Shaping-Lathe Headrig Will Convert Small Hardwoods into Pallet Cants Plus Flakes for Structural Exterior Flakeboard

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Abstract

Virtually all nations have an under-utilized resource of small-diameter, low-grade hardwoods of mixed species in a range of densities. The shaping-lathe headrig, now in the final stages of commercialization, is a key to utilizing these hardwoods for pallets, industrial lumber, and—with further development—railroad crossties. Lathe residues in the form of flakes can be the raw material for a new major industry manufacturing structural exterior flakeboard competitive in price and function with sheathing grades of plywood. In an eight-hour shift, a single shaping-lathe headrig will convert 51 tons of barky hardwood bolts (at 40 lbs per ovendry cubic ft) into cants containing 12,500 board ft of 7/8-in. thick pallet lumber, plus sufficient flakes for 19,200 square ft (18.1 tons) of 1/2-in. structural flakeboard plus 11.2 tons of residues in the form of bark, sawdust, and panel trim (ovendry weight basis). These data assume that the headrig processes 2,400 bolts during an 8-hour shift. A 3-shift operation utilizing two such lathes appears to be economically feasible.

Small, low-grade hardwoods of mixed species and densities have for decades posed a utilization problem to foresters and to wood-consuming industries of the world.

Typical of the world-wide problem is that of hardwoods growing in the southern United States on land better suited for pines. Such trees have generally been uneconomical to harvest; and to destroy them during site preparation for pine plantations is expensive, whether attempted by bulldozing, chaining, or chemical applications. This paper, and the three that follow in these *Proceedings* (Hse, Hse et al., Price), describe a utilization system that has promise of converting these hardwoods from liability to asset and at the same time easing site preparation for succeeding plantations.

The Resource

The economic importance of the southern pine resource is well recognized. By the end of the century these pines—which grow on 138 million acres in the twelve southern states—will yield over half the softwood cut in the United States.

Less well recognized is the magnitude of hardwood volume on the very same acres. Forest Survey data show that, for every cubic ft of southern pine growing, there exists about 0.8 cubic ft of hardwoods on the same sites. Total volume of pine-site hardwoods is about 54 billion cubic ft (Murphy and Knight 1974). This volume is increasing (12% over the last decade), with annual growth exceeding removals by 71% (Sternitzke 1974).

Forest Survey data for Alabama, Louisiana, Oklahoma, and Texas indicate that the volume is in 22 species, of which half are oaks (Table 1). Probably much the same situation prevails Southwide. On an average, the trees are slow-growing, with stems 6 to 8 in. in dbh predominating. Figure 1 illustrates a stand on easy terrain in central Louisiana. Mountain sites and more scattered stands present harder tasks to the converter.

Over the years, countless attempts to use pine-site hardwoods have been thwarted by the diversity of species, scattered occurrence of trees, smallness and shortness of boles, branchiness of crowns, and prevalence of knots. Further, most species have a wood specific gravity about 15% greater than that of southern pine, and hence it is difficult to make reconstituted panel products whose weight does not exceed that presently acceptable to the trade.

Recent demand for paper, however, has given great impetus to whole-tree chipping of mixed hardwoods to yield barky chips for southern pulpmills. This development will substantially increase drain on the hardwood resource.

Simultaneously, demand has increased for hardwood pallets and for roof sheathing panels. Weight for weight, lumber and structural panels are worth several times more than pulp chips. It therefore seems logical that tree portions that can be converted to such products should be so converted, with the remainder going to a chipper. This has been the course of development in the southern pine industry (Koch, 1967a, 1968, 1972) and will likely be the course for hardwoods if a newly developed shaping-lathe headrig (Koch 1974a,b) proves as workable as it appears.

Shaping-Lathe Headrig Prototypes

Chipping headrigs used in the conversion of southern pine cut in 90-0 and 90-90 modes (Figure 2) are best applied to logs that are 8 ft or more in length and have no pronounced butt

Table 1. Hardwood species predominating on southern pine sites and their volume
Alabama, Louisiana, Texas, Oklahoma, 1963-1965.*

Species	Million cu ft	Percent	Cumulative percent
Sweetgum (*Liquidambar etyraciflua* L.)	2,329.1	21	21
Hickory, true (*Carya* spp.)	1,155.8	10	31
Black tupelo (*Nyssa sylvatica* Marsh.)	1,049.0	9	40
Post Oak (*Quercus stellata* Wangenh.)	984.8	9	49
Southern red oak (*Q. falcata* Michx.)	969.1	9	58
Water oak (*Q. nigra* L.)	942.0	8	66
White oak (*Q. alba* L.)	912.1	8	74
Yellow-poplar (*Liriodendron tuliperifera* L.)	422.1	4	78
Sweetbay (*Magnolia virginiana* L.)	325.0	3	81
Black oak (*Q. velutina* Lam.)	292.9	3	84
Cherrybark oak (*Q. falcata* var. *pagodaefolia* Ell.)	276.1	2	86
White ash (*Fraxinus americana* L.)	241.1	2	88
Green ash (*F. pennsylvanica* Marsh.)	186.1	2	90
Red maple (*Acer rubrum* L.)	167.4	1	91
American elm (*Ulmus americana* L.)	167.2	1	92
Winged elm (*U. alata* Michx.)	159.2	1	93
Hackberry (*Celtis* spp.)	135.3	1	94
Northern red oak (*Q. rubra* L.)	122.8	1	95
Scarlet oak (*Q. coccinea* Muenchh.)	92.5	1	96
Shumard oak (*Q. shumardii* Buckl.)	82.1	1	97
Laurel oak (*Q. laurifolia* Michx.)	75.9	1	98
Blackjack oak (*Q. marilandica* Muenchh.)	?	1	99

*Data compiled by Forest Resources Research Work Unit, Southern Forest Experiment Station, Forest Service–USDA, New Orleans, Louisiana.

