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Cover: Commercial prototype of a swathe-felling mobile chipper operating in red alder near Seattle, Washington. The machine fells standing trees and picks up logging debris and down trees.

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Development of the Swathe-Felling Mobile Chipper

Peter Koch and Thomas E. Savage

ABSTRACT—A harvesting machine and auxiliary equipment are being developed to recover logging residues as chips for fuel and fiber, and to deliver these chips to mills at about $18 per green ton including 30 percent pre-tax profit on the equipment investment. The harvester, a 575-horsepower tracked mobile chipper equipped with a front-mounted felling bar, was field-tested on red alder stands (Alnus rubra *Bong.) north of Seattle, Washington, during July and August 1979. On the basis of these preliminary tests, the institutions and companies cooperating in the development have scheduled extensive southern field trials for 1980. If the machine meets its performance goals, it could harvest 30,000 tons of green cull wood from about 1,500 acres annually.*

Conversion of unmanaged southern forests to pine plantations and cultivation of ensuing rotations necessitate brush control, thinning, and disposal of logging slash. In the South, brush is usually controlled by periodic prescribed burning or by injecting or spraying with herbicides. Trees are thinned by many mechanical methods, all of which waste tons of wood. After crop trees are felled, the tops, branches, stumps, and noncommercial trees are usually windrowed and burned to facilitate planting of the new stand.

This paper describes a way to accomplish these operations with a mobile machine that chips residual wood and delivers the chips into mobile bins that carry them to roadside piles. Such chips can serve as fuel or fiber for nearby mills. The system is an adaptation of that suggested by Koch and McKenzie (1976).

Besides providing a degree of energy self-sufficiency for timber companies operating mills, the system proposed has several other benefits:

- Changes the capital investment for site preparation to a harvesting expense.
- Should improve public reaction to harvesting because it eliminates waste wood and unsightly slash.
- Eliminates the smoke that occurs in windrow-and-burn operations.
- Compared with the windrow-and-burn system, increases (by perhaps 10 percent) the plantable area—because not all windrows are completely burnt.
- Protects land productivity, because scalping inherent in pile-and-burn operations is eliminated.
- Hastens replanting by several months, because harvesting accomplishes site preparation.
- Because no wood is skidded over the ground, wood delivered via mobile chipper and chip forwarding bins should be essentially free of dirt.

The first step in making the proposed system practical was to develop a commercial mobile harvester. After considering many designs, we decided on one in which a ground-level cylindrical felling bar feeds a drum chipper *(fig. 1)*. Material from a drum chipper is easier to handle in conveyors than chunks from a hammer-type hogging head. Also, chips have more potential than chunks for use in fiber products, which are more valuable than fuel.

To develop a prototype commercial machine, the Southern Forest Experiment Station of the Forest Service, five timber companies with southern operations, and Nicholson Manufacturing Company signed a cooperative agreement in March 1977. The U.S. Energy Research and Development Administration (now the Department of Energy) contributed substantially to the cooperatively funded effort.

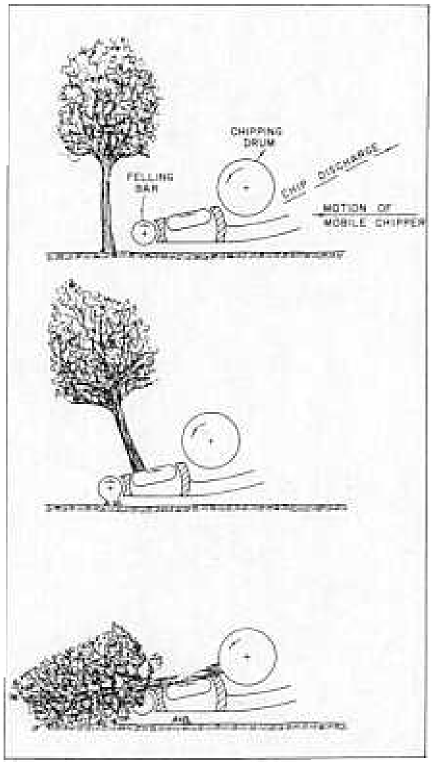


Figure 1. Concept of mobile machine with a felling bar arranged to feed a drum chipper. (Top) *Approaching tree.* (Center) *Butt of severed stem thrown rearward to rest on live bed.* (Bottom) *Felled tree moving into drum chipper through feeding action of felling bar and live bed, self-feeding action of drum chipper, and forward motion of the machine.*

