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Peter Koch. Part I.—Key to utilization of hardwoods on pine sites: the shaping-lathe headrig. For. Ind. 103(11): 48-51.

Part II.—New approaches, new machines to utilize hardwoods on pine sites. For. Ind. 103(12): 22-25.

Part III.—All processes to utilize hardwoods on pine sites can be combined. For. Ind. 103(13): 24-27.

EDITOR'S NOTE: This is Part I of a series encompassing the report and talk given by Dr. Peter Koch, Chief Wood Scientist, Southern Forest Experiment Station, USDA Forest Service, Pineville, Louisiana, at the 1976 Sawmill Clinic in New Orleans in June. The subject is biomass recovery and utilization with shaping-lathe headrigs. Dr. Koch designed the shaping-lathe headrig and the first unit is now installed in a West Virginia mill. The utilization is keyed basically to conversion of hardwoods found growing on pine sites in the South.

PART I

Key to utilization of hardwoods on pine sites: the shaping-lathe headrig

EVIDENT, as we approach the end of the century, are several long-term trends in the forest resource. Chipping headrigs and other continuous-feed slabbing systems have enabled sawmillers to convert smaller and smaller logs into lumber. Development of this technology, which has been exploited in western and northern mills as well as southern, was well timed since logs harvested throughout the commercial softwood forests of North America are getting smaller with

each passing year. This long-term trend will likely continue.

Southern pines. The emerging dominance of small logs is evident in the southern pine resource in Alabama, for example. T. R. Dell, biometrician for the Southern Forest Experiment Station, analyzed diameters of logs extractable from existing pine stands in this state (see accompanying table opposite) and the manuscript of his study is in prep-

aration. Although data are for Alabama, proportions would probably be similar throughout the South.

Western forests have dominated the scene in recent decades, but the economic importance of the southern pine resource is increasing. By the end of the century, these pines—which grow on 138 million acres in the 12 southern states—will yield half the softwood cut in the United States. Trends evident in southern pine, therefore, significantly affect the national situation. Moreover, knowledgeable people in industry readily confirm that diameters of logs harvested from western forests are also steadily decreasing.

OVERVIEW

IN PAST YEARS, only 30% of southern pine biomass (above- and below-ground parts) ended as primary product. Moreover, hardwoods on pine sites were, and in many cases still are, destroyed with no thought of utilization. Now, however, processes have been invented that can raise utilization of each tree—pine and hardwood on pine sites alike—to 67% of total biomass, thereby increasing product yield fourfold.

These processes are built around the *shaping-lathe headrig*. Products include cross-ties, pallets, studs; long, wide structural lumber laminated from ¼-in. veneer, and structural exterior flakeboard to compete in price and function with sheathing grades of plywood.

Reasons for seriously considering the proposed processing system are:

- The raw material is presently underutilized and is available in many Southern and Eastern locations.
- The system is self-sufficient in energy.
- Markets for the products should be strong.
- The manufacturing processes are simple.
- Degree of utilization of the wood resource is high.
- The processes have minimal water demand.
- The processes are non-polluting.
- Ecologically and silviculturally, the processing cycle is sound.
- Raw material feeding the system will be regenerated at an expanding rate.
- The system appears capable of alleviating impending national shortages of sheathing, long, wide structural lumber, crossties, and pallets.
- The intensive utilization proposed should yield reasonable net return to the landholder, thereby encouraging increased production from presently poorly managed private non-industrial woodlands in the South.
- Long-term practice of the system would not necessarily lead to a pine monoculture but could result in substantial mixed-species upland forests.

Preliminary computations indicate that generous net returns to landholders (e.g., \$23 per acre per year) need not result in excessive stumpage costs. Since adequate economic return to non-industrial landholders is the key to expanding forest area under intensive management, the concept appears to warrant further economic analysis. Needed is an estimate of capital costs for harvesting equipment and manufacturing plant. Work is underway to assemble these data on capital requirements as well as other data on manufacturing costs.

Hardwoods. Total volume of pine-site hardwoods is about 54 billion cu ft (Murphy and Knight 1974). This volume is increasing (12% over the last decade), and annual growth exceeds removals by 71% (Sternitzke 1974).

Forest Survey data for Alabama, Louisiana, Oklahoma, and Texas indicate the volume is in 22 species, of which half are oaks. Probably much the same situation prevails Southwide.

Over the years, countless attempts to use pine-site hardwoods have been thwarted by 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 use them for reconstituted panel products and other products commonly made from southern pine. Therefore, most of these hardwoods are destroyed during site preparation for subsequent pine crops. Not only is this destruction costly (perhaps \$85 per acre), but bulldozing of topsoil during typical pile and burn operations dimin-

LOG DIAMETER MIX-ALABAMA

Small-end diameter class	Numbers of logs falling in class	Volume in class (calculated as cylinders)
Inches	Percent	
5.0-6.9	72.1	36.2
7.0-8.9	13.8	20.2
9.0-10.9	7.2	16.0
11.0-12.9	3.8	12.0
13.0-14.9	2.5	10.9
15.0-16.9	.6	4.7
	100.0	100.0

Biometrician T. R. Dell's analysis of Alabama stands indicates that if all pines 6 in. in diameter and larger were cut in 6- to 16-ft lengths to a minimum small-end diameter inside bark of 5 in., log diameter mix would be as shown in this table.



For every foot of southern pine growing, about 0.8 cu ft of hardwoods grows on the same sites. Generally, the trees are small and slow-growing, with stems 6 to 8 in. d.b.h. Many stands are on flat, easy terrain; others are on less easily logged mountain sites.

ishes soil productivity significantly on some sites.

To design conversion systems that will accommodate the entire resource—softwoods and hardwoods alike—knowledge of trends in demand is essential.

Wood demand to rise

Housing. In spite of the 1974-1975 slump in the housing industry, most economists anticipate a rising demand for houses toward the end of the century and particularly in the 1980's. For example, *The Outlook for Timber in the United States* (USDA Forest Service 1973, p. 156) estimates that by 2000 the nation will be building 2,560,000 units (single and multi-family units plus mobile homes). Marcin (1975) concludes that from 1980 through 1989 total annual

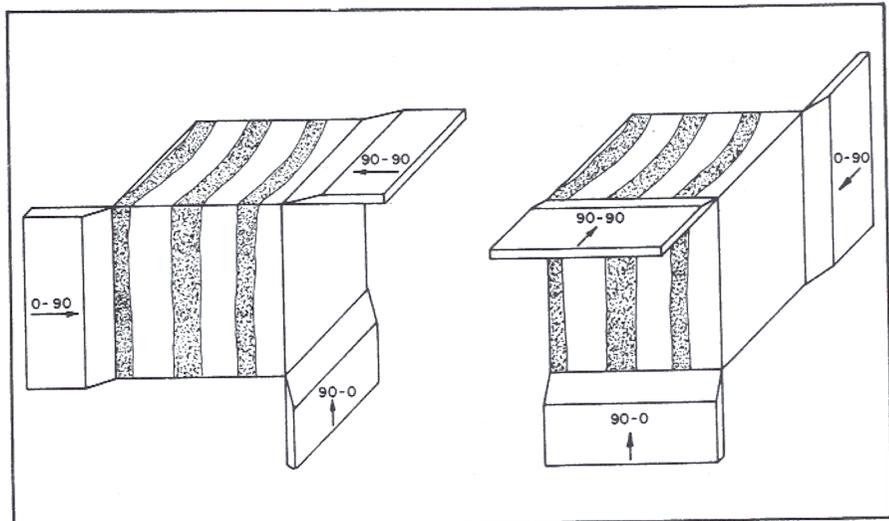
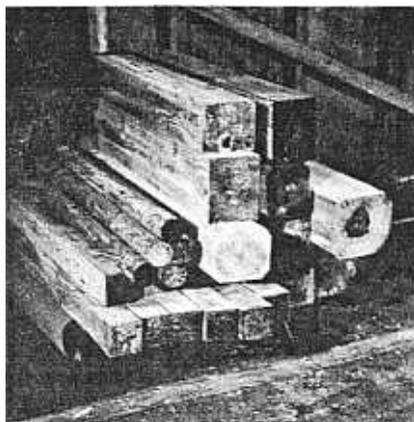
production will average between 2,110,000 and 2,563,000 units. These predictions are substantially above the rate of housing starts from 1960 to 1969, which averaged 1,648,700 units annually, and somewhat above the level for 1970 through 1972, which averaged 2,468,570 units annually.

As the housing industry revives, demand for joists, rafters, studs, and sheathing will recover from 1975 lows and during the decade 1980-1989 will equal or surpass peak demands recorded in the early 1970's. In preparing for this anticipated demand, it is useful to know something about likely product mix.