Figure Small, Slow-Growing Hardwoods Occupy Millions of Southern Acres That Would Be More Profitable if Converted to Pine. The New Shaping-Lathe Headrig Will Facilitate Such Conversion by Creating Markets for the Hardwoods.

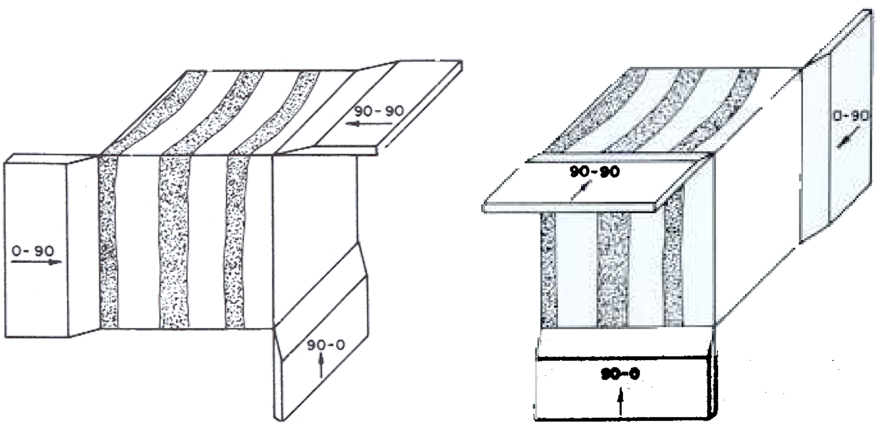

Figure 2. Designation of the Three Major Machining Directions. The First Number Is the Angle the Cutting Edge Makes with the Grain, the Second Is the Angle Between Cutter Movement and Grain.

swell, crook, or sweep. Products are cants to be resawn into structural lumber and pulp chips from the peripheral wood. The cants characteristically display some torn grain around knots.

A prototype headrig cutting in the 0-90 mode was first demonstrated more than 10 years ago (Koch 1964, 1967b) and now nears commercial application (Koch 1974a). Operating on the principle of a shaping lathe, it is particularly adapted to short logs of irregular contour, since it relies for workpiece position on end chucks rather than on through-feed chains or rolls. Smoothness of the machined surfaces approaches that of millwork. In contrast to other headrigs, this version can readily produce rounds, hexagons, octagons, and trapezoids as well as square or rectangular cants. Thus it lends itself to the manufacture of pallet parts and other industrial lumber, together with posts and rails for fencing. Moreover, its residue is veneer-like particles well adapted for use in structural flakeboard. Such flakes are commonly 2 to 3-in. long, 0.015 to 0.045 in. thick, and perhaps 3/8-in. wide. Structural exterior flakeboard is being test-marketed and appears likely to compete effectively with sheathing grades of plywood. It is currently manufactured from softwoods and aspen (*Populus* spp.), but research indicates it can be made from mixed southern hardwoods.

The original prototype established the principle of the shaping-lathe headrig. A second prototype was constructed in 1973, under contract with Stetson-Ross of Seattle, Washington, to provide detailed information necessary to the design and construction of a commercial machine (Koch 1974a). This model is capable of chucking a bolt 12 in. in diameter and 6.5 in. long (Figure 3). Bolts are clamped in the chucks of the workpiece spindle, which turns at about 15 rpm. Attached to the spindle is a replaceable cam having the shape and dimensions of the desired cant. The cam rotates and moves with the workpiece (bolt) until it strikes a follower aligned with the cutterhead. The center distance between cutterhead and workpiece changes in response to the cam, and in a single revolution the workpiece is machined to the shape and dimensions of the cam. Since the bolt makes only a single revolution while being sized, machining time is brief—about 4 seconds.

Testing of the 1973 prototype showed that flaking heads yield cants with excellent surface quality and dimensional accuracy. Up-milling is more practical than down-milling. Water-soaked wood cut at 160°F required 5.5% less net cutterhead power than green wood at 72°F. Net specific cutting energy showed positive linear correlation with wood specific gravity and negative correlation with flake thickness (Figure 4). For up-milling of hot and cold loblolly pine, sweetgum, hickory, and southern red oak, it averaged 9.92 horsepower minutes per cubic ft of wood removed as flakes (pooled data for flake thickness of 0.015, 0.025, and 0.035 in.).

