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SIX NEW MACHINES AND NINE PRODUCTS CAN TRIPLE  
COMMODITY RECOVERY FROM SOUTHERN FORESTS

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In the South, about 0.8 ton of hardwoods grow on pine site for every ton of pine biomass. About half of this hardwood volume is in 11 oak (Quercus sp.) species, with sweetgum (Liquidambar styraciflua L.) and hickory (Carya sp.) also comprising important fractions. About half the volume is in trees 5.0 to 10.9 inches in dbh, with the remaining volume about evenly divided between trees 11.0 - 14.9 inches dbh and trees 15 + inches in dbh (Christopher et al. 1976, Murphy and Knight 1974).

We can keep up with the increasing demand for wood products while avoiding projected timber shortages by taking advantage of this enormous hardwood resource. The six new machines and nine products (seven of them new) that I will describe are the elements of a concept that makes harvesting the unwanted hardwoods feasible. Implementation of the concept, called Biomass Retrieval and Utilization With Shaping-Lathe Headrigs (BRUSH), can triple the commodity recovery from biomass on southern forest land. And, the process should be energy self-sufficient.

The machines and products are as follows

Machines

1. Tree puller (harvests central root mass along with stem)
2. Mobile chipper (recovers residual biomass)
3. Green fuel burner (burns small wet wood particles)

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4. Continuous dry kiln (makes straight studs from juvenile wood)
5. Shaping-lathe headrig (makes cants, peelers, and flakes)
6. Sequential velocity refiner (makes a high-strength mechanical pulp)

### Products

1. Structural exterior flakeboard from mixed species
2. Composite structural panels with veneer faces and flake cores
3. Medium-density fiberboard
4. Lumber laminated from veneer
5. Straight, kiln-dried southern pine studs from veneer cores and small logs
6. Dowel-laminated crossties (no adhesive needed)
7. Shipping containers from high-yield thermomechanical pulp (instead of 50%-yield kraft)
8. Adhesives from southern pine or hardwood bark
9. Hog fuel (hardly a new product, but certainly important again)

### PRESENT AND PROPOSED USE OF BIOMASS

Southern pine biomass is composed of the following (Howard 1973)

<u>Biomass components</u>	<u>Percent</u>
Foliage	4.0
Stembark	12.5
Stemwood to 4-inch top	58.5
Barky tops and branches	8.5
Central root mass	<u>16.5</u>
TOTAL	<u>100.0</u>

Hardwoods on pine sites have slightly higher percentages of biomass in bark and tops than southern pine, and less in stemwood.

Sawmills cutting lumber from trees grown on southern pine sites convert about 40 percent (or less) of the volume of bark-free stemwood into dry sized lumber; while all pine logs in pine saw-timber stands are sawn, only about 10 percent of the hardwood volume in such a stand is sawn. The lumber yield percentage of the biomass is (fraction of stemwood sawn) x (sawmill recovery) x (biomass fraction). Assuming the biomass fraction of pine is 1/1.8 and hardwood is 0.8/1.8, the lumber yield for pine is (0.585) (0.4) (1/1.8) x 100 = 13.0%, and for hardwood, (0.1) (0.4) (0.8/1.8) x 100 = 1.8%. Thus, output of dry sized lumber expressed as a fraction of total biomass is only 14.8 percent. Additional fractions of pine stemwood are converted to pulp chips and pulped with 50-percent yield, and planer shavings are converted to particleboard. With the addition of these byproducts, perhaps 22 percent of the total biomass becomes lumber, paper, or particleboard.

Kraft pulp mills ship about 1/2-pound of paper for each pound of wood pulped, and for every pound of pine pulped, perhaps 1/4 pound of hardwood is pulped. Thus, output of paper expressed as a percentage of total biomass of cordwood stands is about 20 percent:

$$\text{Paper yield, percent} = \frac{(1)(0.585)(1/2) + (0.25)(.585)(1/2)}{1.8} = 20.4\%$$

The BRUSH system (Figure 1) could recover about 67 percent of tree biomass of all species (Table 1) as solid wood products salable at perhaps \$150 per dry ton. Product yield would be 3 times that currently obtained in sawmills (67%/22%) and 3.3 times that obtained in kraft pulp mills (67%/20%).

#### HOW BRUSH WORKS

Trees 5 to 12 inches in dbh of all species are harvested with the central root mass intact by a tree puller developed by the Southern Forest Experiment Station (Figure 2). Trees larger than 12 inches are cut 6 inches above ground level. Tops and limbs are severed on the site, and full-length stems (including roots) are transported to the mill. Tops, branches, and all residual trees are chipped in place with a mobile chipper (Figure 3), and the chips are then hauled to the mill and screened; half are used for fuel and half for core flakes made on a ring-flaker. At the mill

Table 1. Merchantable solid-wood recovered by proposed facility for processing mixed species.

