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FULL-TREE UTILIZATION OF SOUTHERN PINE AND HARDWOODS GROWING ON SOUTHERN PINE SITES[1]

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Abstract--In 1963, approximately 30 percent of the dry weight of above- and below-ground parts of southern pine trees ended as dry surfaced lumber or paper; the remaining 70 percent was largely unused. By 1980, computer-controlled chipping headrigs, thin-kerf saws, lamination of lumber from rotary-cut veneer, high-yield pulping processes, and more intensive use of roots, bark, and tops will likely double the yield of lumber, paper, bark products, and reconstituted board to 60 percent of the dry weight of above- and below-ground tree parts.

On southern pine sites, for every cubic foot of pine, there is about 0.8 cubic foot of hardwood. The Koch shaping-lathe headrig is a key to utilizing these small mixed hardwoods for pallet and industrial lumber. Lathe residues can be the raw material for a new major industry built to manufacture exterior, structural flakeboard competitive in price and function with sheathing grades of plywood.

Additional keywords: chipping headrigs, roots, bark, stem, foliage, needles, tops, particleboard.

The timber industry in the southern pine region, as elsewhere in North America, faces two pressing problems:

- The forests must be made to yield more utilizable wood to satisfy an unprecedented demand for houses, paper, and industrial products.

- Forest residues, including under-utilized species, must be reduced to lessen the impact of logging on the environment and to improve the growing capacity of timberlands.

In discussing these problems, I am first going to present some proposals for better utilization of southern pine. The second half of my comments will describe methods to improve utilization of hardwoods growing on southern pine sites.

1/ This paper was initially presented at the *Forest Industries* Small Sawmill Clinic in New Orleans, La., November 9, 1973; it comprises a chapter in *Forest Industries'* book, *Modern Sawmill Techniques*, Vol. 2, Miller Freeman Publications, Inc.

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SOUTHERN PINE UTILIZATION

The southern pines are the primary softwood timber species in the United States. Moreover, their commercial importance is increasing. By the end of the century, over half of the softwood manufactured in this country will probably come from the South. It therefore seems useful to examine the implications of recent wood-machining and conversion research on the degree of utilization of these species.

Better Main-Stem Utilization

A convenient point for beginning the appraisal is 1963. In that year, the chipping headrig was still below the horizon, the southern pine plywood industry had not been established, and widespread use of southern pine planer shavings for particleboards was yet to come. Merchantable stems were utilized primarily for lumber and pulp chips. The degree of utilization in 1963 can be simplified by analyzing yield from trees cut into sawlogs for conversion with circular saws:

End use	Percentage of merchantable bark-free stem (basis of ovendry weight)
	Percent
Rough lumber	48
Pulp chips	28
Sawdust	24

About 25 percent of the ovendry weight of 2-inch-thick rough dry lumber was converted to shavings during planing; at that time the shavings had only a nominal value--primarily as fuel. Of the fraction of the stem (28 percent) that went into papermills, only about half emerged as paper; the remainder was spent black liquor. Therefore, in 1963 about 36 percent of the bark-free merchantable stem ended as lumber and 14 percent as paper, for a total utilization of 50 percent. The remaining 50 percent ended as residuals with minimal value. Moreover, all other above- and below-ground tree parts were left in the woods, and bark was burned as a residue.

Analysis of 22-year-old slash pine trees (table 1) has shown that the merchantable bark-free stem to a 4-inch top comprises 58.5 percent of the entire tree; the remaining 41.5 percent consists of roots, stump, bark, top, branches, and needles. Comparable data (including roots) for sawlog-size timber are not available, but in this discussion the percentages are assumed to be the same[3/]. In 1963, therefore, no more than 30 percent (58.5 × 50 percent) of total tree weight was recovered in primary manufacture. I predict that this percentage will be doubled by 1980.

3/ In a personal communication, M. A. Taras of the Southeastern Forest Experiment Station, USDA Forest Service, states that loblolly pine trees from 6 to 20 inches d.b.h. show only slight differences in percentages of crown but that proportions of bark are greater in small loblolly pines than in large. Readers whose interest lies in trees older than 22 years should therefore decrease bark percentages and increase stemwood percentages somewhat over the values shown in table 1.

Table 1.--Weight distribution (ovendry basis) of above- and below-ground parts of three 22-year-old, 7.7-inch, unthinned, plantation-grown slash pine trees cut in central Louisiana[a]

Portion of tree	Weight fraction of-- Total tree	Above-ground parts	Bark-free stem to 4-inch top (d.o.b.)
	------	Percent	------
Bark-free stem	58.5	70.2	100.0
Roots and stump[b]	16.5	19.8	28.2
Stem bark to 4-inch top	12.5	15.0	21.4
Top (with bark)	5.0	6.0	8.5
Needles	4.0	4.7	6.7
Branches (with bark)	3.5	4.2	5.9
Total	100.0		

a/ Adapted from Howard (1973); see also Koch (1972, p. 1541).

b/ Roots to a 3-foot radius.