Of all southern pine lumber produced in 1974, 29% was random-length 2 x 4s; 23%, random-length 2 x 8s through

2 x 12s; 18%, random-length 2 x 6s; 16%, boards; 11%, studs; and 3%, timbers (Southern Forest Products Assn. 1975). The high percentage of 2 x 8s through 2 x 12s is the statistic of interest since it would be difficult to cut structural grades of lumber with a heavy percentage of such widths in desirable long lengths from the present resource—much less from the future resource. Also, softwood veneer for sheathing will likely be in short supply, and siding grades of softwood lumber will become scarce and expensive.

Pallets. Demand for wood in containers, dunnage, blocking, bracing, and especially in pallets has been rising sharply in recent years. In 1972 about 15% of all lumber cut in this country



Above: Fig. 1. There are three major machining directions. In the two-part numeral code relating to them, the first number is the angle the cutting edge makes to the grain and the second is the angle between cutter movement and grain (0-90; 90-90; 90-0). The shaping-lathe headrig cuts in the 0-90 mode, rather than in 90-0 or 90-90. **Left, above.** Typical cams for the headrig—the largest being 8 in. square, the round one 3 in. in diameter. **Left, below.** Selection of hardwood and softwood cants produced on the shaping-lathe headrig.

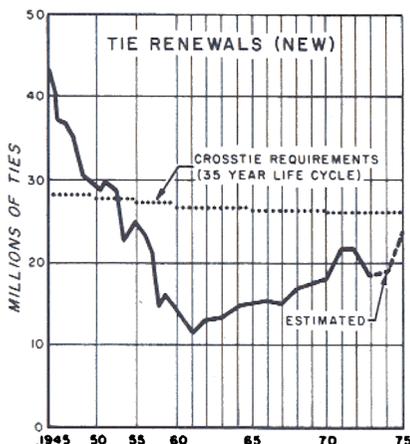


Fig. II. Railway data show the serious dimensions of the tie problem. Replacements diminished from 47 million during WW II to a low of 12 million in 1961. Only 25 million ties were expected to be installed in Class I railroads in 1975 (Anonymous 1975).

was consumed in pallets and containers. Substantial further increases in pallet demand are projected because of continued mechanization of materials handling and because of anticipated continuing industrial growth (Cliff 1973, p. 2-25, 2-26). Demand for hardwood pallets will increase beyond the ability of some regions to supply them.

Crossties. The nation's railroads must substantially increase their rate of tie renewals if roadbeds are to be properly maintained. A large percentage of the billion ties in the nation's roadbeds have deteriorated because they have been in place (Fig. II) longer than their 35-year normal service life. Moreover, axle loads are increasing with passing years, causing accelerated wear on crossties. For example, it is anticipated that heavily laden coal trains will be moving in increasing numbers from western mines to the industrial East.

Increased tie demand during the rest of the century therefore seems likely, but the supply of hardwood logs large enough to yield one-piece 7- by 9-in mainline ties will be limited and probably insufficient.

Meshing resource with demand

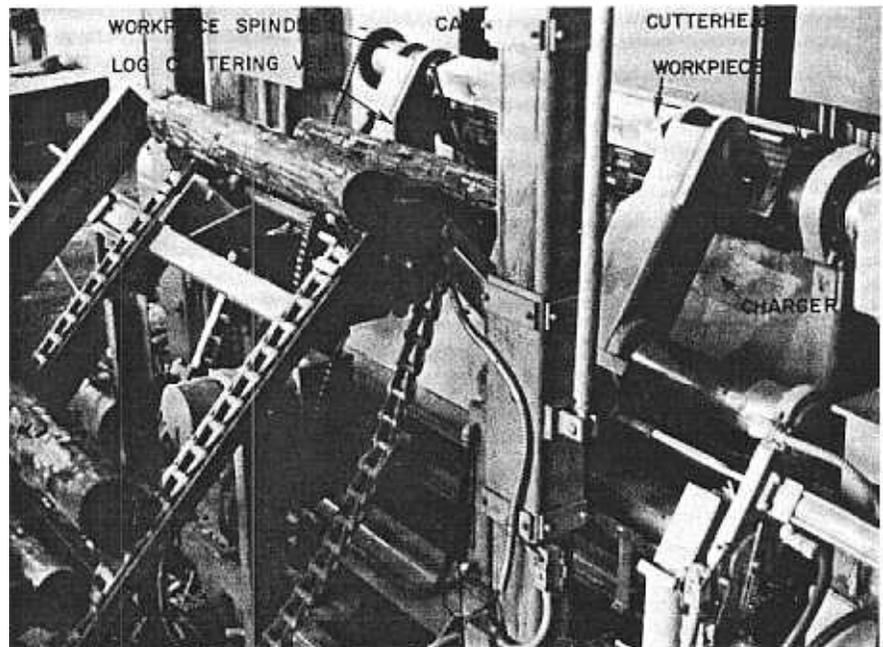
The problem, then, is to meet rising demands for wood products while faced with an increasing shortage of large logs of desirable species. An additional complication is rising cost and short supply

of energy. Solutions proposed here center around two processes: first, converting small hardwood logs into cants and flakes by means of the shaping-lathe headrig; and second, fabricating long lengths of wide dimension lumber from rotary-peeled veneer. To fuel the processes, new harvesting equipment will retrieve a greater proportion of tree biomass from the forest for combustion in improved burners.

Shaping-lathe headrig. In summer 1976, Hinchcliff Products Co., Parsons, West Virginia, placed in operation the first commercial shaping-lathe headrig—a machine based on a design conceived and demonstrated 13 years ago (Koch 1964, 1967a,b, 1968, 1974). The new headrig offers four main advantages over traditional chipping headrigs. It cuts in the 0-90 mode rather than in the 90-0 or 90-90 mode (Fig. I) and therefore produces a smoother machined surface than other headrigs. Operating on the principle of a shaping-lathe, it relies for workpiece position on end chucks rather than on through-feed chains or rolls; thus, it can accept short logs with butt swell, crook, or sweep while other headrigs

cannot. Unlike other headrigs, this version can produce rounds, hexagons, octagons, or trapezoids as well as rectangular cants because cant shape is determined by replaceable cams (See photo adjacent to Fig. I). Moreover, its residue is veneer-like particles well adapted for use in structural flakeboard.

In the West Virginia operation, the headrig cuts mixed Appalachian hardwoods, principally red and white oaks (*Quercus* spp.), and yellow-poplar (*Liriodendron tulipifera* L.). Bolts, previously sorted by diameter, are clamped in the chucks of the workpiece spindle, which revolves slowly. 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 until it strikes a follower aligned with the cutterhead. As the workpiece makes a single revolution, the center distance between cutterhead and workpiece changes in response to the cam, and the workpiece (log) is machined to the shape and dimensions of the cam. Since the log makes only a single revolution while being sized, machining time is brief—about 4 seconds. Feed rate is five to six bolts per minute.



The commercial version of the shaping-lathe headrig, installed at Hinchcliff Products, can handle logs 40 to 53 in. long and 4 to 12 in. in diameter. Key elements (arrows) are: lower left, log deck and unscrambler; upper left, log centering vee and workpiece spindle; center top, cam; upper right, workpiece, cutterhead and charger; lower center, take-a-way belt.

The 54-in-long cutterhead is turned at 3,600 rpm by a 300-hp motor. Its 12 knives are notched with 3-in-long cutting edges to produce a 3-in flake length and staggered so that only six knives cut any given point on the log. If desired, half the knives can be removed so that only three are cutting. By altering knife holder and knife design, flakes of any length can be cut.

To minimize power requirement and enhance flake quality, rake angle is large—43°. Clearance angle, at 5°, is considered the minimum necessary to avoid undue interference with the workpiece. The resulting sharpness angle of 42° yields a cutting edge moderately resistant to nicking. Knives are 5/16-in thick, smooth on both sides, and slotted to accept three clamp bolts.

Dull knives must be removed from the head and sharpened on a long-knife grinder. Knives will dull after cutting 1,000 to 1,400 hardwood bolts—a 4-hour run. To minimize down-time, the cutterhead is carried in quick-release bearings that permit fast removal of the entire cutterhead, via monorail hoist, to the grinding room and immediate replacement with another head holding freshly

sharpened knives. Down-time for cutterhead replacement is estimated at 25 minutes. Knives can wear about 1/2-in. before replacement is necessary.

Flake thickness is controlled by varying either the workpiece rotational speed or the number of knives cutting. To accommodate such adjustments, the workpiece is driven from one end with a 3-hp, variable-speed motor. The operator's control pedestal carries a digital readout display of workpiece rpm, permitting him to continuously monitor workpiece speed. He can change workpiece rotational speed to correspond with log diameter. For example, a bolt 9 in. in diameter being machined to a 6-in. square must turn at about 13 rpm to yield flakes averaging 0.015 in. thick when cut with a six-knife cutterhead. In practice, rotational speeds range from 9 to about 16 rpm. Flake thicknesses of 0.010 to 0.030 are available by operating with six or three knives cutting.