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

<sup>1/</sup> 25% recovered as flakeboard furnish

<sup>2/</sup> 50% recovered as flakeboard furnish

<sup>3/</sup> These residues recycled by fiberizing and used as flakeboard furnish

<sup>4/</sup> Most of this, except foliage, ends as fuel

Table 2. Annual output by product<sup>1/</sup>

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

<sup>1/</sup> 100 effective operating hours per week, 50 weeks per year

merchandising deck, roots and bark are removed from the stem. The bark and most of each root are used as fuel (Figure 4); about one-quarter of each root becomes 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 inches in diameter are cut in 8-1/2-foot lengths and a shaping-lathe headrig (Figure 5, bottom, left) converts them into face flakes and cants that are later dowel-laminated into 7- by 9-inch mainline crossties (Figure 6). Hardwood bolts 5 to 8.5 inches in diameter are converted on a 54-inch shaping-lathe headrig (Figure 5, top) to face flakes and pallet cants for deck boards and stringers (Figure 7). Hardwood less than 5 inches in diameter and rotted bolts are chipped and ring-flaked into core flakes.

With pine, 8-foot logs with diameters as small as 8 inches are rounded on a shaping-lathe (Figure 5, bottom right), producing flakes and perfect cylinders to be peeled into 1/4-inch veneer. The veneer is then parallel-laminated into wide, long structural lumber (Figure 8). Veneer cores and small pine logs are converted on another shaping-lathe headrig into flakes and cants for resawing into studs (Figure 9). Very small bolts are chipped and ring-flaked into core flakes.

Thus, output of the plant is crossties (Figure 6), pallets (Figure 7), studs (Figures 9 and 11), structural exterior flake-board (Figures 10 and 11) 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-inch veneer (Figures 8 and 11). A plant equipped with 7 shaping-lathe headrigs and a rotary veneer lathe would produce about 585,000 tons of product annually (Table 2) and be energy self-sufficient.

#### LAND BASE, SALES, COSTS, AND MILL CAPACITY

##### Land Base Required

Let us assume that our long-range objective is to bring to full productivity land that supports half pine and half mixed hardwoods and averages 100 small stems per acre at harvest in trees 7 inches dbh and larger (average 10.5 inches dbh). The average dry biomass (above- and below-ground parts) of such trees is 650 pounds.

Next, let us assume that a mill processes 360 trees per hour for 100 hours each week, 50 weeks a year. Annually the plant uses 1,800,000 trees with total oven-dry biomass of 585,000 tons cut from

18,000 acres. Over a rotation of 25 years, 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 were 585,000 tons (oven-dry) and 67% was converted to products selling for \$150 per dry ton net fob mill, then annual sales would total \$58,793,000 (i.e.,  $585,000 \times .67 \times \$150$ ). Actually, biomass harvested would considerably exceed 585,000 tons annually because of tonnage recovered from residual trees and brush before initial planting, because of thinnings that could be made 15 and 20 years after planting, and because of heavy final cuts at 25 years.

### Stumpage Costs

How would the land base be assembled, and what would the stumpage cost? My premise is that many people owning 100 to 1,000 acres would be willing to put their property into the land base if they could be assured of an annual cash income of perhaps \$23 per acre and be relieved of all management and regeneration costs.

Assuming a 25-year rotation after planting, total cash income to the farmer, spread over 25 years, would be \$575 per acre. We will assume that he leases his land the year it 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 owner retains use of his land for recreation, hunting, and other non-timber uses.

What are the costs of such an arrangement to the company operating BRUSH? When each acre is leased, the present cost (\$246) of an 8% annuity paying \$23 per acre annually for 25 years would be due. To this immediate expense must be added about \$42 per acre for planting; the planting cost would be this low because of the extensive site preparation provided during harvesting. Total immediate expense per acre leased 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%)	<u>91</u>
Total present value	

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 chipper would yield additional fuel. The commercial thinnings at ages 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 be \$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-year thinnings commenced, again when the 20-year thinnings came due, and still again when final cut began -- but stumpage costs would not change.

#### Shaping-Lathe Headrig Capacity

Six trees per minute crossing the merchandising deck could yield four or five 8½-foot hardwood logs per minute large enough (8.5 inches minimum diameter) to yield a half-tie and four or five 8-foot pine bolts large enough to be peeled (8-inch diameter or larger). Thus, one 8½-foot crosstie headrig would be required for hardwoods and one 8-foot roundup headrig and a rotary veneer lathe for pine.

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

Finally, one might expect that the tree merchandising deck would yield 15 to 18 bolts per minute measuring 40 to 53 inches long and 5 to 8 1/2 inches in diameter; conversion of this boltwood (mostly hardwood) would call for three 54-inch shaping-lathes.

Total headrig complement would therefore be seven shaping-lathes: an 8½-foot crosstie machine, an 8-foot roundup machine, two 8-foot canters for studs, and three 54-inch machines for pallet cants. Additionally, an 8-foot veneer lathe would be required, as well as cant resaws. These machines would yield a product mix about as shown in Table 2.

## ALTERNATIVE PRODUCTS

### Composite Panels

It is possible that, rather than flakeboard, a structural composite panel of veneer faces over a flake core will be marketed to compete with plywood. Only slight revision of the layout shown in figure 1 would be required to manufacture such panels. To this end, logs would be rounded on a shaping-lathe to perfect cylinders (resulting flakes serving as panel cores) and these cylinders rotary peeled to yield panel faces. Springate et al. (1978), and Springate (1978) have explained the profit potential of such a manufacturing system.