By then, processing research will have resulted in significant utilization advances, some of which are already in being. Widespread applications of chipping headrigs and edgers, and increased use of thin-kerf saws, have diminished sawdust from about 24 to 5 percent of the bark-free merchantable stem. Further development of technology for sawing with lasers or liquid jets may further reduce sawdust percentage.

Development of log scanning devices coupled to computer-controlled headrigs and resaws will likely boost the percentage of rough lumber recovery from 48 to perhaps 60 percent of the merchantable bark-free stem. Moreover, thickness allowances for planing will be reduced for most structural lumber; this will be made possible through more accurate techniques for smooth resawing. It is possible, and even probable, that certain products, such as 2- by 4-inch studs, will be sold rough. Planer shavings will accordingly be reduced from 25 percent of rough dry lumber weight to perhaps 10 percent.

Since 1963, some 51 plywood plants have been built to utilize southern pine. These mills recover approximately 60 percent of log volume as sheathing plywood and studs from veneer cores (Koch 1972, p. 1537). Should a proposed method (Bohlen 1972; Echols and Currier 1973; Jokerst 1972; Koch 1973; Moody and Peters 1972; Schaffer *et al.* 1972) of making structural lumber from rotary-peeled or sliced veneer take hold in the South, it will provide another method of recovering 60 percent of log volume in the form of sized dry lumber.

It is also likely that higher yielding pulping processes will be in widespread use by 1980. Variations of the kraft process--or entirely new chemical processes--may boost yields from 50 to 60 percent. And it is hoped that a new method of mechanically pulping southern pine chips can be developed to improve the properties and market acceptability of very-high-yield pulp (McMillin 1969). Should both developments be successful, then yield of southern pulpmills, in toto, may average close to 70 rather than 50 percent.

One might predict, therefore, that in 1980 merchantable stems cut for lumber will be converted as follows:

End use	Percentage of merchantable bark-free stem (basis of ovendry weight)
	Percent
Rough lumber	60
Pulp chips	35
Sawdust	5

As noted above, lumber volume will be reduced perhaps 10 percent when planed, and pulping losses will average about 30 percent. Therefore, about 79 percent ($0.9 \times 60 + 0.7 \times 35$) of the bark-free merchantable stem (ovendry weight basis) will end as dry merchantable lumber or as paper. Since the bark-free merchantable stem to a 4-inch top comprises 58.5 percent of the entire tree weight (including roots, stump, bark, branches, tops, and needles), it is therefore likely that by 1980 about 46 percent (79×0.585) of the whole-tree volume of trees cut for lumber will end as merchantable lumber or paper.

If this percentage is to be raised to 60, it is evident that another 14 percent must also end as products. I believe that such further gain is likely.

Utilization of Taproots

It is seen from table 1 that 16.5 percent of total tree weight is in stump and roots; more than two-thirds of this weight is in the taproot. Therefore, the taproot of a 15- to 30-year-old slash pine, with lateral roots pruned away, weighs about 20 percent as much as the bark-free merchantable stem to a 4-inch top (dry weight basis). Maximum taproot diameter, a few inches below ground level, is 1.5 to 2 times stem diameter at breast height. Length in sandy loam soils is commonly 3 to 5 feet.

The fibers in such taproots are about 1 mm. longer, and the fiber cell walls are thinner, than those in wood above stump height. Chemical constituents do not differ greatly from those of stemwood. The taproot should therefore be suitable for pulping by the kraft process. (For additional details on roots, see pages 379-383, 535-574, and 1540-1543 of Koch 1972.)

It seems then, that wood yields from a southern pine stand could be considerably increased by harvesting the taproot. To this end, I advance the concept of first shearing the lateral roots close to the taproot, and then plucking the entire tree from the ground like a carrot.

It appears that the laterals are best left in the ground. They comprise less than one-third the weight of the total root system, and greatly increase the difficulty of extraction. Further, their bulk would cause severe problems during handling, transport, and chipping.

Most laterals on southern pines are within 18 inches of the surface. I visualize that they could be severed with a tubular shear sharpened on its lower edge and hinged like a clamshell to encircle the tree.

To try the idea, an order was placed with Rome Industries of Cedartown, Georgia, to make a prototype tubular shear and to utilize a JD544A prime mover as a crane to lift the tree. The prototype was tested during October 1973 with 15-year-old plantation-grown pines on dry, hard Georgia clay (fig. 1).

Figure 1.--This prototype whole-tree harvester grips a young pine near ground level and, after lateral roots have been sheared, lifts the tree free of the ground with taproot attached. The harvester is mounted on, and powered by, a rubber-tired prime mover.

The concept worked as planned. During the first stage of harvesting the tubular shear was driven into the ground to sever the laterals. Then the stem and taproot were lifted through the shear. The hole left by the root was small and quickly caved in as the felling machine traveled about the area (fig. 2).