Pallet cants and lumber. The shaping-lathe headrig is a key to vastly increasing pallet lumber supply because it can economically convert portions of the nation's large and underutilized resource

of small mixed-species hardwoods into short cants to be subsequently resawn into lumber. Hinchcliff Products Co. uses the shaping-lathe headrig to make octagonal cants from which it rips pallet stringers and deckboards (Fig. III).

Ties, cants, posts, rails. Other possibilities for high-yield products include crossties, round or octagonal fence rails, highway posts, blocking, and industrial end-grain flooring. Engineering studies are underway to design a shaping-lathe capable of producing such products in lengths up to 8.5 ft. Seven- by 9-in. mainline crossties can be made from pairs of 4.5- by 7-in. cants cut on the shaping-lathe headrig and joined by steel dowels.

Cylindrical veneer bolts. The shaping-lathe headrig can serve as a roundup machine to deliver perfectly cylindrical logs to rotary veneer lathes. Such logs can be easily and quickly peeled into continuous veneer and dried before clipping into standard-size sheets; this procedure saves considerable labor by virtually eliminating short or narrow pieces of veneer. The design concept for the roundup machine is near completion. ■

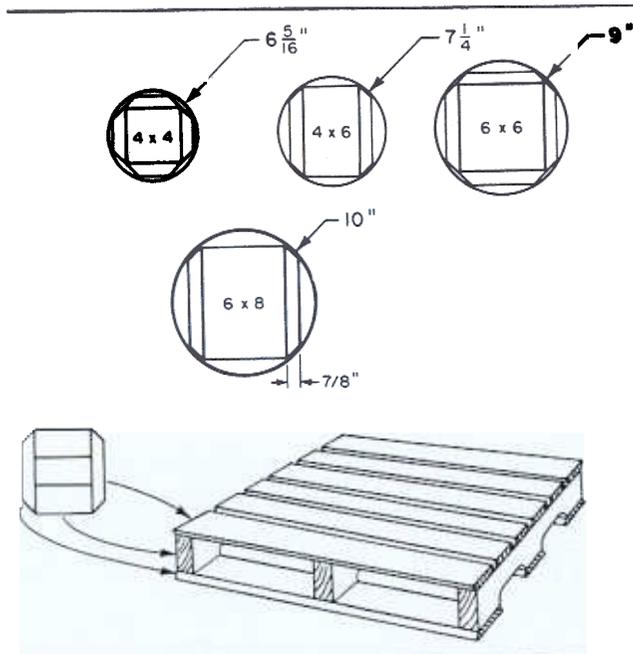
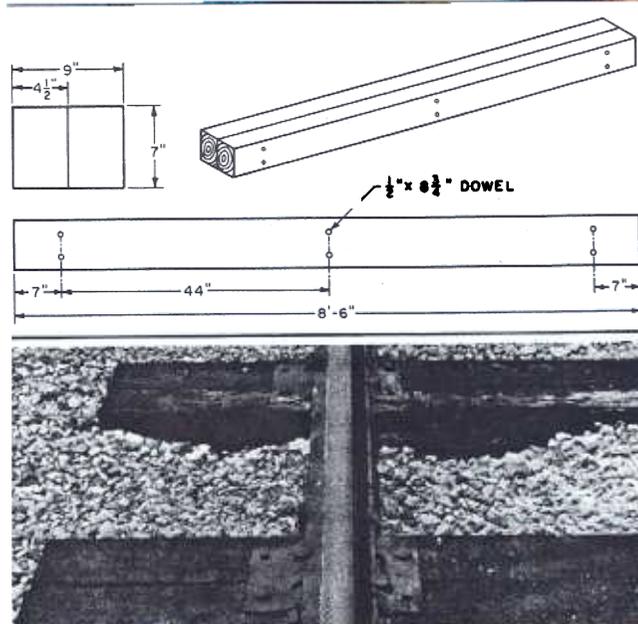


Fig. III. When square-edged lumber is ripped from the center of octagonal cants and bevel-edged boards are cut from outer portions, lumber recovery from diameter-sorted logs should be about 7.5 bd ft of 3/8-in-thick boards per cu ft of log.



Top, Fig. IV. Dowel-laminated mainline crosstie secured with three pairs of 1/2-in. spirally fluted steel dowels. No adhesive used. **Bottom.** Steel-doweled mainline ties have been in place 13 years and have given service comparable with one-piece ties. These can be made from logs 8.5 in. in diameter, a size in plentiful supply (Howe and Koch 1976; Murphy and Knight 1974; Sternitzke 1974).

EDITOR'S NOTE: In this second of three parts, Dr. Peter Koch, Chief Wood Scientist, Southern Forest Experiment Station, USDA Forest Service, Pineville, Louisiana, continues his comments on 'meshing resource with demand for products' in his description of the potential of the shaping-lathe headrig in the total utilization picture. The overall topic represents Dr. Koch's presentation at the 1976 Sawmill Clinic in New Orleans in June. This part of the series also includes Dr. Koch's analysis of a 'machine to harvest trees with central root attached,' and it deals with a machine to hog and retrieve logging slash.

PART II

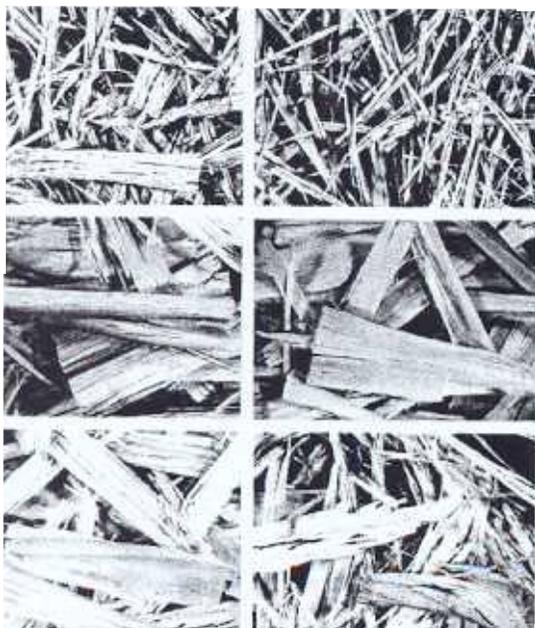
New approaches, new machines to utilize hardwoods on pine sites

ALONG WITH the pallet cants and lumber; ties, cants, posts and rails; and cylindrical veneer bolts cited earlier in the utilization picture, structural exterior flakeboard must also be considered. This flakeboard can be competitive in pricing with plywood—particularly in those regions where flakeboard can be manufactured from

local woods and where plywood must be transported from distant production centers.

Structural flakeboard. Such a flakeboard would enable utilization of the many low-quality hardwoods growing on southern pine sites. Using the shaping-lathe headrig, Hse et al. (1975)

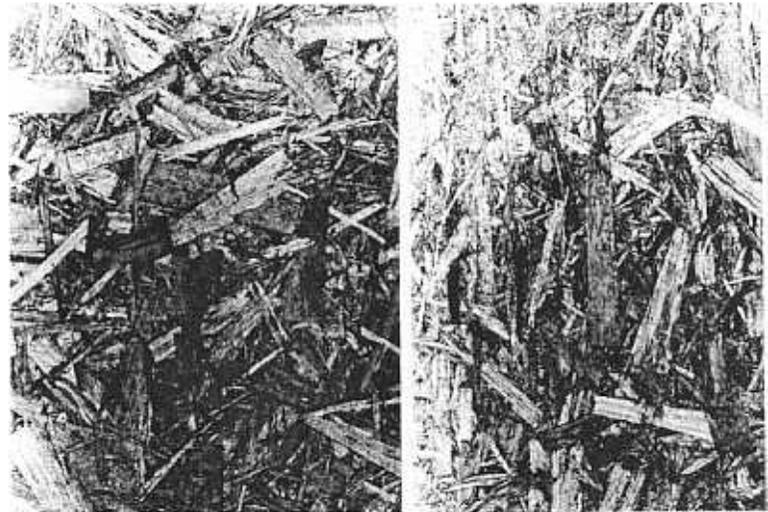
made ½-in boards from equal-weight portions of hickory (*Carya* spp.), white oak (*Quercus alba* L.), southern red oak (*Quercus falcata* Michx.), sweetgum (*Liquidambar styraciflua* L.), and southern pine (e.g., *Pinus taeda* L.) flakes bound with phenol-formaldehyde (5.5%) and pressed for 5 minutes at 335° F. Properties observed in 18-in.-square



Left. Face flakes 0.015 in. thick and 3 in. long in random widths produced on shaping-lathe headrig. These can be manufactured into structural exterior flakeboard. Shown are samples of white oak, southern red oak, hickory, sweetgum and southern pine. Lower right photo is a mixture of the species. Above. Such structural flakeboard is applied as both roof and wall sheathing on this shed.