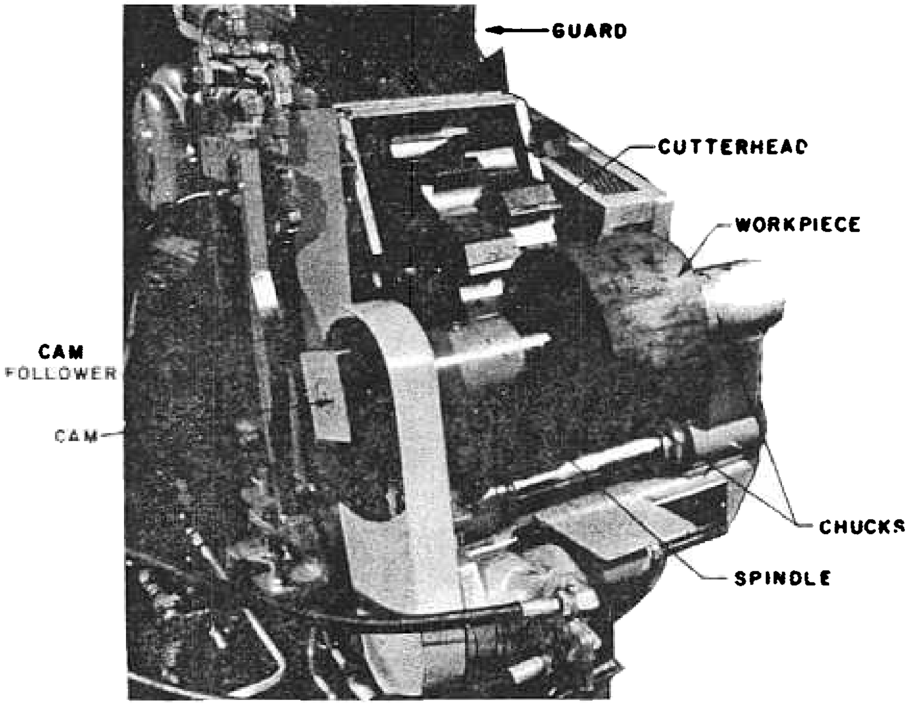

Figure 3. Second Prototype of Koch Shaping-Lathe Headrig with 10-Knife Flaking Cutter in Place. Cam Is 4 in. Square. The Bolt, When Machined, Will Also Measure 4 in. Square.

Commercial Shaping-Lathe Headrig

The first commercial version of the shaping-lathe (Figure 5) underwent preliminary tests in February 1975. It carries a 54-in.-long, 12-slot cutterhead with 12-in. cutting circle. To minimize power requirement and enhance flake quality, rake angle of knives is large—43°. Clearance angle, at 5°, is considered the minimum to avoid undue interference with the workpiece. The resulting sharpness angle of 42° yields a cutting edge moderately resistant to nicking. Flake length of 3 in. is established by notching each knife so that 3-in. long cutting edges alternate with 3-in. non-cutting zones. Alternate knives cut zones left uncut by immediately preceding knives. The cutterhead is turned at 3,600 rpm by a 300-hp motor designed to momentarily carry a 200% overload without pullout from synchronous speed.

To manufacture 0.015-in.-thick flakes with this head (6 knives cutting) rotating at 3,600 rpm, average cutterhead demand is about 267 hp when green, unheated hardwoods of 0.75 density, 12-in. diameter, and 53-in. length are being machined into 8-by 8-in. cants. Peak demand, at a maximum cutting depth of 3 in., is about 510 hp.

The workpiece is driven from one end with a 3-hp, variable-speed motor that provides rotational speeds in the range from 9 to 27 rpm. One-and-one-half horsepower net delivered to the workpiece spindle is sufficient to turn the bolt against peak forces exerted by the cutterhead.