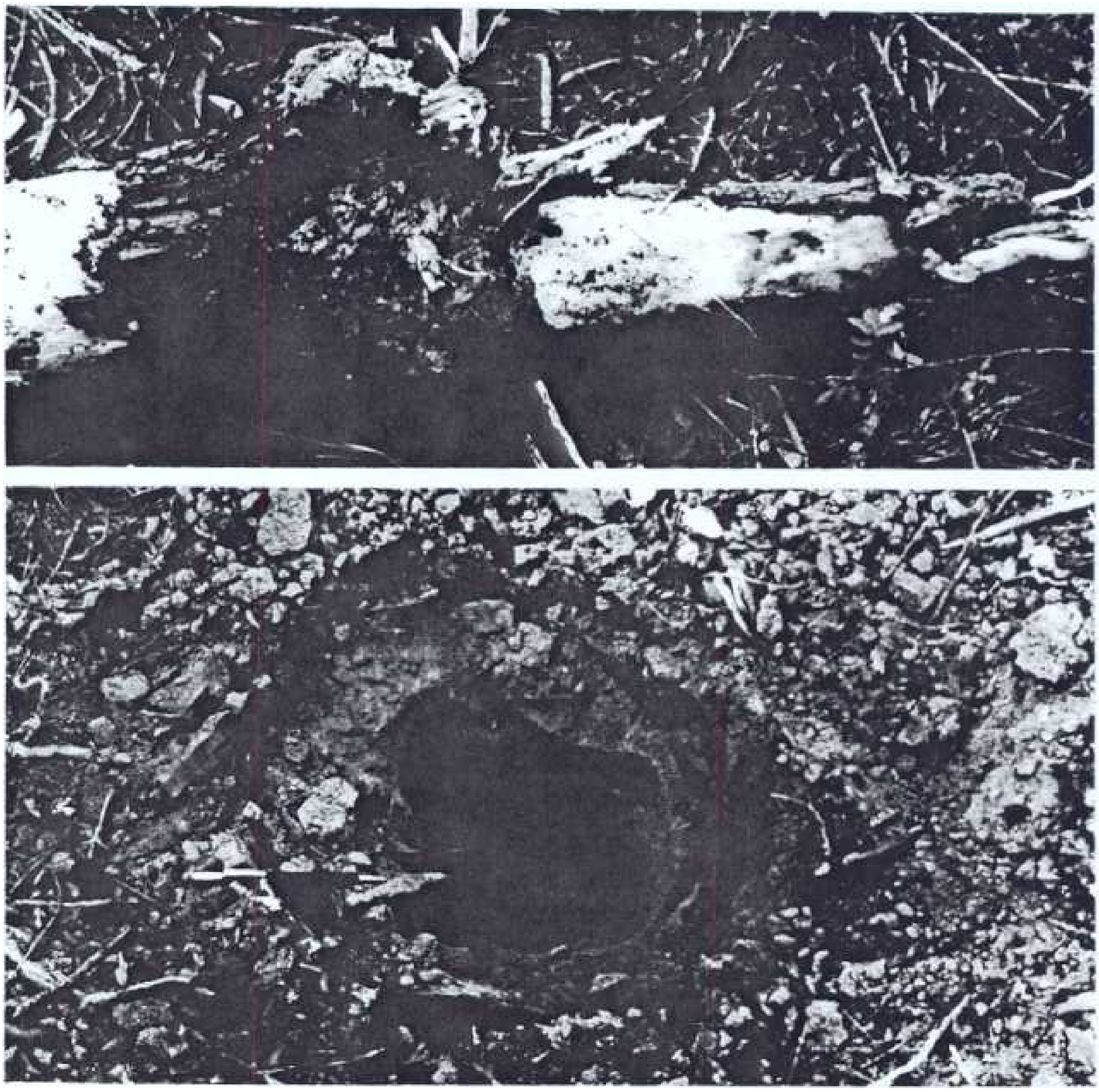

Figure 2.--Top: Taproot of 15-year-old slash pine as it appeared when lifted free of the ground still attached to the stem; normal stump height is about where bark has been skinned from the stem. Bottom: Hole left when tree was lifted. Surrounding hole is slot cut by tubular shear that severed lateral roots prior to lifting.

Table 2 gives data illustrative of the trees harvested.

Table 2.--Taproot dimensions and lifting forces for 15-year-old slash pines in hard clay soil

D.b.h.	Diameter at below-ground swell of taproot	Length of taproot	Vertical lifting force required after laterals were sheared
----------------	*Inches*	------------	*Pounds*
5-3/4	9	54	20,000
6	9	34	16,000
10	20	44	25,000

Considerably more force is required to shear the laterals than is needed to lift the tree after the laterals have been severed. With the tubular shear, it is likely that forces approaching 200,000 pounds will be needed to cut away the laterals of trees 30 years old. In the Georgia trials, dagger-like subsoil plows did a fairly good job and appeared to require less force than the tubular shear. In current design efforts, both avenues are under study.

Once lifted free of the ground, stems with taproots attached can probably be yarded in the customary manner, but loaded for transport with root ends alternated for compactness. On arrival at the mill merchandizing deck, taproots will probably be severed from stems for special washing and chipping procedures. This special handling appears necessary because considerable dirt remains attached as the taproots come from the ground. Harvesting and handling will remove some bark, and washing will take off additional amounts. It is probable, however, that significant quantities will remain on the roots when chipped.