PANEL PROPERTIES

	Face flake orientation	
	Random	Aligned
Density (lb/ft ³)	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



Right. Three-layer, five-species flakeboard with randomly oriented flakes throughout (left side) or with aligned face and randomly oriented core (right side). Properties of the laboratory panels are in the table above.

panels at 50% relative humidity were as shown in the table.

Several hundred 4- by 8-ft panels of these flakeboards are now under intensive evaluation. Results to date are promising. Commercially made 4- by 8-ft panels will likely have modulus of elasticity and modulus of rupture values about 10% lower than those tabulated for the small laboratory-made boards.

Flow analysis of the process (Fig. V) indicates that for each ton (ovendry basis) of barky log input, output will be 375 sq ft of ½-in structural flakeboard weighing 45.3 pounds per cu ft (ovendry weight) and 242 square feet of ¾-in-thick lumber (ovendry weight of 40 pounds per cu ft of wood is assumed). Moreover, residues will be sufficient to supply heat and power requirements.

Processing this 1 ton of barky hardwood bolts should require about 3.12 man-hours of labor, supervision and management, 55.6 horsepower-hours of mechanical energy, and 1,800 pounds of process steam; during such conversion the manufacturing plant will depreciate \$6.50 (10-year, straight-line basis). A preliminary evaluation of economics of a plant consuming 308 tons (ovendry basis) of boltwood per 24 hours can be found in Koch (1975). A more sophisticated economic analysis is in preparation by the Forest Service and should be published by late 1976 or early 1977. Preliminary indications are that the profit potential is excellent.

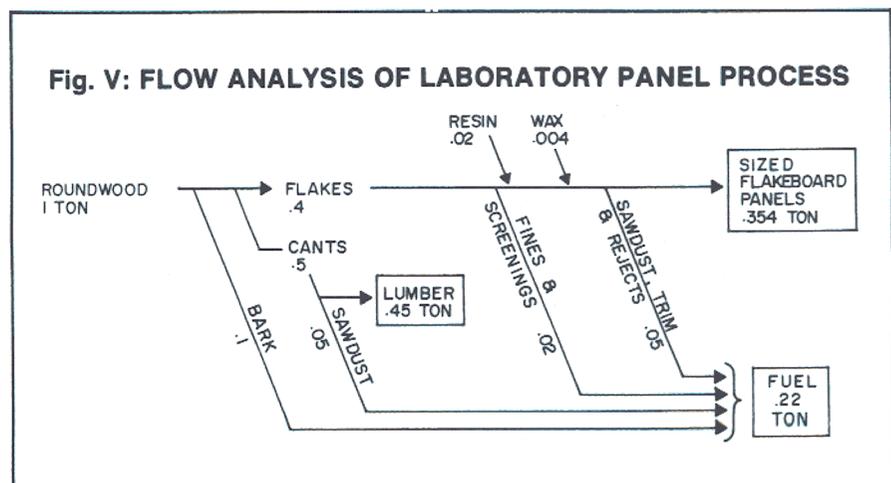
To increase panel yield substantially, the process (Hse et al. 1975) can be mod-

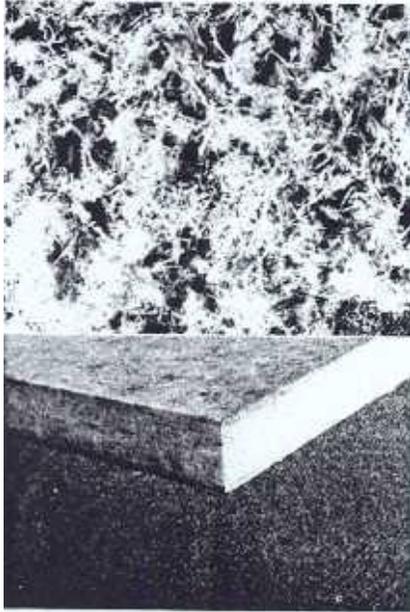
ified so that panel trim, coarse sawdust, and some of the fines are converted to thermo-mechanical fiber in a pressurized disk refiner and reintroduced into the panel forming line. This procedure, plus utilization of core flakes made from coarsely chipped logging residues processed through a ring flaker, is contemplated for the high-yield process described in the next and final part in this series.

Medium density fiberboard. Fibers (derived from shaping-lathe headrig flakes) of a wide variety of hardwood and softwood species can be mixed with small amounts of resin to yield hot-pressed boards with near uniform density throughout panel thickness, good edge integrity and internal

bond strength, and reasonably high moduli of rupture and elasticity (Suchsland and Woodson 1974, Woodson 1976). Such boards are finding an increasing market in the furniture industry, primarily because their sound edges and smooth faces permit direct printing of surface patterns. The board also finds wide acceptance as a siding material.

Foamed urethane products. Wood has always suffered in competition with plastics because of its inability to flow under pressure into molded forms. But now, A.A. Marra et al. (1975) have developed a process whereby fibrillated wood particles of matchstick size can be carried in a foaming urethane resin to fill curved cavities in a mold. Matchstick flakes produced





Fibers disk-refined from southern red oak, top photo, are used to make a fiberboard, bottom photo, that is 3/4-in. thick and weighs 42 lbs/cu ft at 7% moisture content. MOE is 367,000 psi; MOR is 3,190 psi.

with the shaping-lathe headrig can thereby be molded into intricate forms.

Because molds are inexpensive and the system is tolerant of species and tree grade, the process has substantial promise for manufacture of a wide range of products including such diverse items as caskets, speaker cabinets, pallets, containers, and structural panels. Economic potential of the process depends on the price of resin since the end

product may contain one-quarter to one-third resin by weight.

Lumber from veneer

To make needed strong, long, wide structural lumber from ever smaller logs, it is proposed that such lumber be laminated from rotary-peeled veneer. In trials at a plant in central Louisiana, southern pine logs yielded about 50% more lumber when rotary-peeled than when sawn by 1973 methods; moreover, the laminated lumber was 10% stiffer and justified 100% greater design stress than lumber sawn from the same logs (Koch 1973a). Lumber laminated from butt-jointed veneer rotary-peeled from log-run southern pine can be expected to have a modulus of elasticity of about 1,950,000 psi and an allowable design stress in bending of 2,650 psi; moreover, the product is attractive looking and easy to use.

Nearly 60% of log volume inside bark ends as salable laminated products or studs—the latter from veneer cores. Procedures for drying studs cut from veneer cores while effectively restraining them against warp are described by Koch (1971) and Koch and Wellford* With a shaping-lathe roundup machine ahead of the veneer lathe and another shaping lathe to convert veneer cores to 4- by 4-in. cants for stud manufacture, virtually all the manufacturing residue would be quality flakes for structural exterior flakeboard.

Conversion of a-ton (ovendry basis) of baky log, yields about 0.53 ton of salable lumber product; manufacturing

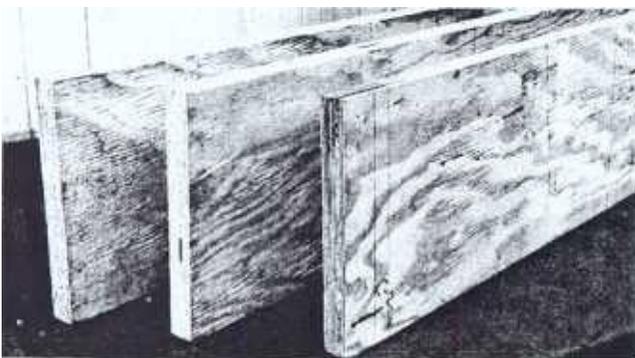
expenditures are about 3.62 man-hours, 14.15 horsepower-hours, 2,775 pounds of steam for heating bolts and drying the veneers, and \$9.62 of depreciation of the manufacturing plant. By this process, horsepower-hours are lower, but other expenditures are somewhat higher than expenditures for conventional manufacture of softwood lumber, i.e., about 1.92 man-hours, 62.8 horsepower-hours, 1,396 pounds of steam, and \$2.43 capital depreciation per ton (ovendry basis) of baky log converted. Further data on the economics of laminating wide, long lumber from rotary-peeled veneer are contained in Koch (1976b).