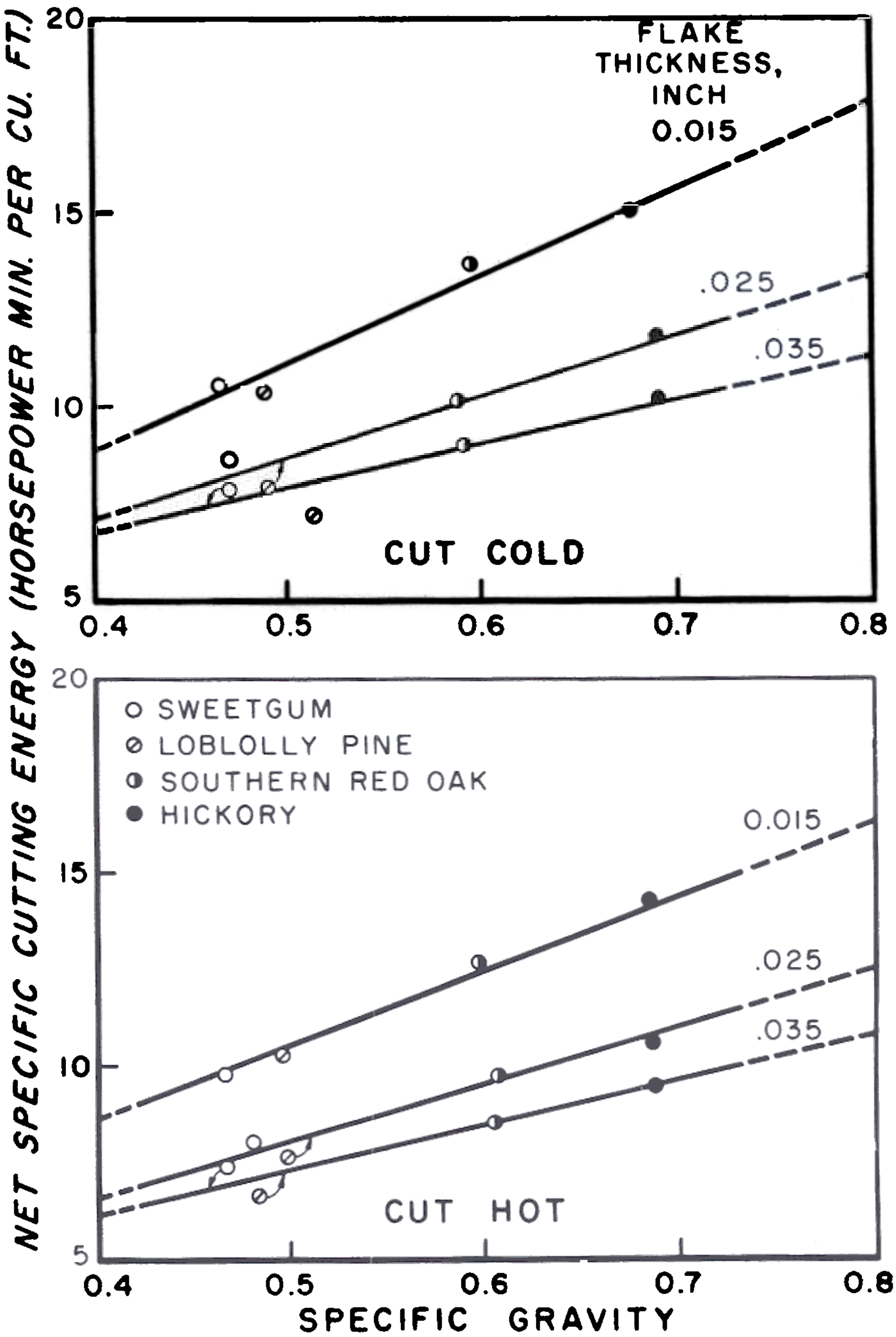

Figure 4. Regression of Specific Cutting Energy on Wood Specific Gravity (Basis of Ovendry Weight and Green Volume) for Wood Cut at 72°F (Top) and 160°F (Bottom). Plotted Points Are Averages for the Species Named.