A second prototype of the tree harvester is currently being designed. Should the research prove successful, it will permit owners of plantations in rock-free soil to harvest 20 percent more wood weight per acre than is customary.

In summary, then, it seems likely that about 70 percent of total root volume will be readily recoverable, i.e., about 11.6 percent of total tree weight (fig. 2, top). Further, only a fraction--perhaps 50 percent--of all trees cut will be harvested with roots. Because stumpwood (with bark attached) has lower cellulose content than bark-free stemwood (Koch 1972, p. 569), the yield from chemical pulping will be about 50 percent. All things considered, paper yield from roots may not exceed 3 percent of all trees harvested ($16.5 \times 0.7 \times 0.5 \times 0.5$).

Utilization of Bark, Tops, Branches, and Needles

Stem bark is also an important component of tree weight, averaging 12.5 percent in 22-year-old slash pines (table 2). By 1980, perhaps three-fourths of the tonnage will be profitably sold by processors of southern pine. Much will be burned as a source of energy for kilns and power plants. Increasing amounts will be marketed as mulches, soil amendments, and growing media. Some will be used in Herreshoff furnaces to manufacture charcoal and combustible gases. Additional volumes may be incorporated in particleboards of various kinds. And chemical processes--as yet undeveloped--will likely account for significant sales.

Tops and branches (with bark) comprise about 8.5 percent of total tree weight. It is assumed that 25 percent of this available tonnage will be converted to medium-density fiberboard or other reconstituted product, thus increasing whole-tree utilization by 2 percent. If kraft mills begin to accept chips with some bark attached, a greater percentage of tops and branches may be utilized. Some will be harvested for fuel.

Approximately 4 percent of whole-tree weight is comprised of needles (table 1). Moreover, each year a slash pine tree casts off needles (ovendry basis) equal in weight to the wood laid down during the year (Koch 1972, p. 586). New uses are likely to be found for some of this material, but for present purposes the total is assumed to be small.

From the foregoing discussion we can compare the degree of utilization in 1963 with that probably achievable by 1980. In the following tabulation, product yields in primary manufacture are stated in percentages of total tree weight (ovendry basis):

Portion of tree	Fraction of total tree	Product recovery in-- 1963	1980
	------------	*Percent*	------------
Bark-free stem to 4-inch top	58.5	30	46
Roots and stumps	16.5	0	3
Stembark to 4-inch top	12.5	0	9
Top and branches (with bark)	8.5	0	2
Needles	4.0	0	0
Total	100.0	30	60

I conclude that it is not only possible, but probable, that by the end of the present decade percentage of tree weight recovered as primary products will be double that of 1963.

HARDWOODS ON PINE SITES

Southern resource data indicate that for every cubic foot of pine on southern pine sites there is about 0.8 cubic foot of hardwoods. Although present in huge volumes, these hardwoods on pine sites have proven difficult to utilize at a profit. They have therefore been left standing to the detriment of pine production, or have been destroyed at substantial expense--but not utilized--during site preparation for pine plantations.

In the last year or two, southern pulp companies have been rapidly increasing the amount of hardwood they will accept; as of November 1973 the majority are equipped to pulp most species. The hardwood volume is so vast, however, that little dent has yet been made on the available supply.

Utilization of the hardwoods is made difficult because of the nature of the stands. The hardwoods are interspersed in the pines, they are small (diameter classes of 6 to 8 inches predominate), and few contain substantial amounts of clear lumber; many have crooked stems and in some stands heart rot is present in substantial amounts. Moreover, many species are present, all of which present different utilization problems. Of the 22 species comprising 95 percent of this volume, 11 are oaks, and most exceed a specific gravity of 0.55 (green volume, ovendry weight basis).

Koch Lathe Headrig

Recent work at the Pineville laboratory has been focused on invention of processes to convert this heterogeneous hardwood resource into commodity products. Central to all of the processes devised to date is the shaping-lathe headrig (Koch 1964, 1967), a machine designed to convert small, crooked, dense hardwood logs into smoothly surfaced and accurately sized cants.

A prototype (fig. 3) was first displayed at this year's Southern Forest Products Association machinery exhibition in Atlanta, where it attracted wide interest.

The commercial version being manufactured by Stetson-Ross, Seattle, is much like the prototype, except that the cutterhead is 54 inches in length and the chucking mechanism will accept bolts 40 to 53 inches in length. The 12-inch-diameter cutterhead is driven by a 300-hp. motor at 3600 r.p.m. and carries 12 castellated knives. Delivery of the first commercial machine will be made by Stetson-Ross in June 1974.

Logs to be machined are charged semi-automatically into the chucks of the workpiece spindle, which revolves at about 15 r.p.m. Attached to the workpiece spindle is a replaceable cam having the shape and dimensions of the desired cant. The cam rotates and moves with the workpiece toward the cutterhead until it strikes a cam follower aligned with the cutterhead. As the workpiece makes a single revolution, the center distance between cutterhead and cam changes in response to the cam, and the workpiece (log) is machined to the shape and dimensions of the cam (fig. 3).