Alleviating energy problems

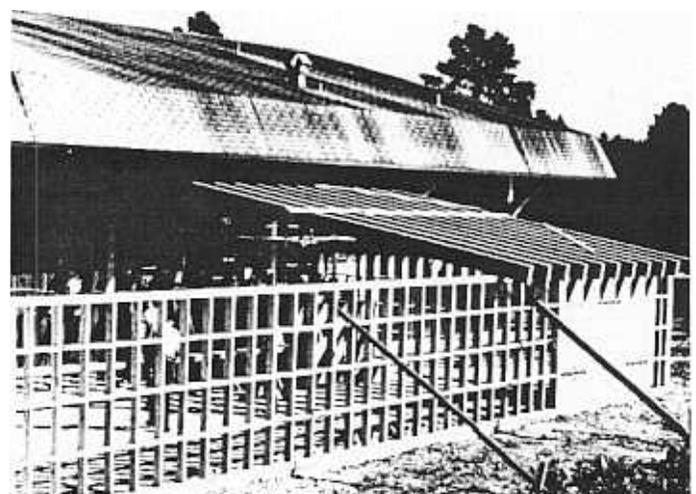
Residuals from forest and manufacturing plants are sufficient to provide the energy necessary to drive the manufacturing processes envisioned. Such energy self-sufficiency requires solution to three problems, however: first, a means is needed for harvesting below-ground biomass of trees as well as that above ground; second, logging slash (or at least a portion of it) including tops, branches, and residual trees must be harvested; finally, economical burners are needed to release the energy from heterogeneous fuels comprised of mixed wet bark and wood.

Harvesting tree and root. The stump and root system (to a 3-ft radius) of a 20-year-old southern pine comprises about 16.5% of the biomass of the entire tree. When root laterals are trimmed close to the central root mass, about

* (in press)



Above. Joists 12 in. deep were manufactured from rotary-peeled thick southern pine veneer. **Right.** Rafters in this shed, 24 in. on center, are 3 ft. thick and 32 ft. 10 in. in length. Fabricated from rotary-peeled veneer, they are designed to take roof load of 39 lbs. per sq ft.



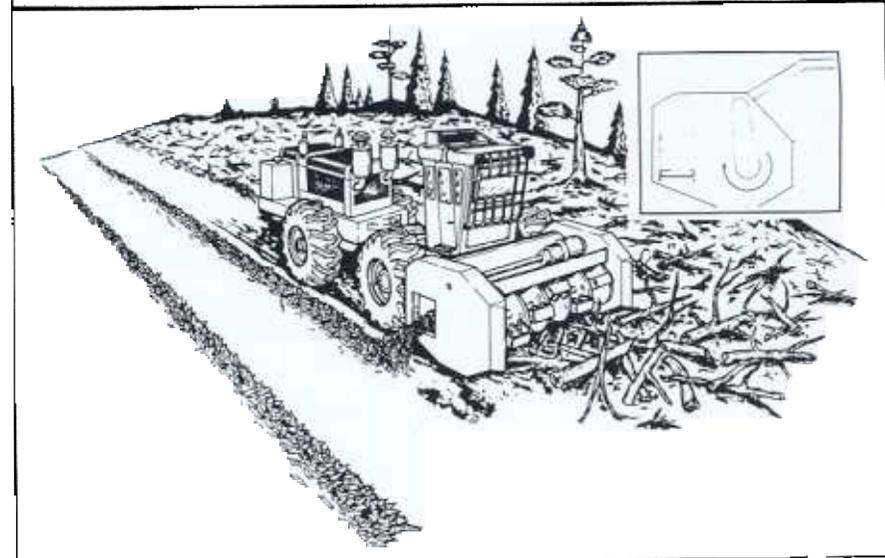
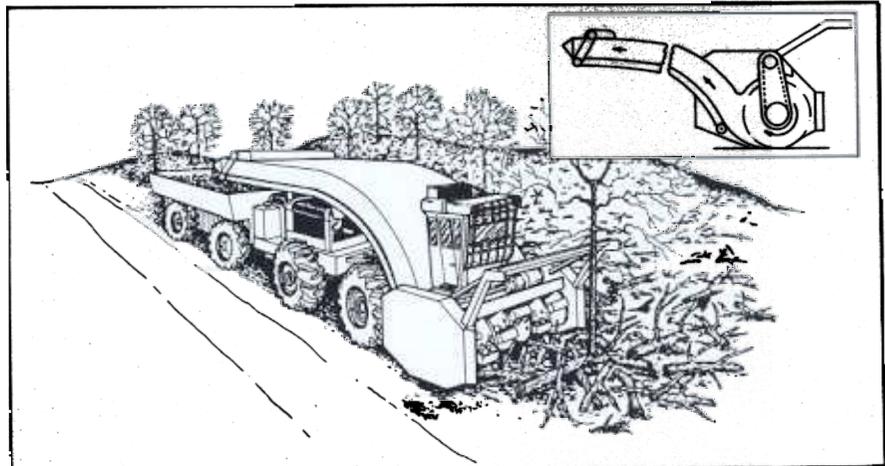


Machine designed to harvest tree and root is at work here. It has lifted loblolly pine, with taproot attached, as a carrot might be lifted. Machine severs lateral roots, then lifts vertically.

two-thirds of the weight in the root-stump system remains (Howard 1973, Koch 1972, p. 562). Proportions are not greatly different for southern hardwoods. With this in mind, a machine was developed to first sever lateral roots and then pull trees from the ground like carrots (Koch and Coughran 1975). The machine can pull and bunch 4- to 12-in. pines at a rate of 1.5 to 2 trees per minute. On hardwoods, the current equipment is limited to trees 4 to 8 in. in d.b.h.

Numerous loggers in the South have demonstrated that weight harvested per tree can be increased by at least 20% with the new harvesting technique (Koch 1976c).

Hogging, retrieving logging slash. After felling final crop trees, loggers typically windrow and burn residual tops and branches, thereby removing obstacles to replanting and reducing hazard from wildfire. This procedure has several disadvantages. First, burning slash pollutes the air. Second, site productivity may be significantly reduced if bulldozer operators inadvertently blade off topsoil during piling operations. Finally, the pile and burn practice commonly wastes about 20 tons (dry) per



A mobile hogging machine of this type would traverse the acreage, top photo, and hogged material would be collected from the cutterhead and delivered to a hopper trailing the prime mover. If it were determined that needle cast and foliage drop were not sufficient for adequate nutrient recycling, mulching concept depicted in bottom photo could be adopted.

acre of wood and bark that could be harvested for fuel or fiber. To reduce hazard from wildfire, to avoid loss of fertility through scalping, to prepare sites for replanting, and to retrieve significant tonnages per acre for fuel and fiber, a simple site preparation technique is proposed.

The concept calls for tops, branches, stumps, underbrush, and small trees residual after harvest (in short, all logging slash) to be hogged by a long, cylindrical cutterhead mounted across the front of a prime mover. As this mobile hogging machine slowly traverses the acreage, hogged material would be collected from the cutterhead and delivered into a

hopper trailing the prime mover. At intervals the mobile hog would transfer its hopper load of wood to a forwarder for movement to a landing where large vans would be filled for transport to the mill. A commercial version of this machine should be in operation by the end of 1977.

Optimum degree of biomass removal from important site classes has yet to be determined, but many southern silviculturists believe that annual needle cast and foliage drop alone provide adequate nutrient recycling. Where this is not the case, the mulching concept proposed by Koch and McKenzie (1975) could be adopted. ■

EDITOR'S NOTE: In this final of three parts, Dr. Peter Koch, Chief Wood Scientist, Southern Forest Experiment Station, USDA Forest Service, Pineville, Louisiana, begins with comments on systems for burning green hog fuel and bark. In his overall goal of improved utilization of hardwoods on pine sites, he then discusses a proposed integrated plant — for a non-pulp solution to the utilization challenges. This embraces all previously discussed machinery and processes. He concludes with an analysis of the land base and some economic factors. Utilization is the goal! Some of the equipment described in the series — such as the Koch-designed shaping lathe headrig — is already working. Other kinds of innovative machinery may be on the near horizon and even more innovative designs may develop in the not-too-distant future as both public and industrial efforts are directed to recovering more from the resource and to meeting particular market needs.

PART III

All processes to utilize hardwoods on pine sites can be combined

EFFICIENT BURNING SYSTEMS (suspension burners) for wet hog fuel and bark are needed if the forest products industry is to be self-sufficient in energy. A high proportion — 70 to 80% — of energy needed in wood converting plants is in the form of heat for lumber and veneer kilns, for flake and particle dryers, and for hot ponds to condition bolts before rotary peeling or flaking. This heat demand can, in many cases, be satisfied by injecting hot combustion gases directly into the chamber to be heated, thus obviating the necessity to generate steam and providing greater thermal efficiency.