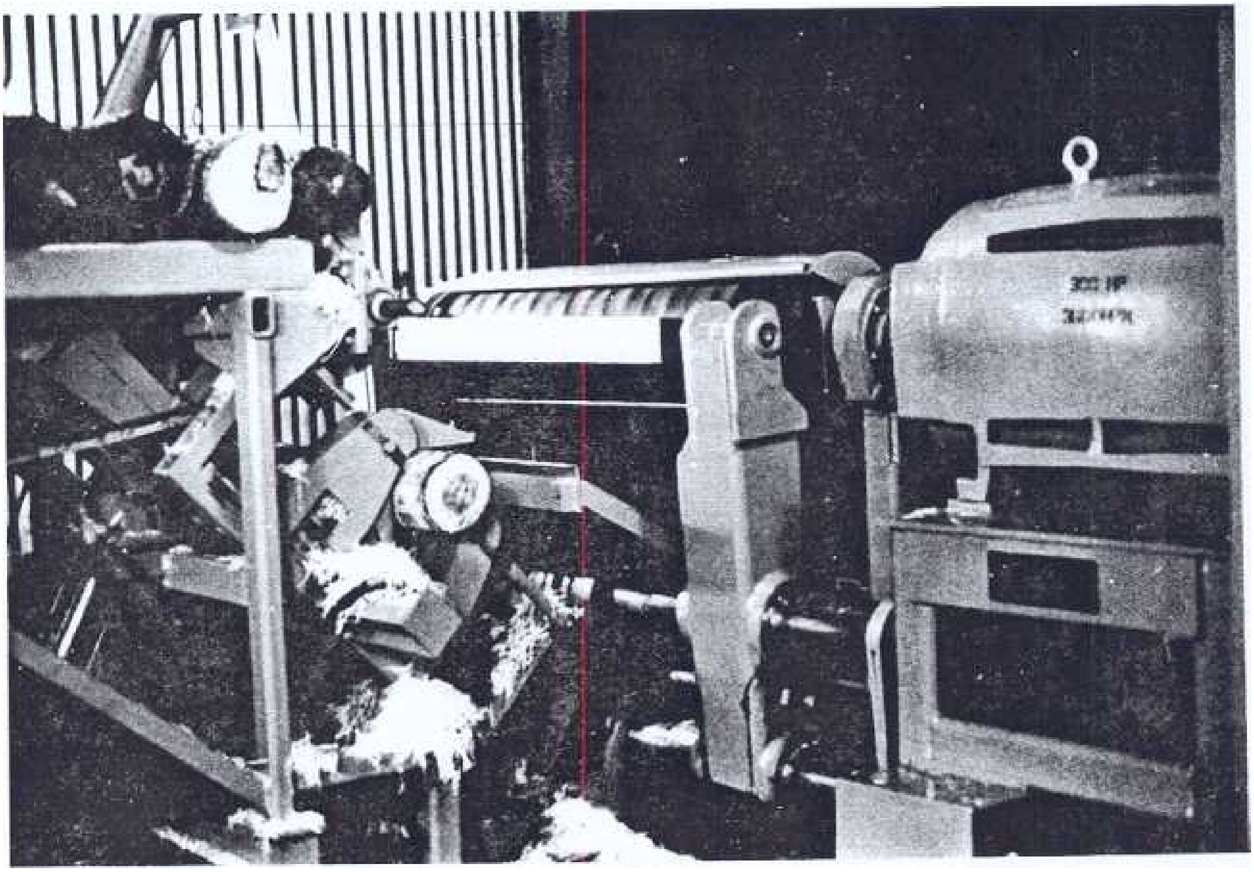

Figure 5. Commercial Version of the Shaping-Lathe Headrig, Including Log Deck, Centering Device, Charger, and Takeaway Conveyor for Machined Cants. Flakes Are Blown from the Cutterhead Hood for Conveying to Flakeboard Plant. Design Feed Rate Is Six Logs per Minute. Smoothly Machined Cants Have the Shape and Dimensions of Replaceable Cams Mounted on the Workpiece Spindle. The 40 in.-long 4- by 4-in. Cant Illustrated Has Been Completely Machined and Is Poised Just Prior to Chuck Withdrawal and Discharge to the Takeaway Belt. (Photo from Stetson-Ross, Seattle.)

Bolt deflections in bending and torsion are not serious when cants have diameters above 6 in. But if bolts are highly eccentric (for example, if 3-in.-deep cuts are needed to make 4-in.-round posts), bending deflections may be as much as 1/16-to 1/8-in., and torsional deflection may be 2 degrees.

The headrig will accept bolts 4 to 12 in. in diameter in lengths from 40 to 53 in. (Figure 6). Since the log needs to make only a single revolution to be sized, machining time is a brief 4 seconds. With semi-automatic log centering and charging, the lathe processes six logs per minute.

The February trials demonstrated the practicality of the 54-in. design. After incorporation of some design revisions, final trials will be held in late summer 1975, and then the machine will be placed in commercial operation.

Figure 6. Oak, Hickory and Sweetgum Bolts 40 to 53 in. Long and 4 to 12 in. in Diameter Piled in Readiness for Conversion to Cants and Flakes During Trials of the Commercial Shaping-Lathe Headrig.

Products

The shaping-lathe headrig can be central to manufacture of several products such as pallet cants, posts, rails, crossties, and structural exterior flakeboard.

Pallet Cants, Posts, Rails, and Crossties

As previously noted, the headrig can readily make rounds, hexagons, or trapezoids as well as square or rectangular cants, according to the shape of cam used on the setworks (Figure 7). Such solid-wood products, when machined with a flaking head, have surfaces approaching millwork in quality (Figure 8) and can be distinguished by faint circumferential traces across the grain at ends of knife segments which determine flake length.

The headrig should find its primary application in the manufacture of industrial wood parts—particularly cants for pallet deckboards and stringers. Figure 9 illustrates opportunities 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; blocking; and industrial end-grain flooring, will doubtless occur to the reader.

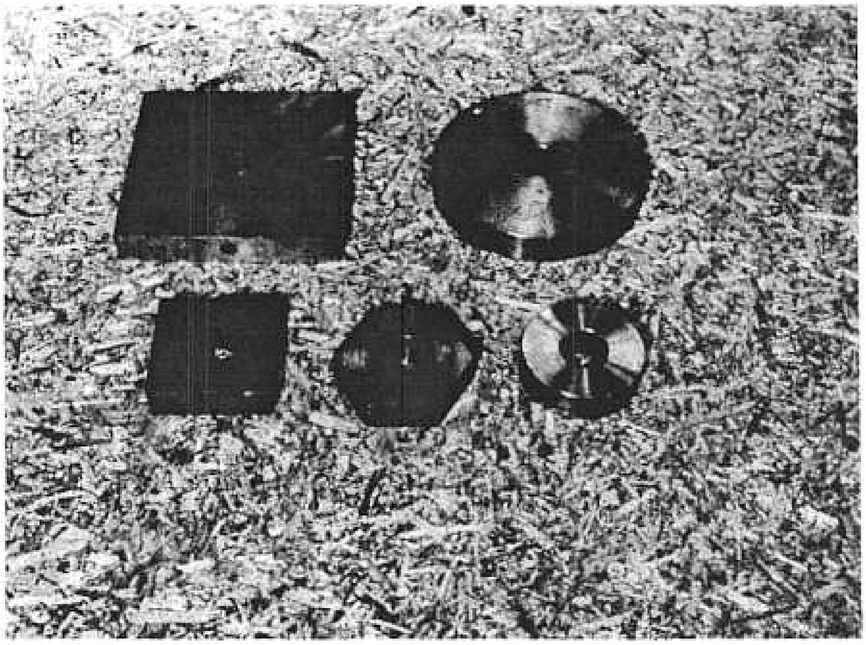

Figure 7. Typical Cams for the Shaping-Lathe Headrig. The Largest Is 8 in. Square, and the Smallest Is 3 in. in Diameter.