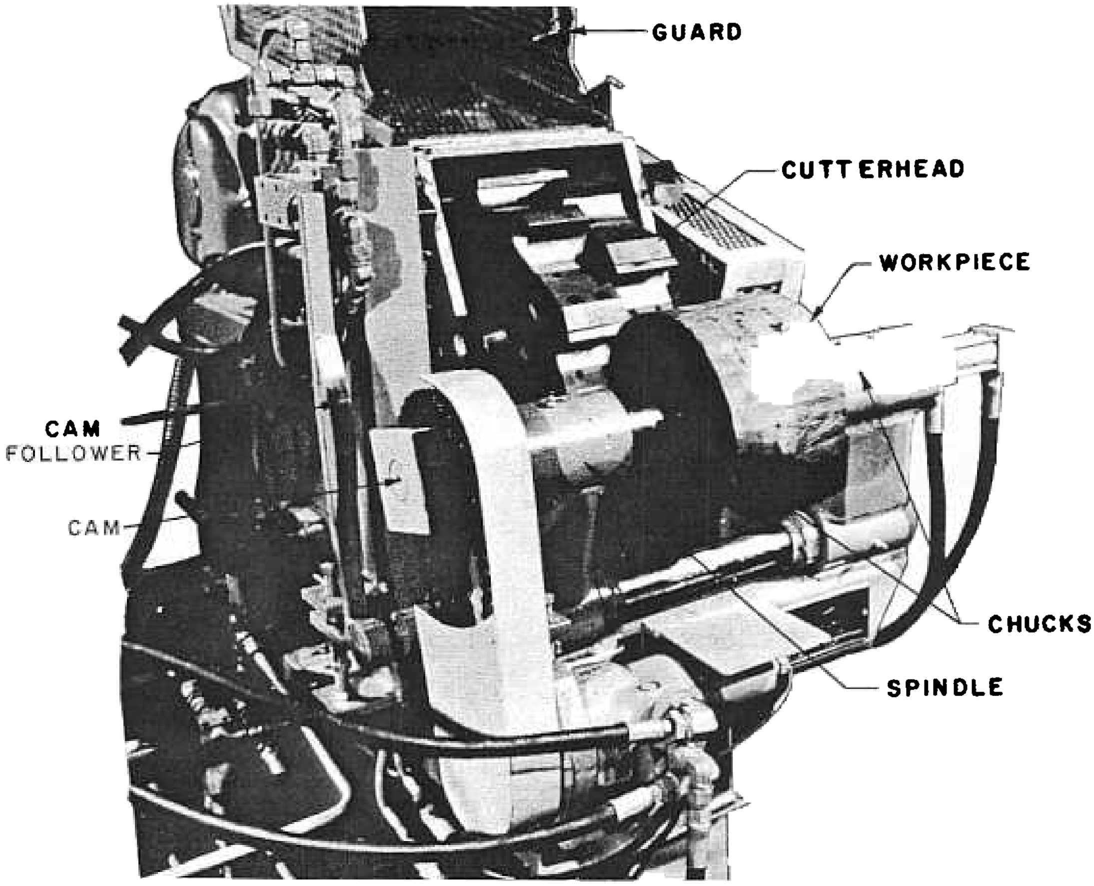

Figure 3.--Prototype Koch lathe with 7-inch-long, 10-knife cutterhead. The commercial version will carry a 12-inch-diameter, 54-inch-long head capable of machining 40- to 53-inch-long logs in a single 4-second revolution of the workpiece. Smoothly machined cants will have the shape and dimensions of replaceable cams mounted on the workpiece spindle.

Since the log need rotate only a single revolution to be sized, machining time is brief--approximately 4 seconds. With semi-automatic log centering and charging, the lathe should consume six logs per minute. Per-shift production of 4 by 4's from 6-inch logs 4 feet long should therefore be about 12,500 board feet of cants plus 30 tons of green flakes or chips. If logs are larger, e.g., of sufficient diameter to yield 8 by 8's, then per-shift production will approach 50,000 board feet with proportionately greater yield of flakes or chips.

The headrig can readily produce rounds, hexagons, octagons, or trapazoids as well as square and rectangular cants (fig. 4); it therefore should find its primary application in the production of industrial wood parts--principally cants for pallet deckboards and stringers. Figure 5 illustrates possibilities for very high lumber recovery by ripping pallet deckboards from octagonal cants. Other possibilities for high-yield products such as round or octagonal fence rails, highway posts, and industrial blocking will doubtless occur to the reader as he studies this sawing diagram.