However, few commercial burners are capable of direct-firing kilns using wet hogged wood or bark as fuel. To fill this need, Jasper and Koch (1975) proposed a furnace design based on data collected from a laboratory model (Fig. VI). The commercial furnace would burn about 30 tons of green fuel in the suspended-particle combustion zone each 24 hours. The combustion chamber is an annular space between two concentric vertical cylinders. An inner cylinder slightly less than 2 feet in diameter houses a vertical down-feeding feed screw to introduce fuel into the bottom of the chamber. The outer cylinder confining the upward-moving combustion gases is about 3 ft, 4 in. in diameter. The fuel is partially dried in transit to the combustion zone. Surrounding the outer cylinder, along a portion of the 20-ft-high burning zone, is a heat exchanger that preheats air to 500°F and introduces it at high velocity (325-375 fpm) into the bottom of the burner. This air suspends the fuel parti-

cles in the combustion zone, where the temperature is about 1500°F (Fig. VI). A compressor of about 11 hp is required for the preheated air to assure required air flow and velocity.

The burner has neither grate nor fuel bed. Combustion occurs throughout a zone in which particles are suspended in the air stream. The outer cylinder is flared at the top of the combustion zone. Since the inner cylinder has constant diameter, the flare increases flow area for upward-moving combustion gases with resultant loss in velocity. This causes particulate matter (other than fine ash) to fall back into the burning zone for continuous recirculation until completely burned. In the laboratory model, slag formation did not prove to be a problem since combustion chamber temperatures did not exceed 1800°F. Ash formed during combustion is finely particulate and is discharged upwards, along with hot combustion gases, for later separation.

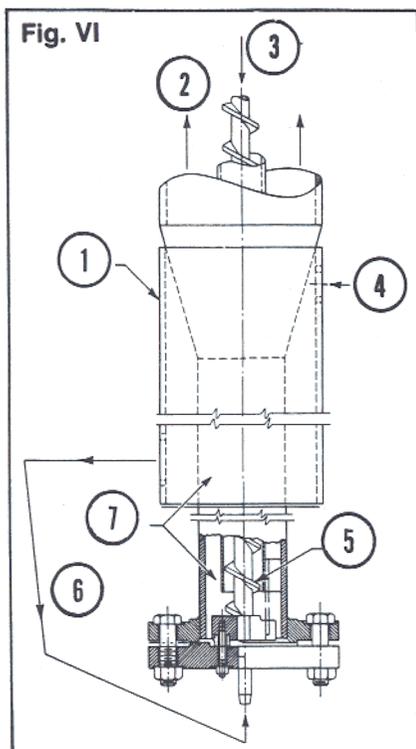
Capitalizing on the concept

To capitalize on this burner concept, a tunnel kiln for southern pine studs is proposed (Fig. VII). In the drying process planned, studs are pre-surfaced green to 1.75-in. thickness and then stickered mechanically 5 ft wide and 10 ft high on 1¼-in.-thick sticks and continuously transported through a zone-controlled, 96-ft-long kiln at 8 ft per hour to yield 500,000 bd ft of lumber dried to 10% moisture content per 168-hour week. In the tunnel, the lumber is dried for 8 hours at 270°F, conditioned for 3 hours at 195°F, and cooled for 1 hour at ambient temperature before discharge

to cooling sheds and subsequent unstacking. Air velocities may vary by zone, e.g., 1,600 fpm at inlet, 300 fpm while conditioning, and 1,000 fpm while cooling. To control warp, a top load (12 in. of concrete) is automatically placed on the moving lumber stacks as they enter the tunnel kiln and removed as they exit. Weekly consumption of green hogged wood or bark to dry 500,000 board feet should be less than 200 tons; mechanical energy to drive motors (including lumber handling, bark preparation and burning equipment, and fans) will total about 34,000 horsepower-hours. To heat the kiln, three burners based on the Jasper and Koch (1975) commercial design—but slightly smaller (Fig. VIII)—should provide the flexibility and turn-down ratio needed. Readers interested in details of this tunnel kiln will find the description by Koch and Wellford (in press) useful.

Proposed integrated plant

All the processes and machines previously discussed can be combined to yield a non-pulp general solution for mixed-species southern forests on pine sites (Fig. IX). The system proposed is described as Biomass Recovery and Utilization with Shaping-Lathe Headrigs (BRUSH). Economic significance of the idea becomes apparent on realization that only about 30% of the biomass (above and below ground) of southern pine trees presently harvested for lumber or pulp is recovered and sold as dry, planed, double-end trimmed lumber or as kraft paper (Koch 1973b). Only a fraction of the hardwoods on pine sites are utilized to a significant



Above, Fig. VI. Laboratory-scale suspension burner for hogged green wood or bark. 1. Heater jacket; 2. Combustion gases; 3. Green bark; 4. Primary air to heater; 5. Bark-feed auger; 6. Preheated air flow; 7. Combustion zone. **Right, top, Fig. VII.** Southern pine studs being dried in 12-hr transit through continuous tunnel kiln direct-fired with green hog fuel or bark. Insert shows transverse X-section of 10-ft-high stack top-loaded (to prevent warp) with Caterpillar-like track having 12-in.-thick concrete flights. **Right, bottom, Fig. VIII.** Suspension burners fueled by green fuel admitted through down-feeding central tubes and designed to direct-fire tunnel kiln. Three such are required to dry 500,000 bd ft of southern pine weekly. Normal rating of each is about 3,500,000 Btu/hr (0.45 ton green fuel/hr) with turndown ratio of 1.6 to 1 (permitting output of about 3-5 million Btu/hr).

Fig. VII

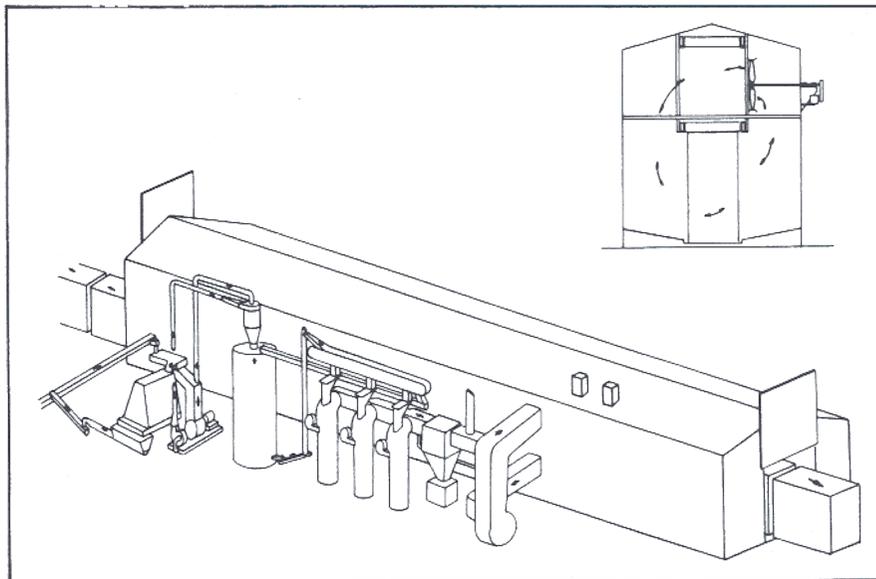
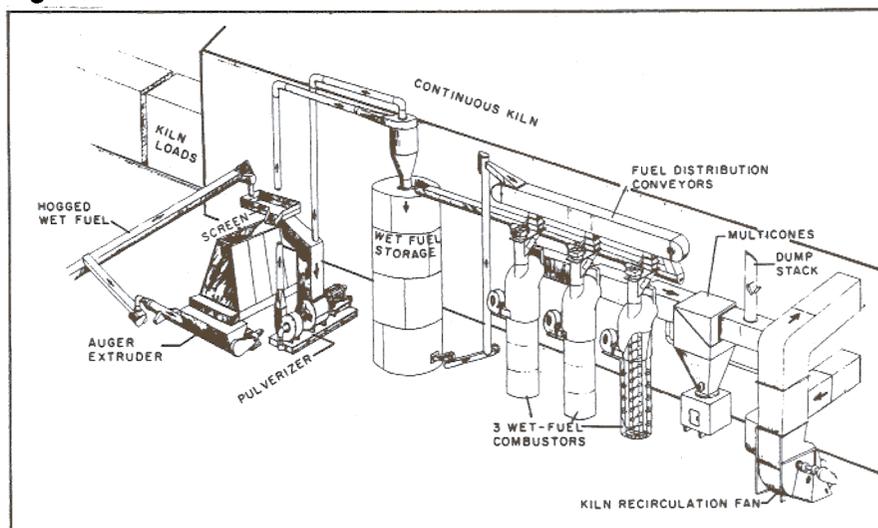


Fig. VIII



degree, and a major forestry expense in the South is destroying them.