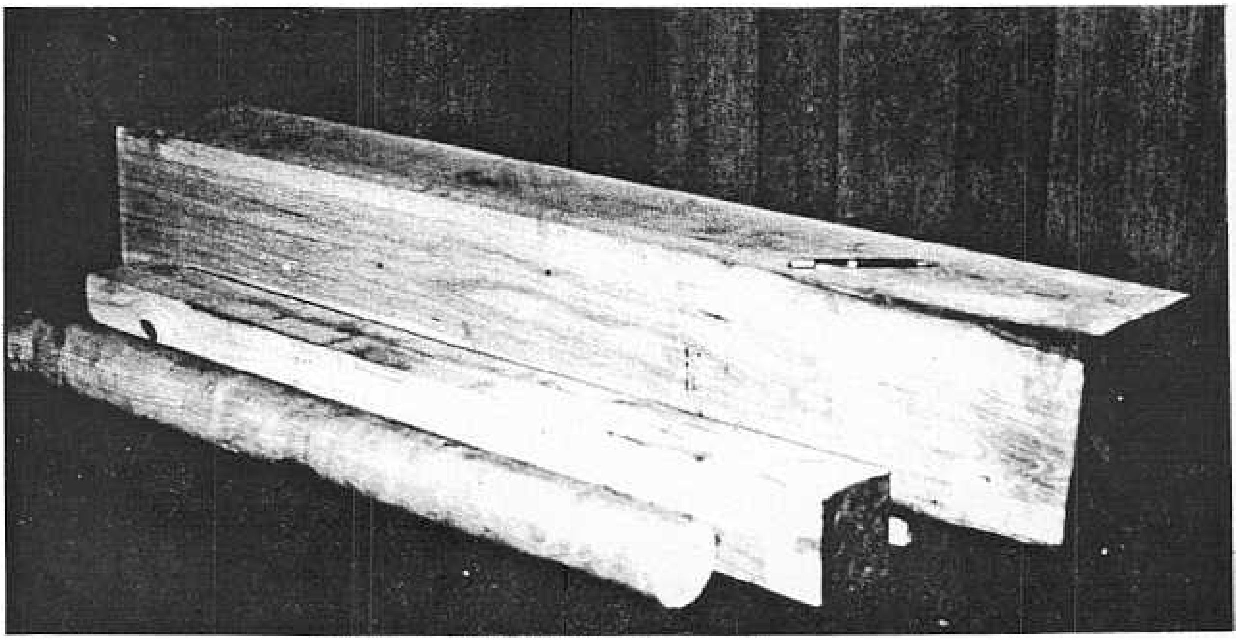

Figure 8. Cants Made During Trials of the Commercial Model. The Large Cant Is White Oak and Measures 8 in. Square and 53 in. Long. The Dowel Is Southern Pine and Is 3 in. in Diameter. Cants May Be Rectangular, Octagonal, Trapezoidal, or Triangular As Well As Square or Round. Because Knives Cut in the Veneer Direction and Take Shallow Cuts, Cant Surfaces Are Smoothly Machined with No Tearout Around Knots.

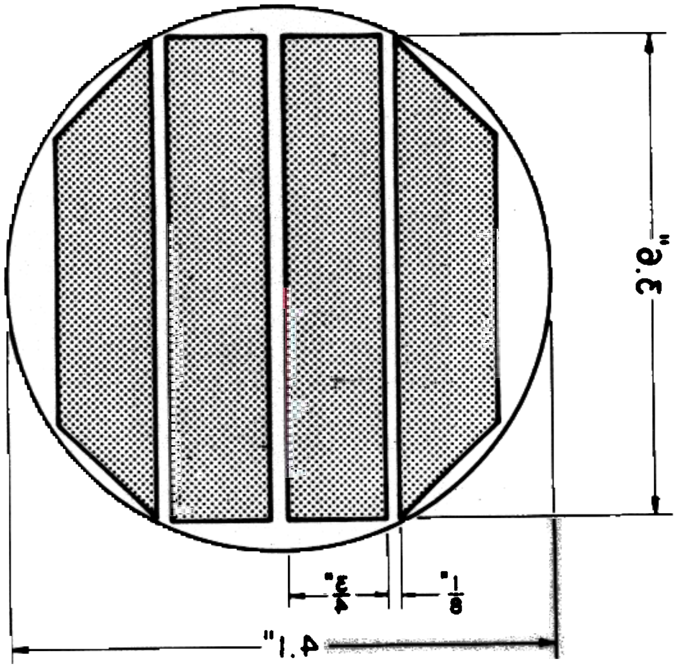

Figure 9. Sawing Pattern Whereby Square-Edged Pallet Deckboards Can Be Ripped from the Central Portion of Octagonal Cants, and Bevel-Edged Deckboards Cut from Outer Portions. By this Pattern, Lumber Recovery Can Be As Much As14 Board Ft per Cubic Ft of Log.

Extension of the machine to handle crossties 8-1/2 ft long would not be difficult, but few firms can log the 2,000 daily tie cuts required to keep the machine occupied. Should crossties steel-doweled from pairs of 4.5- by 7-in. cants be proved feasible, a shaping-lathe headrig could economically make such cants from logs 8.4 in. in diameter (Howe 1975).

Structural Exterior Flakeboard

A major potential for the lathe lies in its ability to cheaply produce, as a residue, large tonnages of veneer-like flakes measuring perhaps 3 in. long and 0.015 in. thick (Figure 10). With the addition of about 5-1/2% of phenol-formaldehyde resin, these flakes can be manufactured into a structural exterior flakeboard that should compete in function with sheathing grades of plywood. Price competitiveness of flakeboard sheathing will depend on future supplies and pricing of the required resin.