### Adhesive

Adhesive for composite panels, for flakeboard, and for lumber laminated from veneer may possibly be derived from the phenolic content of southern pine or oak bark. Research is underway (Hemingway 1978, Schroeder<sup>2/</sup>). A practical process for industry is not available, but the next decade could see substantial progress.

### Paper and Fiberboard

As described, the system yields no paper or fiberboard, although both are important commodities from southern forests

Achievement of 67-percent product yield from total biomass obviously cannot be achieved by a kraft process with a 50-percent

<sup>2/</sup> Personal communication, January 1978 with H.A. Schroeder, Colorado State University, regarding tannin and catechin content of oak barks.

yield. Headrig flakes or clean chips salvaged by the mobile chipper could be processed by a new pulping device (Figure 12) to yield high-strength high-yield paper for containers. The device, described by McMillin (1977) and called a sequential velocity refiner, should yield nearly one pound of pulp from each pound of wood.

Also, fiberboards of low, medium, or high density (Figure 13) could be manufactured from flakes and residual chips instead of the structural flakeboard called for in Figure 1 (Woodson 1976a, 1976b, 1977; Suchsland and Woodson 1976).

#### CONCLUSION

The flexible system that I have proposed can yield a range of commodities that will satisfy major product demands on southern forests and triple commodity recovery from them. Other reasons for seriously considering the proposed manufacturing system are:

The raw material is now underused and is available in many southern (or 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 generous net return to the landholder, thereby encouraging increased production from now poorly managed private non-industrial woodlands in the South.

- Yet, cost of new material to the mill is low.
- Long-term practice of the system need not lead to a pine monoculture but could result in substantial mixed-species upland forests.

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DISCUSSION

Question: What kind of residual material do you have to have to make it feasible?

Answer: We need 25 to 26 tons per acre on the ground after harvest. We think we can recover 85 percent of it and we will lose 5 percent of that in transfer from roadside piles in hauling residual materials to the mill. So we can get 20 tons per acre to the mill. We will schedule it 9 hrs. a day, 7 days a week with 38 percent down time for repairs and 16 percent down time because of rain. Thus, operating time will be 46 percent of the scheduled time. Therefore, we should be able to cover 1500 acres per year.

Question: What is the effect of steep terrain and rocks on the mobile chipper?

Answer: It cannot be used on steep terrain or rocky areas such as the Ozarks.

Question: Is there a possibility of sorting chips by size in the mobile chipper?

Answer: Yes.

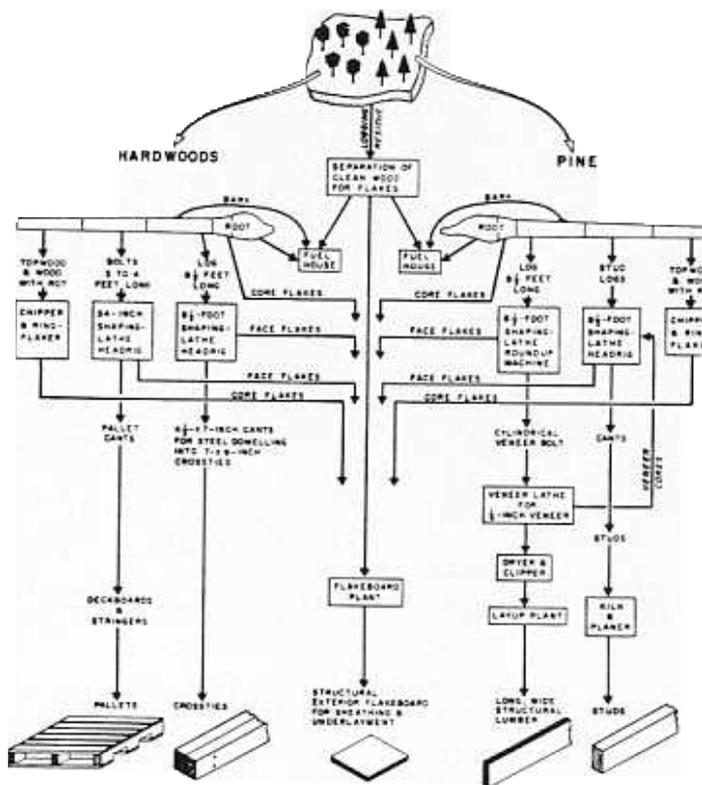
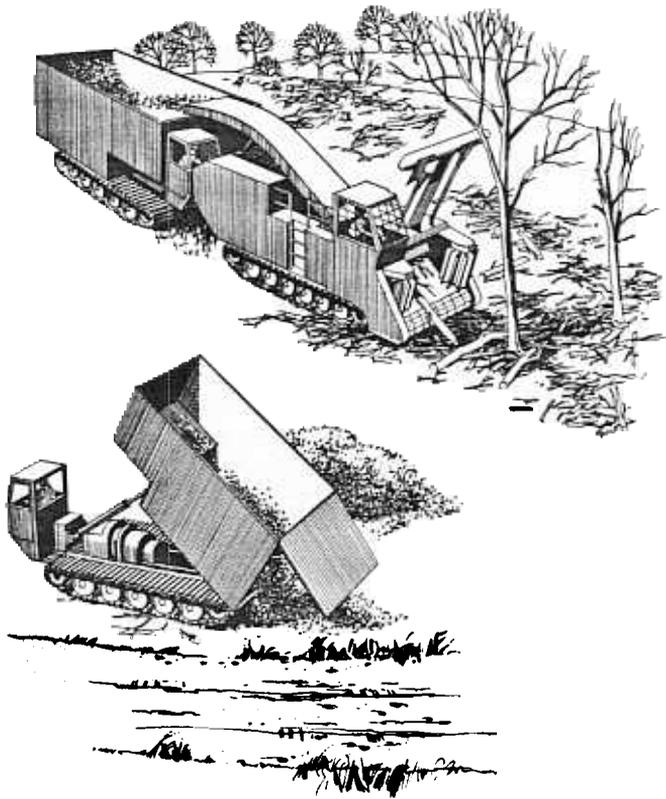