The proposal advanced (Fig. IX) calls for a harvesting and utilization system that could recover 67% of tree biomass of all species as solid wood products saleable at about \$150 per ton (Table I). Thus, product yield from a mixed-species forest would be four times that currently obtained since hardwood tonnage on pine sites is 0.8 of pine tonnage (i.e., $0.67 \times 1.8/0.30 = 4.0$). Technology exists to put this system known as BRUSH into effect immediately; by the early 1980's it could be in widespread practice.

How BRUSH works

Trees of all species measuring 7 to 12 in. in d.b.h. are harvested with the central root mass intact by the newly developed tree puller (See Part II). Tops and limbs are severed on the site, and full-length stems (including roots) are transported to the mill. Trees larger than 12 in. are cut 6 inches above ground level and topped. Trees of 5- and 6-in. d.b.h. can either be pre-logged or harvested separately. Tops, branches, and all residual trees are chipped in place with the mobile hog previously described (see Part II), and the chips are hauled to the mill and screened; half are utilized for

fuel and half for core flakes made on a ring-flaker. At the mill merchandising deck, roots and bark are removed from the stem. The bark and most of each root are used as fuel; about $\frac{1}{4}$ of each root is processed as core flakes.

A few high-grade saw logs and veneer logs are cut from the hardwood stems and resold. Remaining hardwood logs down to 8.5 in. in diameter are cut in 8½-ft lengths and converted by a shaping-lathe headrig into face flakes (see Part II) and cants that are later dowel-laminated into 7- by 9-in. main-line crossties (see Part I). Hardwood boltwood 5 to 8.5 in. in diameter is con-

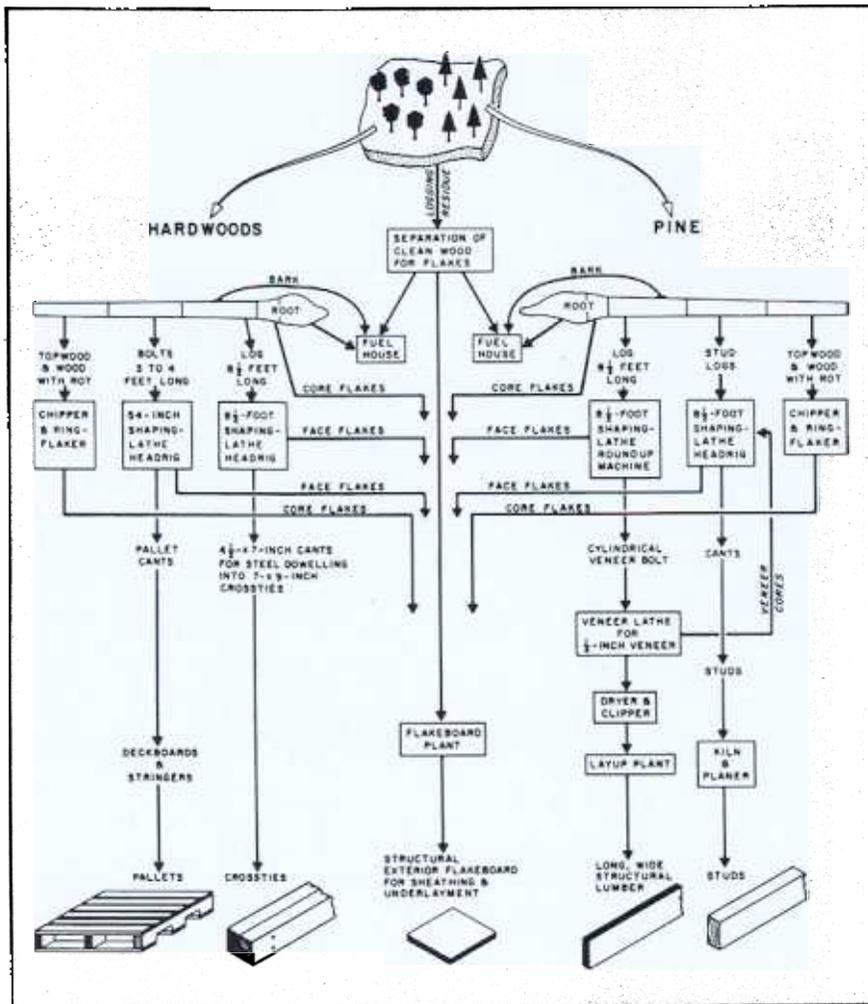


Fig. IX. Flow plan whereby 67% of the above- and below-ground biomass of trees in mixed-species southern forests ends as pallets, crossties, structural exterior flakeboard, long wide structural lumber, or as studs. The system is self-sufficient in energy (Koch 1976 a).

verted on a 54-in. shaping-lathe headrig to face flakes and pallet cants (to yield deck boards and stringers). Hardwood bolts less than 5 in. in diameter and rotted bolts are chipped and ring-flaked to yield core flakes.

With pine, 8-ft logs down to 8 in. in diameter are rounded on a shaping-lathe to yield flakes plus perfect cylinders to be peeled into 1/4-in. veneer. The veneer is then parallel-laminated into wide, long structural lumber (See Part II). Veneer cores and small pine logs are converted on another shaping-lathe headrig into flakes and cants for resawing into studs. Very small bolts are chipped and ring-flaked to yield core flakes.

Thus, output of the plant is crossties, pallets, studs, structural exterior

flakeboard that can compete in price and function with sheathing grades of plywood, and structural lumber in any desired length or width laminated from 1/4-in. veneer. A secondary product of the process is fuel comprised of wood and bark; quantities produced are sufficient to provide all of the power and heat required by the manufacturing complex (Table I).

Appropriate regeneration techniques applied immediately to the harvested sites will quickly yield plantations of much greater productivity than the present-day forests.

Land base required. Let us assume our long range objective is to bring to full productivity an understocked land base which carries mixed species (half pine

and half mixed hardwoods) and averages 100 small stems per acre at time of harvest in trees 7 in. in d.b.h. and larger (averaging 10.5 in. d.b.h.). Let us further suppose that average dry biomass (above- and below-ground parts) of each tree is 650 pounds. Additionally, let us assume that the tree merchandiser feeding the mill processes 360 trees per hour for 100 hours out of each week, 50 weeks per year. Annually, then, the plant would consume 1,800,000 trees with total oven-dry biomass of 585,000 tons cut from 18,000 acres. Over a period of 25 years (the assumed rotation period), total cut would be 45,000,000 trees, which, under the assumptions made, would have been harvested from 450,000 acres, or 703 square miles — a block of land measuring nearly 27 miles square.

Gross sales. If the total annual biomass harvested amounted to 585,000 tons (oven-dry) of which 67% was converted to products selling for \$150 per dry ton net fob mill, then annual sales would total \$58,793,000 (i.e., $585,000 \times .67 \times \150). In actuality, biomass tonnage harvested would considerably exceed 585,000 tons annually because of recovered tonnage from residual trees and brush before initial planting, because of thinnings that would be available 15 and 20 years after planting, and because of heavy final cuts 25 years after planting.

Stumpage costs. How would the land base be assembled, and what would be the stumpage cost? Our premise is that private landowners would be willing to put their small properties (100 to 1,000 acres) into the land base if they could be assured of an annual cash income of perhaps \$23 per acre and at the same time be relieved of all management and regeneration costs.

Assuming 25-yr rotation after initial cropping, total cash income to the farmer, spread over 25 years, would amount to \$575 per acre (25 years x \$23/acre). We will assume that he joins the land base the year his land is first cut and that the company prepares the site, plants it, and gets the thinnings and the final cut, with the understanding that the contract is to be renegotiated after final cut. During this time, the landowner retains use of his land for recreation, hunting, or other non-timber uses.

**Table I.
MERCHANTABLE SOLID-WOOD PRODUCT
RECOVERED BY PROPOSED FACILITY
FOR PROCESSING MIXED SPECIES**

	<u>Percent</u>
Total biomass (above and below ground)	100
Less:	
75% of roots and stump ¹	12.3
Foliage	4.0
Stem bark	12.5
50% of barky tops and branches ²	4.2
Sawdust and trim losses ³	0
	33 ⁴
Percentage ending as product	67

¹ 25% recovered as flakeboard furnish.

² 50% recovered as flakeboard furnish.

³ These residues recycled by fiberizing and used as flakeboard furnish.

⁴ Most of this, except foliage, ends as fuel.