Experiments have been conducted (Hse et al 1975) to develop such a board in 1/2-in. thickness. The design settled on is comprised of equal-weight portions throughout of *Carya* spp., *Quercus alba* L., *Quercus falcata* Michx., *Liquidambar styraciflua* L., and southern pine (e.g., *Pinus taeda* L.). These species were cut with a shaping-lathe headrig to yield face flakes 0.015 in. thick and core flakes 0.025 in. thick. All flakes were 3 in. long; those used in the core were reduced in width by milling. Phenol-formaldehyde binder (5.5%) was blended with flakes initially at 4% moisture content. Just prior to pressing, the mat was water-sprayed on both sides. Press

Figure 10. Upmilled Flakes 0.015 in. Thick and 3 in. Long Cut from Sweetgum (Top), Southern Red Oak (Center), and Hickory (Bottom) Soaked in Water at 72°F (Left) and 160°F (Right). The Flakes Have Near Optimum Dimension for Manufacture of Structural Exterior Flakeboard.

time was 5 minutes (including 45 to 60 seconds to close press against stops) at 335°F. All panels had random flake orientation in the core; half had random faces (Figure 11); the other half had faces of aligned flakes. Properties observed in 18-in.-square panels at 50% relative humidity were:

	Face flake orientation	
	Random	Aligned
Density (lbs per cubic ft)	47.5	45.5
Internal bond strength (psi)	83	82
Modulus of elasticity (psi)	800,000	1,090,000
Modulus of rupture (psi)	5,300	6,625

It is believed that commercially manufactured panels can be made to approximate these properties, except that modulus of elasticity of the random board may drop to near 700,000 psi.

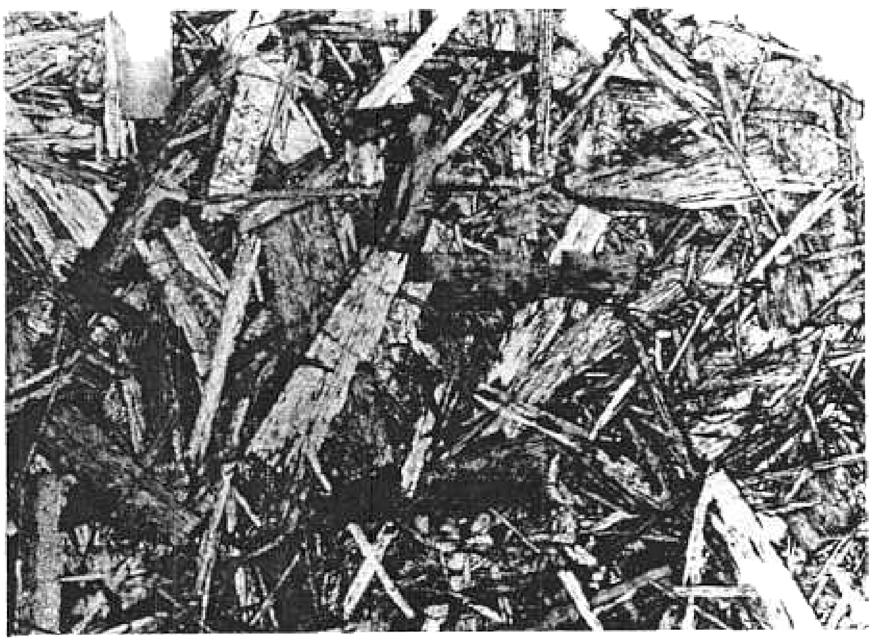

Figure 1 Three in. Long Flakes Are Randomly Oriented Throughout This 1/2-in. Thick 3-Layer Structural Exterior Flakeboard Intended to Compete in Price and Function with Sheathing Grades of Plywood. The Board Is Comprised of a Mixture of Five Species in Equal Weight Proportions (White Oak, Red Oak, Hickory, Sweetgum, and Southern Pine). Face Flakes Are 0.015 in.Thick and Core Flakes Are 0.025-in. Thick.

Process Raw Material Balance

Figure 12 illustrates raw material balance in the process under development. On the basis of ovendry weight, a ton of barky roundwood should yield about 0.45 ton of 7/8-in.-thick pallet lumber, 0.354 ton of sized panels of structural exterior flakeboard for sheathing, and 0.22 ton of fuel in the form of bark, sawdust, fines, and panel trim. These tonnages include board components of 0.02 ton of phenol-formaldehyde resin and 0.004 ton of wax (added to increase board stability during brief changes in relative humidity).