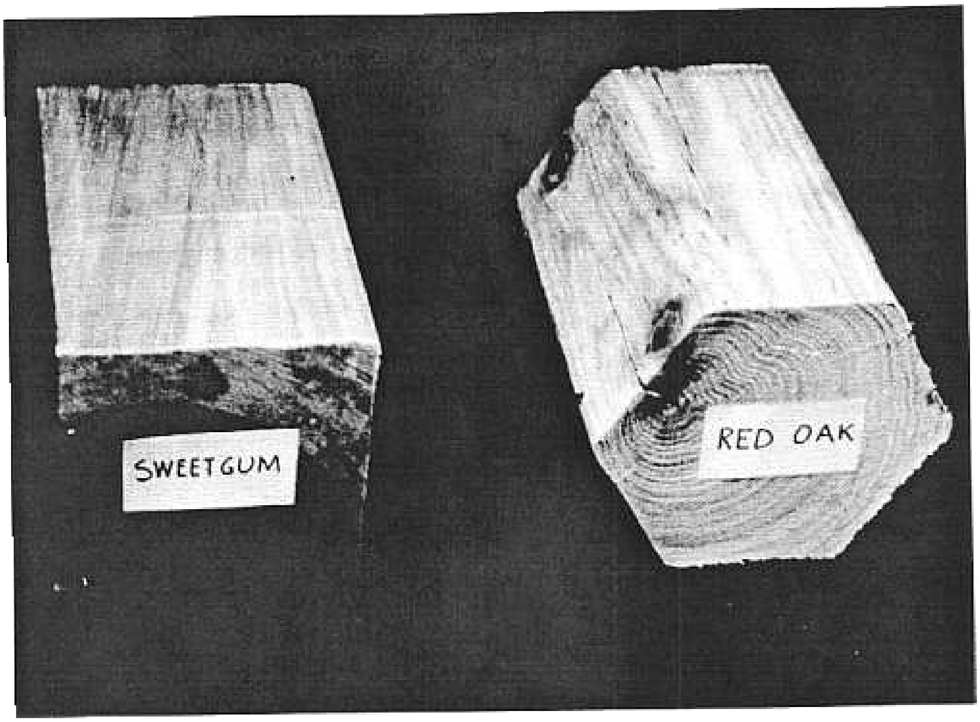

Figure 4.--Cants produced on the lathe may be rectangular, round, octagonal, trapezoidal, or triangular, as well as square or hexagonal. Because knives cut in the veneer direction and take shallow cuts, cant surfaces are smoothly machined with no tearout around knots.

Extension of the machine to handle 8-foot-6-inch crossties would appear to be a logical development, but few firms can log the 2,000 tie cuts per day required to keep the machine occupied.

Structural Exterior Flakeboard

Residue from the shaping lathe can be in the form of thin pulp chips, toothpick-like particles, or flakes. The pulp chips do not have optimum screen analysis for many chemical pulping processes because they contain too many pin chips; they should, however, be excellent furnish for medium-density particleboard produced from disk-refined fiber.

When the cutterhead is fitted to produce long, coarse particles, the resulting toothpick-like material can be combined with foamed urethane resins to make light-weight moulded structural aggregates of surprisingly high strength.

In my mind, however, the real potential of the lathe lies in its ability to cheaply produce large tonnages of veneer-like flakes measuring perhaps 3 inches long and 0.015 inch thick (fig. 6). These flakes--with the addition of about 5 percent of phenol-formaldehyde resin--can be manufactured into a structural exterior flakeboard that should compete in price and function with sheathing grades of plywood (fig. 7).

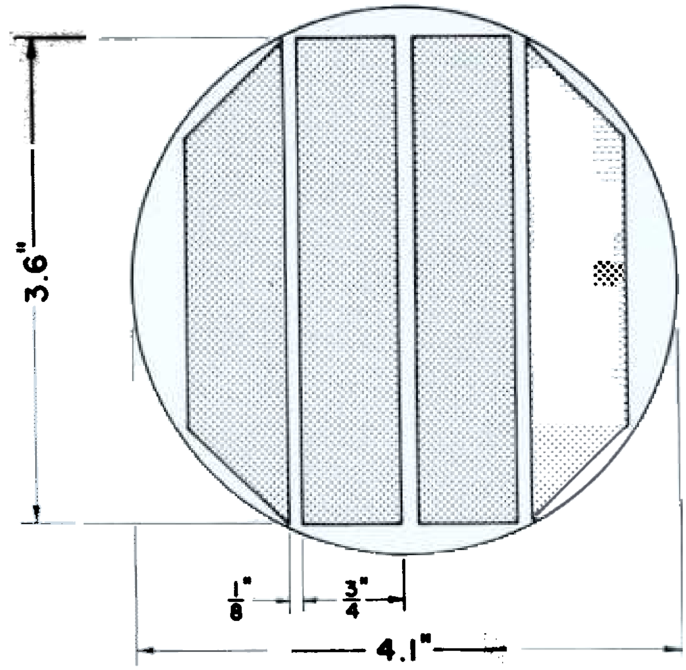

Figure 5.--Sawing pattern whereby square-edged pallet deckboards can be ripped from the central portion of octagonal cants and bevel-edged deckboards cut from outer portions. By the sawing pattern diagrammed, lumber recovery factor is about 14 board feet per cubic foot of log.