**Table II.
ANNUAL OUTPUT BY PRODUCT¹**

<u>Commodity</u>	<u>Ovendry tons</u>	<u>Other measure</u>
Crossties (7-by-9 in.)	46,440	675,000 pieces or 30,121,875 bd ft
Long, wide lumber	64,462	4,297,467 ft ³
Studs	26,250	31,980,000 bd ft
Pallets	48,555	31,500,000 bd ft
½-in. sheathing	206,243	215,172,700 ft ²
Fuel (approx.)	<u>193,050</u>	
Total	585,000	

¹ 100 effective operating hours per week, 50 weeks per year.

What are the costs of such an arrangement to the company operating BRUSH? When each acre of land is contracted, the present cost (\$246) of an 8% annuity paying \$23 per acre annually for 25 years would be due. To this immediate expense per acre must be added perhaps \$42 per acre for planting; the planting cost would be this low because of the prior extensive site preparation provided during harvesting. Total immediate expense per acre enrolled would therefore be \$288 (i.e., \$246 + \$42).

Company benefits would also have a present value of about \$288 per acre:

- 32.5 tons of dry biomass (100 trees x 650 pounds per tree/2,000) immediately harvested at \$4 per dry ton \$130
 - 5 cords of first thinnings at age 15 at \$15 per cord stumpage (discounted to present at 8%) 24
 - 10 cords of second thinnings at age 20 at \$20 per cord stumpage (discounted to present at 8%) 43
 - 25 cords final cut at age 25 at \$25 per cord stumpage (discounted to present at 8%) 91
- Total present value \$288**

These benefits to the company are

understated because additional tonnage (perhaps 5 tons dry weight per acre) would be immediately retrieved from residual trees and shrubs; also, at plantation ages 5 and 10, brush control and precommercial thinning with the mobile hog (See Part II) would yield additional tonnages of fuel. Additionally, the commercial thinnings at age 15 and 20 would yield biomass tonnages in excess of the conventional merchantable yield tabulated in cords.

In simpler terms, stumpage cost would total \$4,428,000 annually (i.e., \$246 per acre x 18,000 acres harvested per year). Regeneration costs of \$42 per acre would total \$756,000 annually. Thus, of initial annual gross sales of \$58,793,000, only \$5,184,000 would go to stumpage and regeneration. Annual sales would rise sharply when the 15-yr thinnings commenced, again when the 20-yr thinnings came due, and still again when final cut began — but stumpage costs would remain level.

Shaping-lathe headrig capacity. Six trees per minute crossing the merchandising deck could yield four or five 8½-ft hardwood logs per minute large enough (8.5 in. minimum diameter) to yield a half-tie, plus four or five 8-ft pine bolts of sufficient size to be peeled (8-in. diameter or larger). Thus, one 8½-ft crosstie headrig would be required for hardwoods plus one 8-foot roundup

headrig followed by a rotary veneer lathe for pine.

Since the rotary veneer lathe would yield four or five pine veneer cores per minute and the merchandising deck would be yielding five or six pine stud logs per minute, two more headrigs of 8-ft capacity would be needed to turn out cants from which studs could be resawn.

Finally, one might expect that the merchandiser would yield 15 to 18 bolts per minute measuring 40 to 53 in. long and 5 to 8½ in. in diameter; conversion of this boltwood (mostly hardwood) would call for three 54-in. shaping-lathes.

Total headrig complement would therefore be seven shaping-lathes: an 8½-ft crosstie machine, an 8-ft roundup machine, two 8-ft canters for studs, and three 54-in. machines for pallet cants. Additionally, an 8-ft veneer lathe would be required, as well as a complement of cant resaws. This aggregation of machines would yield a product mix about as shown in Table II.

In conclusion, it might serve well to repeat an observation made in the "overview" which introduced Part I of this series: Processes have been invented that can raise utilization of each tree — pine and hardwood on pine sites alike—to 67% of total biomass (as contrasted with the historic level of only 30%) — pines only, thereby increasing product yield fourfold. ■

ADDENDUM

Literature Cited

- Anonymous. 1975. Seen for 1975: further expansion of rail, tie renewables. Railw. Track and Struct. Jan., p. 22-23.
- Cliff, E. P. 1973. Timber: The renewable resource. Natl. Comm. on Mater. Policy. U. S. Gov. Print. Off. 151 p.
- Howard, E. T. 1973. Physical and chemical properties of slash pine tree parts. Wood Sci. 5: 312-317.
- Howe, J. T., and P. Koch. 1976. Dowel-laminated crossties--performance in service, technology of fabrication, and future promise. For. Prod. J. 26(5): 23-30.
- Hse, C. Y., P. Koch, C. W. McMillin, and E. W. Price. 1975. Laboratory-scale development of a structural exterior flakeboard from hardwoods growing on southern pine sites. For. Prod. J. 25(4): 42-50.
- Jasper, M. T., and P. Koch. 1975. Suspension burning of green bark to direct-fire high-temperature kilns for southern pine. Pages 70-72 in Wood residues as an energy source. Proc. P-75-13, For. Prod. Res. Soc. Symp.
- Koch, P. 1964. Square cants from round bolts without slabs or sawdust. For. Prod. J. 14: 332-336.
- Koch, P. 1967a. Development of the chipping headrig. Pages 135-155 in Proc. Rocky Mt. For. Ind. Conf., Fort Collins, CO.
- Koch, P. 1967b. Too many crooked small logs? Consider a shaping-lathe headrig. South. Lumberman 215(2680): 147-149.
- Koch, P. 1968. Converting southern pine with chipping headrigs. South. Lumberman 217(2704): 131-138.
- Koch, P. 1971. Process for straightening and drying southern pine 2 by 4s in 24 hours. For. Prod. J. 21(5): 17-24.
- Koch, P. 1972. Utilization of the southern pines. USDA Agric. Handb. 420, 1663 p.
- Koch, P. 1973a. Structural lumber laminated from 1/4-inch rotary-peeled southern pine veneer. For. Prod. J. 23(7): 17-25.
- Koch, P. 1973b. Whole-tree utilization of southern pine advanced by developments in mechanical conversion. For. Prod. J. 23(10): 30-33.
- Koch, P. 1974. Development of the shaping-lathe headrig. USDA For. Serv. Res. Pap. SO-98, 20 p. South. For. Exp. Stn., New Orleans, LA.
- Koch, P. 1975. Shaping-lathe headrig now commercially available. South. Lumberman 231(2872): 93-97.

- Koch, P. 1976a. Biomass recovery and utilization with shaping-lathe head-rigs. USDA For. Serv. Spec. Rep., 6 p. South. For. Exp. Stn., New Orleans, LA.
- Koch, P. 1976b. Laminated lumber may be more profitable than sawn lumber. For. Ind. 103(6): 42-44.
- Koch, P. 1976c. New technique for harvesting southern pines with taproot attached can extend pulpwood resources significantly. J. Appl. Polym. Sci., Appl. Polym. Symp. No. 28, Wiley Interscience, John Wiley and Sons: New York. (in press).
- Koch, P., and S. J. Coughran. 1975. Development of a puller-buncher for harvesting southern pines with taproot attached. For. Prod. J. 25(4): 23-30.
- Koch, P., and D. W. McKenzie. 1975. Machine for row-mulching logging slash to enhance site—a concept. Am. Soc. Agric. Eng. Pap. 75-1529, 12 p.
- Koch, P., and W. L. Wellford, Jr. Continuous tunnel kiln direct-fired with bark to dry 1.75-inch southern pine in 12 hours. For. Prod. J. (in press).
- Marcin, T. C. 1975. Will housing demand boom again? Pages II,1 - II,14 in Marketing in a recovery economy: trends in housing. Proc. First Annu. Texas Ind. Wood Conf., Texas A&M Univ.
- Marra, A. A., W. A. Hausknecht, and R. F. Day. 1975. Low-density composites from high-density hardwoods. Mass. Agric. Exp. Stn. Bull. 610, 45 p. Univ. of Mass., Amherst.
- Murphy, P. A., and H. A. Knight. 1974. Hardwood resources on southern pine sites. For. Prod. J. 24(7): 13-16.
- Southern Forest Products Association. 1975. Southern pine sales by sizes, items and grades covering the year 1974. Spec. Mark. Comm. Surv. No. 8, 10 p. South. For. Prod. Assn., Stat. Dep., New Orleans, LA.
- Sternitzke, H. S. 1974. Eastern hardwood resources: Trends and prospects. For. Prod. J. 24(3): 13-16.
- Suchsland, O., and G. E. Woodson. 1974. Effect of press cycle variables on density gradient of medium density fiberboard. Pages 375-396 in Proc., Eighth Part. Symp., Pullman, WA.
- USDA Forest Service. 1973. The outlook for timber in the United States. For. Res. Rep. No. 20, 367 p.
- Woodson, G. E. 1976. Effects of bark, density profile, and resin content on medium density fiberboards from southern hardwoods. For. Prod. J. 26(2): 39-42.