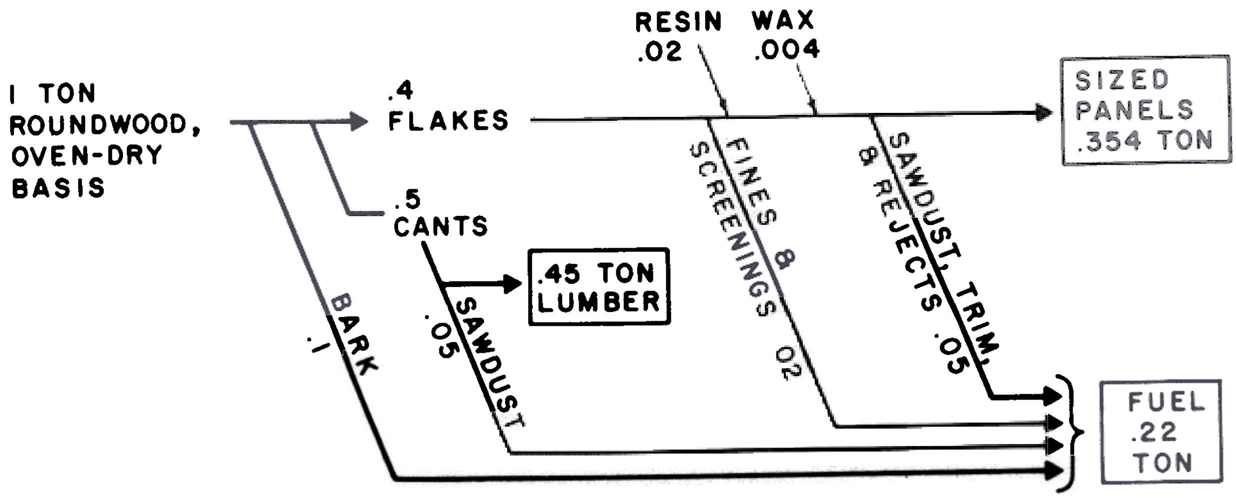

Figure 12. Material Balance (Basis of Ovendry Weight) for Structural Exterior Particleboard Made from Mixed-Species Flakes Cut on a Shaping-Lathe Headrig.

It follows that one ton of barky roundwood will yield 375 square ft of 1/2-in. structural flakeboard weighing 45.3 lbs per cubic ft (both on the basis of ovendry weight). Additionally, the roundwood will yield 242 square ft of 7/8-in.-thick lumber (ovendry weight of 40 lbs per cubic ft of wood is assumed).

Productivity and Economics

Minimum economic plant size for the manufacture of 1/2-in. flakeboard is debatable. For discussion purposes, an output of 109 tons of board (ovendry basis) per 24 hours is assumed. It corresponds to 151 4- by 8-ft panels per hour or 6.3 press loads per hour for a 6-opening 8- by 16-ft press. This rate of production could be satisfied by flakes from two shaping-lathe headrigs operating three shifts per day on mixed hardwoods if: (1) bolts average 4 ft long, 7 in. in diameter outside bark, and have an ovendry weight of 40 lbs per cubic ft, and (2) each lathe turns out 6 bolts per minute for 400 minutes in each of three shifts per 24 hours.

Input would be 15,408 cubic ft, or 308 ovendry tons, of barky boltwood per 24 hours. Output would be 115,000 square ft, or 108.5 ovendry tons, of 1/2-in. flakeboard plus 74,500 square ft of 7/8-in. rough lumber for pallets and 67.8 ovendry tons of fuel. This amount of fuel is more than enough to generate the thermal, electrical, and mechanical energy required to run the plant.

As is commonly the case in board manufacture, it is proposed that the plant operate 7 days per week and 50 weeks per year, i.e., 350 operating days per year. Under these conditions, annual sales of flakeboard for sheathing (at $120 per thousand square feet, 1/2-in. basis) will be $4,851,000, and lumber sales will amount to $3,234,000 (at $124 per thousand board ft). Annual sales could therefore total $8,085,000.

Raw material could annually cost $2,156,000 if cordwood is acquired at $20 per ovendry ton. Phenol-formaldehyde resin, at $0.30 per lb, will annually cost $1,293,600. Wax, at $0.125 per lb, will cost $107,800. Raw material costs therefore total $3,557,400 per year.

If it is further assumed that capital investment in site, plant, and depreciable equipment is $7,000,000, that each shift is manned by 35 laborers, and that supervisory salaries plus all overhead charges (except depreciation) are equal to the labor charge, then the annual statement would be about as follows:

Gross annual sales (after discounts and commissions)		$8,085,000
Annual expenses		
Raw material	3,557,000	
Labor: 35 men per shift x 3 shifts 7 days/week, 50 weeks per year at $4.50/hour including fringe benefits	,323,000	
Overhead	,323,000	
Depreciation	700,000	
		6,903,000
Profit before taxes		$1,182,000

The indicated profit of $1,182,000 after depreciation but before taxes amounts to a return of 16.9 percent on total plant investment. While the assumed prices for sheathing and pallet lumber are unobtainable on today's market (April 1975), they may be considered as likely averages over the next decade.

The assumed roundwood cost of $20 per ovendry ton amounts to perhaps $30 per cord. At this price, it is possible that 3-man teams using bobtailed trucks could be trained to supply the mill with bolts cut accurately to length. With productivity of 10 cords per team per day (15 ovendry tons per day), only 20 such teams would be needed. As capital equipment for each such team is low (about $5,000) the total investment for harvesting might be only $100,000.

Conclusions

All countries in the world need crossties for railroads, lumber for industry and homes, and an economical exterior structural panel for building and industrial uses. Further, nearly all have a presently under-utilized resource that can be the basis of a new industry to supply these needs—small-diameter, low-grade hardwoods of mixed species and densities.

Traditionally, nations seek basic industries that can be internally supplied with raw materials. And today, all nations seek industry that is self-sufficient in energy. The manufacturing system proposed in this paper essentially satisfies these two requirements. Moreover, it takes an insignificant amount of water and need cause no pollution.

Additionally, each manufacturing facility takes only a moderate amount of capital (less than $10,000,000 when inventories and working capital are included) and employs about 120 people. Factory locations might well be rural. Harvesting wood from the surrounding countryside need not be capital-intensive; as little as $5,000 per 3-man producing team might suffice. Approximately 20 such teams could supply the factory.

Finally, only moderate industrial sophistication is required to operate the industry.

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