The structural exterior flakeboard shown in figure 7 is 50 percent southern red oak, 25 percent hickory, and 25 percent sweetgum. With face and back layers oriented and center layer random, it has a modulus of elasticity of 1,000,000 p.s.i., modulus of rupture of 8,000 p.s.i., and internal bond strength of 85 p.s.i. Board density is 43 pounds per cubic foot, and thickness is 1/2-inch. It contains 5 percent phenolic resin and was pressed for 6 minutes at 325° F. If flakes had been randomly oriented in all layers, modulus of elasticity would have been near 800,000 p.s.i.

<u>Commercial Practicality</u>

In addition to offering a partial solution to hardwood lumber shortages, I believe this headrig will give rise to a new industry manufacturing structural exterior flakeboard competitive in price and function with sheathing grades of plywood. My reasons for this prediction are several:

> The hardwood resource of this country is closely adjacent to population centers where sheathing finds its major market.

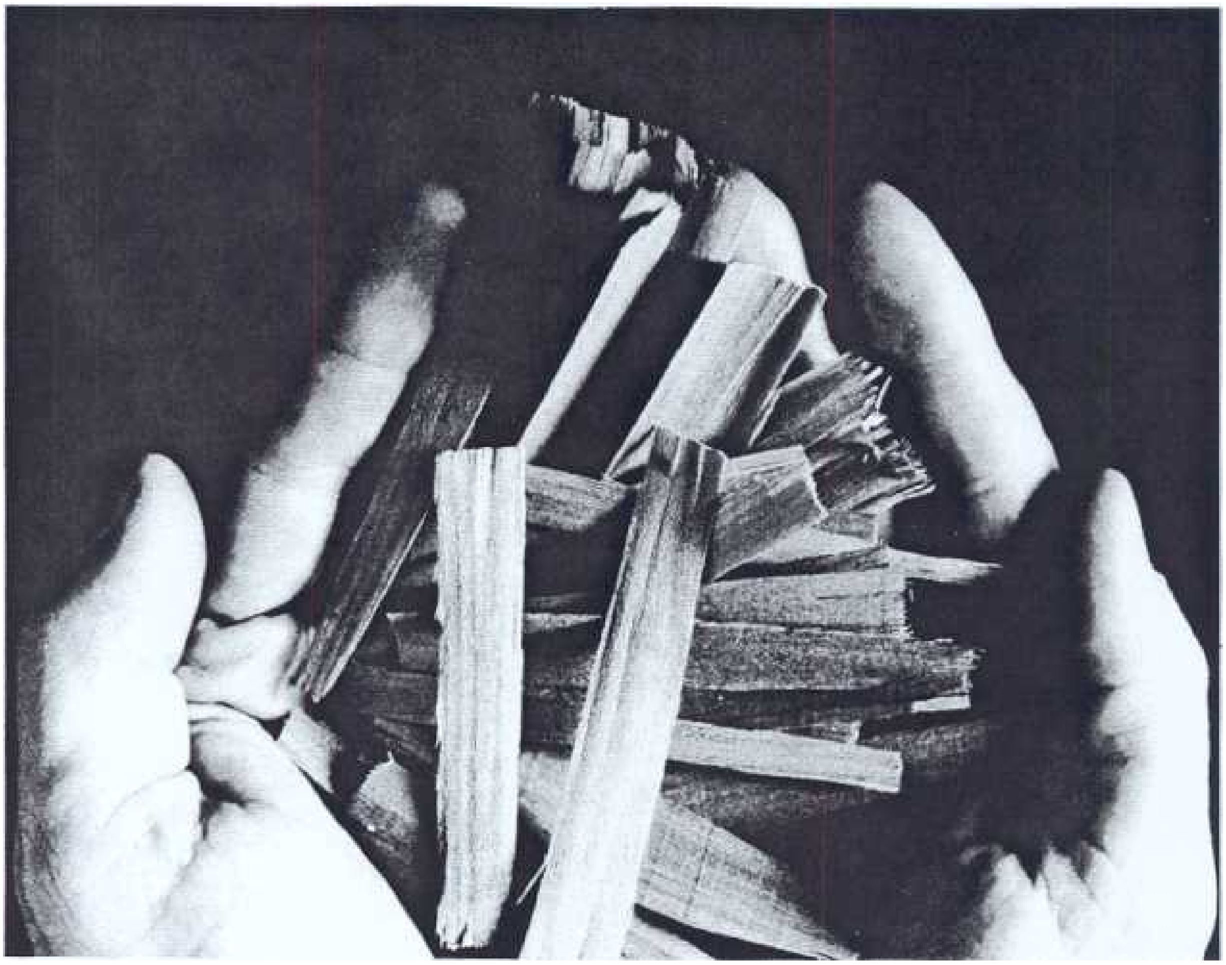

Figure 6.--Flakes 3 inches long and 0.015 inch thick residual from southern hardwood logs cut into cants on the Koch lathe. Such flakes have near optimum dimension for manufacture of structural exterior flakeboard.

- The hardwood resource is also conveniently close to manufacturing centers where hardwood industrial lumber and pallets are used in greatest volume.