Figure 1. Flow plan whereby 67 percent of above- and below-ground biomass of trees in mixed-species southern forests ends as pallets, crossties, structural exterior flakeboard, long wide structural lumber, or as studs. The system is self-sufficient in energy.



Figure 2. Complete loblolly pine tree, with taproot attached, pulled from the soil like a carrot after lateral roots have been severed (Koch 1976, 1977). Small hardwoods can also be pulled with this equipment.



**Figure 3.** Mobile chipper and forwarders for retrieval of cull trees and logging residues. The machines are capable of traversing an acre an hour and delivering chips to roadside inventory (Koch and Nicholson 1978).

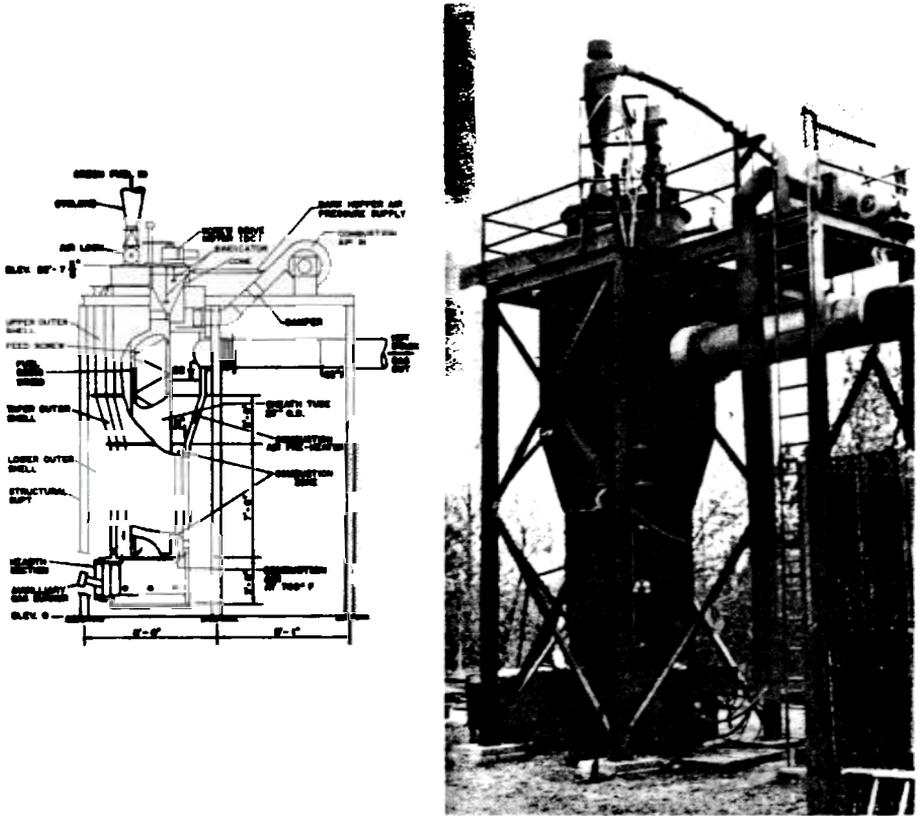
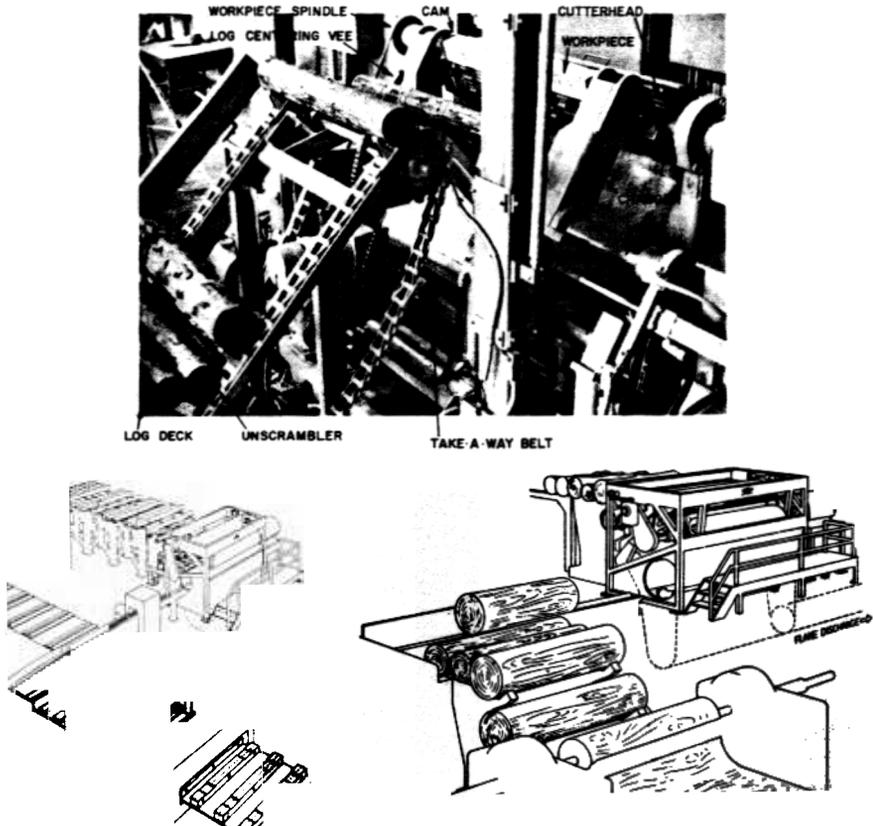


