of resin and wax significantly increased the bending strength of the boards regardless of the fiber or press temperature used. In addition, resin and wax effected a greater strength increase where the boards were pressed at the lower press temperature (320 deg F).

The juniper boards also were noticeably more uniform in specific gravity than boards from other species pressed under the same conditions. This demonstrate that this fiber possesses superior flow characteristics.

In conclusion, this preliminary evaluation shows clearly that extracted juniper chips could be a promising source of raw material for hardboard. A more detailed study is now underway on the use of juniper for hardboard.