- The hardwood pallet market is vigorously growing and cants for manufacture of deckboards and stringers are in short supply. Hardwood stumpage (of the type required by the process described) is in plentiful supply and in many areas is readily available at low cost.

- Flakes residual from the lathe headrig described can be produced at a fraction of the cost of pine veneer.

- Such flakes can be manufactured into structural exterior panels by a less labor-intensive process than that of manufacturing plywood from veneer.

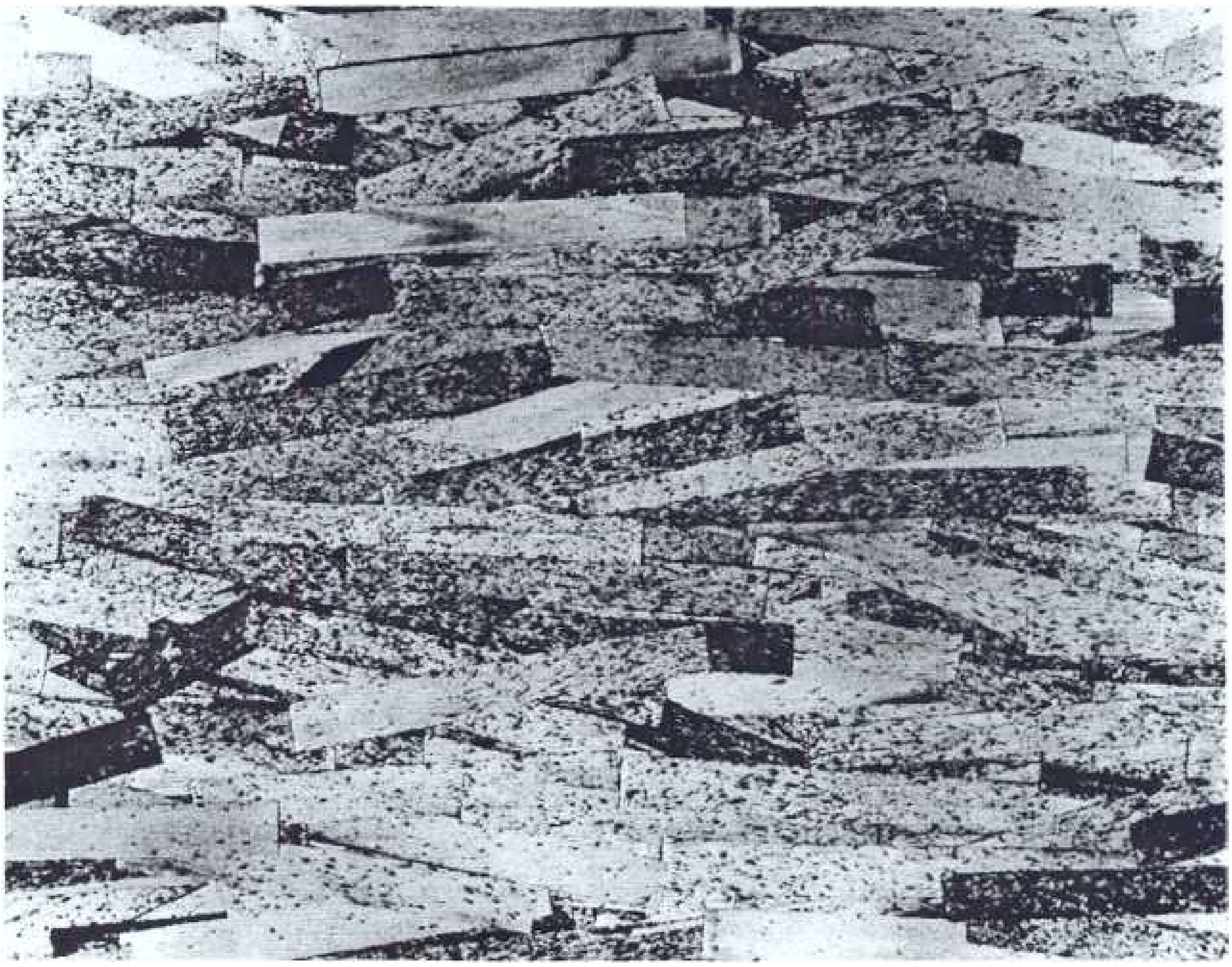

Figure 7.--Face and back layers of flakes are oriented in this structural exterior flakeboard intended to compete in price and function with sheathing grades of plywood. The board is 50 percent southern red oak, 25 percent hickory, and 25 percent sweetgum.

It is recognized that the flakeboard product contemplated will be slightly heavier than sheathing plywood, and that it will use more scarce phenol-formaldehyde resin (5 percent by weight compared to about 2.5 percent for plywood). It seems to me, however, that the compelling economic advantages listed above far outweigh the presently discernible disadvantages.

I predict that this new board--and its close relatives, the fiberboards--are going to change wood procurement patterns in the South over the next 10 years to the same degree the chipping headrig changed patterns during the last 10 years.

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