Figure 4. Suspension burner for hogged green wood or bark. Exiting hot exhaust gas can directly heat kiln, or can heat a boiler to produce steam for process use and power generation. (Left) Diagram of flow of fuel, combustion air and exhaust gas. (Right) Complete burner operating in North Portland, Oregon test facility (Koch, Day, and Jasper 1978).



**Figure 5** Three configurations of the shaping-lathe headrig to make cants or cylinders plus flakes. (Top) Machine for logs 40 to 53 inches long and 4 to 12 inches in diameter it is primarily a pallet-cant producer. (Bottom left) Nine-foot model for production of railroad crossties, highway posts, and cants to be resawn from logs 6 to 9 feet long and up to 15 inches in diameter. (Bottom right) Roundup machine to produce flakes plus perfect cylinders, i.e., peeler bolts from logs 8-1/2 feet long and up to 30 inches in diameter. For description of these machines see Koch (1975), Koch and Caughey (1978), Springate et al (1978), and Springate (1978).

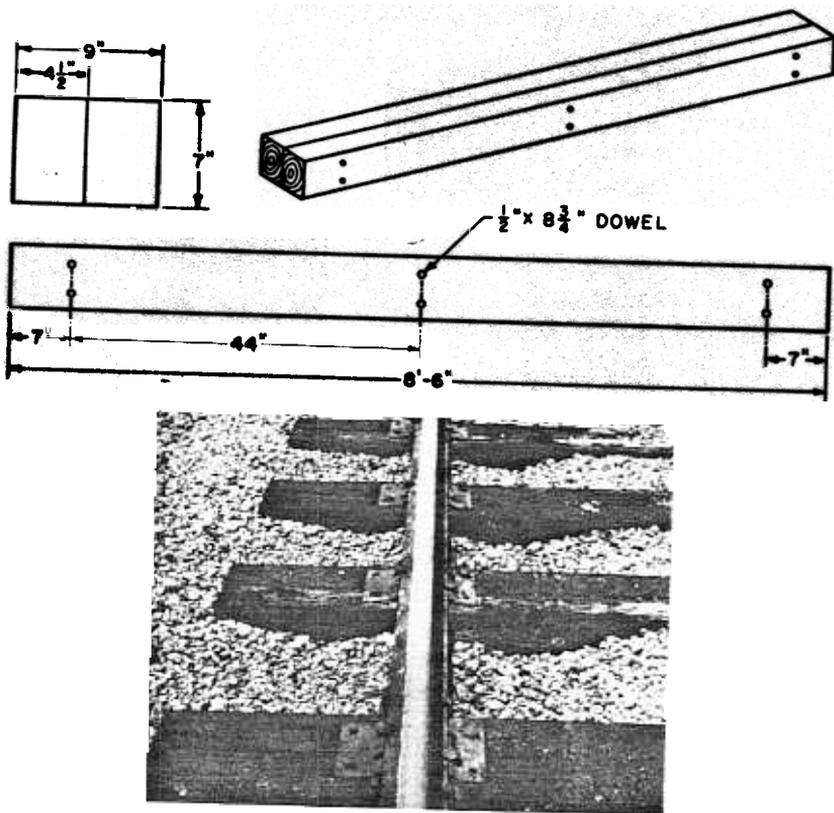
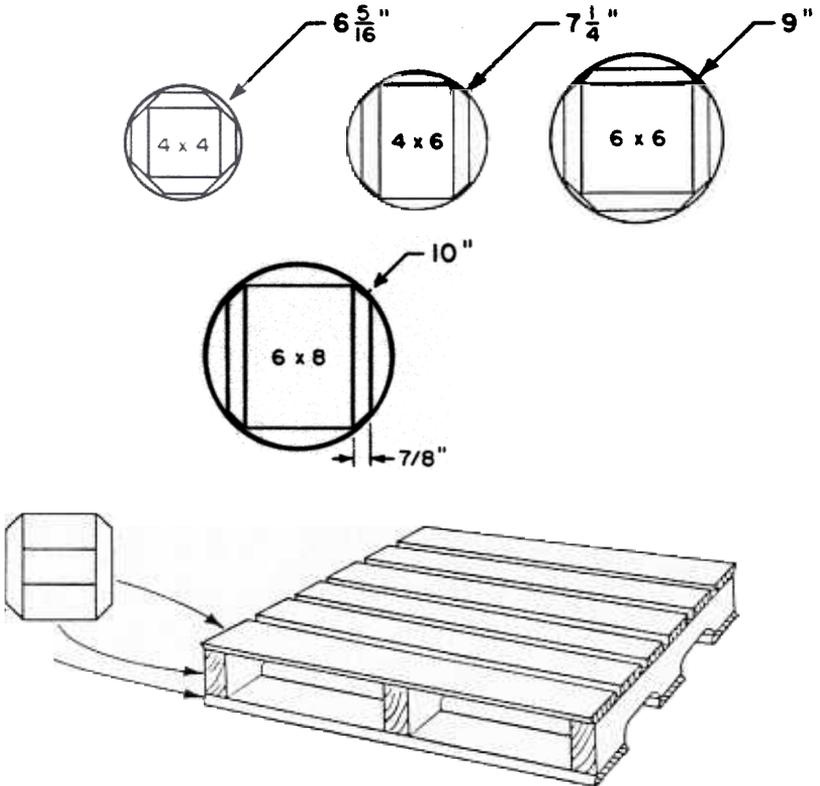
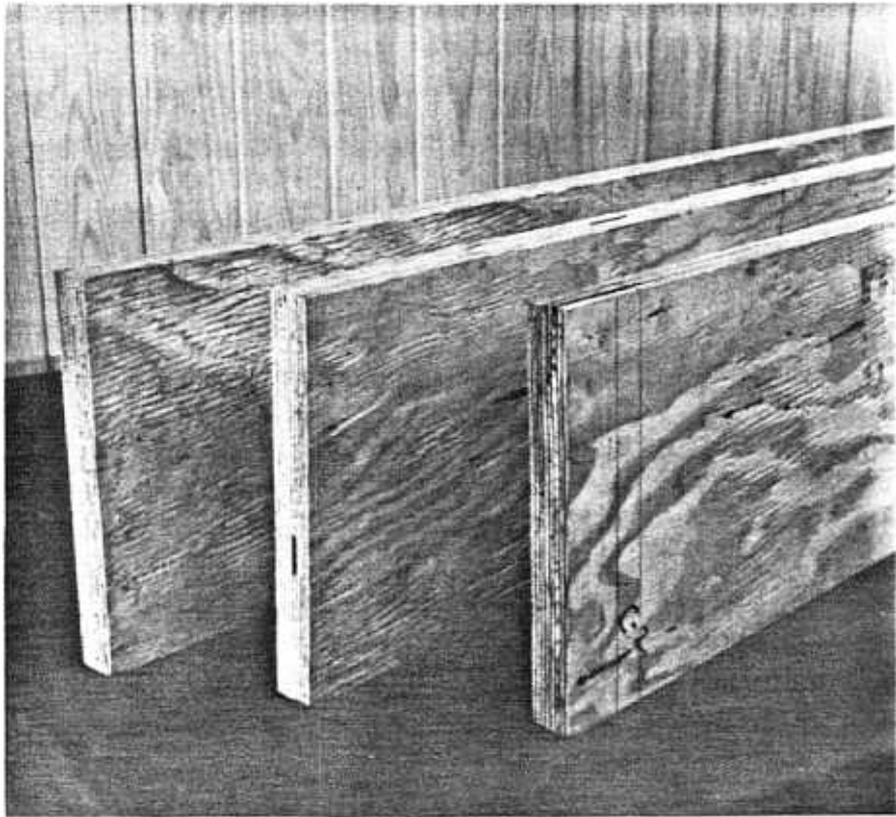


Figure 6. (Top) Dowel-laminated mainline crosstie secured with three pairs of 1/2-inch spirally fluted steel dowels. No adhesive used. (Bottom) These steel-doweled mainline ties have been in place 16 years (12 years at time of photograph) and have given service comparable with one-piece ties. Such dowel-laminated ties can be made from logs 8.5 inches in diameter, a size in plentiful supply (Howe and Koch 1974).



**Figure 7** When square-edged lumber is ripped from the center of octagonal cants and bevel-edges deckboards are cut from outer portions, lumber recovery from diameter-sorted logs should be about 7.5 board feet of 7/8-inch-thick boards per cubic foot of log. Properties of southern hardwood pallets are described by Stern (1978).



**Twelve-inch-deep joists manufactured from rotary-peeled thick southern pine veneer. Such joists are stronger and stiffer than ordinary lumber sawn from matched logs (Koch 1973).**

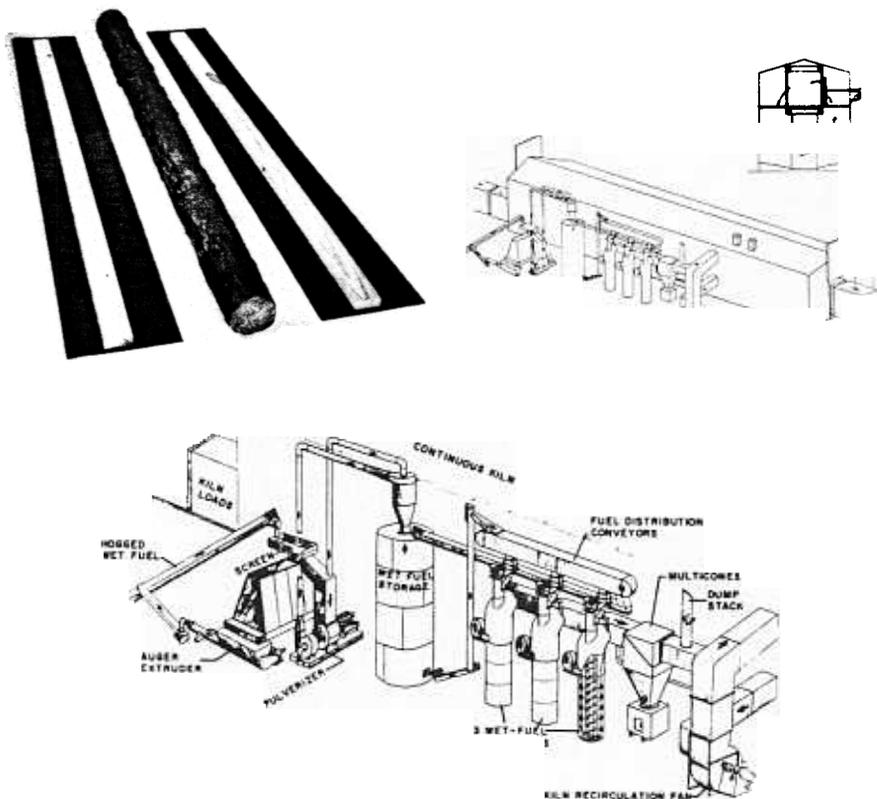
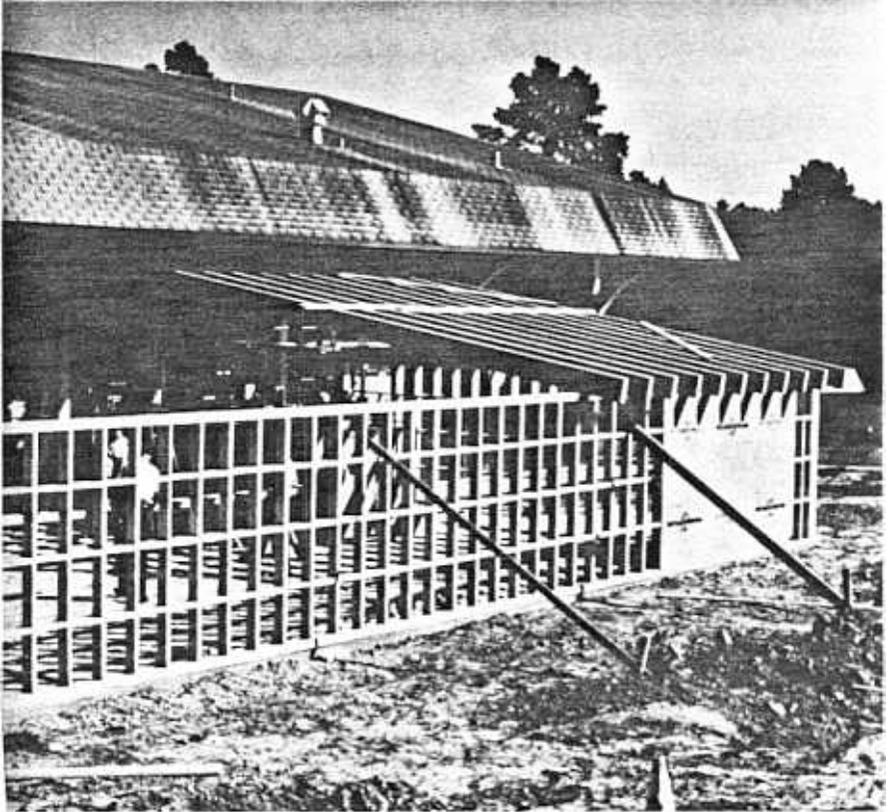


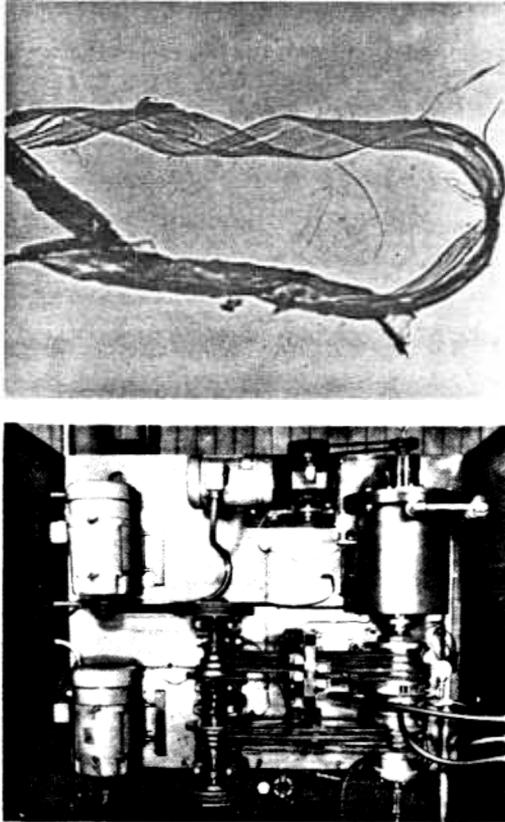
Figure 9. (Top left) Straight studs from small southern pine logs. (Top right) Continuous tunnel kiln to dry such studs in 12 hours; it is direct-fired with three suspension burners fueled with green hog fuel or bark; inset shows transverse cross section of 5-foot wide by 10-foot high kiln stack top-loaded (to prevent warp) with caterpillar-like track having 12-inch-thick concrete flights. (Bottom) Direct-firing arrangement; each burner consumes 1,500 pounds of green bark per hour. Kiln output is 500,000 board feet per week (Koch et al 1978).



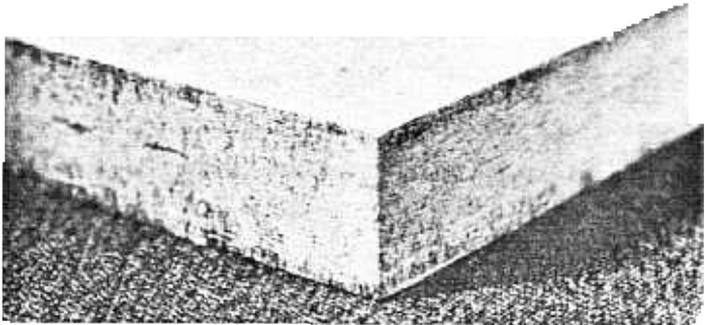
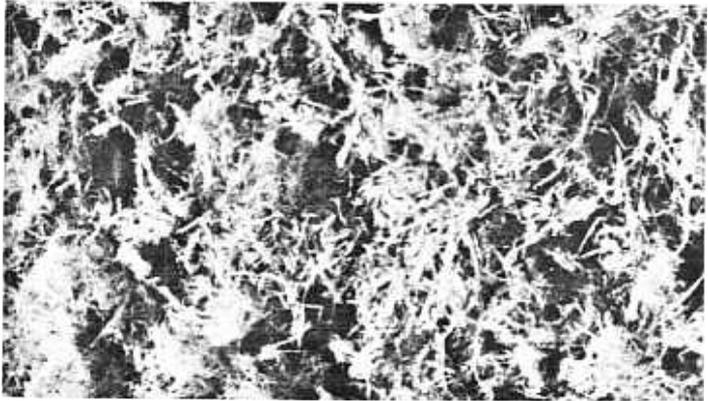
Figure 10. Cants produced on the shaping-lathe headrig may be rectangular or octagonal as well as square, hexagonal, or round. Flakes residual from the machining operation are typically 3 inches long and 0.015 or 0.025 inch thick. With addition of phenol-formaldehyde resin, these flakes can be hot-pressed to yield exterior structural panels of exceptional strength and stiffness (Hse et al. 1975, Price 1978).



**Figure 11** Roof and wall sheathing on this shed is structural exterior flakeboard. The rafters, which are 24 inches on centers, measure 3 inches thick and 32 feet, 10 inches long; they are fabricated from rotary-peeled veneer and are designed to take a roof load of 39 pounds per square foot (live plus dead load) without exceeding 1.5 inches deflection over a 30-foot span. Studs are of southern pine.



**Figure 12** (Top) Unwound southern pine tracheid provides coherence needed for strength in sheets made from mechanical pulp. (Bottom) Laboratory prototype sequential velocity fiber refiner promotes formation of such ribbonlike elements (McMillin 1977).



**Figure 13** Fibers disk refined from southern red oak (top) can be used to make a fiberboard (bottom) that is 3/4-inch thick and weighs 42 pounds per cubic foot when at 7-percent moisture content. Modulus of elasticity is 367,000 psi, and modulus of rupture is 3,190 psi. The process permits use of all hardwood species on pine sites as well as southern pine (Suchsland and Woodson 1976).