Performance goals were that the machine should:

- Operate primarily on terrain that is stone-free, has a slope of 30 percent or less, and supports 8 psi in wheel or track pressure.
- Harvest one acre per hour at 1 mile per hour on land averaging 25 tons (green weight) of logging residue and standing culls per acre.
- Fell and chip southern hardwood and softwood stems up to 12 inches in

diameter (measured 6 inches above ground level) while moving at 1 mile per hour.
- Mill off the top of 12-inch diameter stumps to 6-inch height while traveling at 1 mile per hour (larger stumps at slower speeds).
- Pick up and feed into the drum chipper the tops, branches, and cull stem sections left by loggers.
- Chip felled stem sections up to 19 inches in diameter if properly oriented to the infeeding hopper and if large limbs are notched by chain saw for improved feeding.

Testing the Concept

Koch and Nicholson (1978) reported early trials of the felling-bar concept. Tests during summer and autumn of 1977 measured horsepower, feed thrust needed parallel to the ground, and down thrust on the bar. In January 1978, a felling bar was coupled with a drum chipper (as shown in *figure 1* but without the live bed between felling bar and chipper) and power requirements were monitored while the machine felled and chipped stems of several hardwood and softwood species.

Commercial Prototype

After these tests, a commercial prototype was designed for assembly on the lower hull, undercarriage, and lengthened tracks of an FMC skidder *(cover photo* and *figs. 2, 3,* and *4).* The machine has a 575-horsepower Cummins diesel engine, which powers all functions *(fig. 5).* To better feed brush and logs into the drum chipper, the machine has two semi-vertical side-feed rollers; their direction of rotation can be reversed so that stems lying crosswise to machine travel can be moved for easier pickup. The cab is positioned to give the operator a view of the felling bar. Placed above the bar is a pivoted crowder hydraulically actuated to push brush into the drum chipper *(figs. 2* and *3)* and to break stems that lie transversely across the front of the machine.

The chipper is 9 feet and 2 inches in width and 26 feet long. With the chip spout lowered for travel, the machine's height is 11½ feet. Other specifications are:

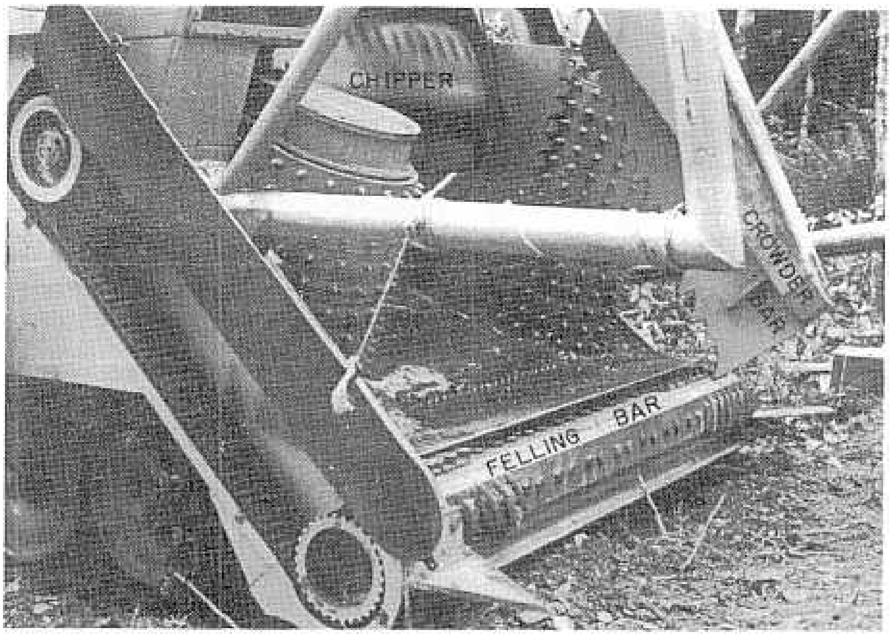
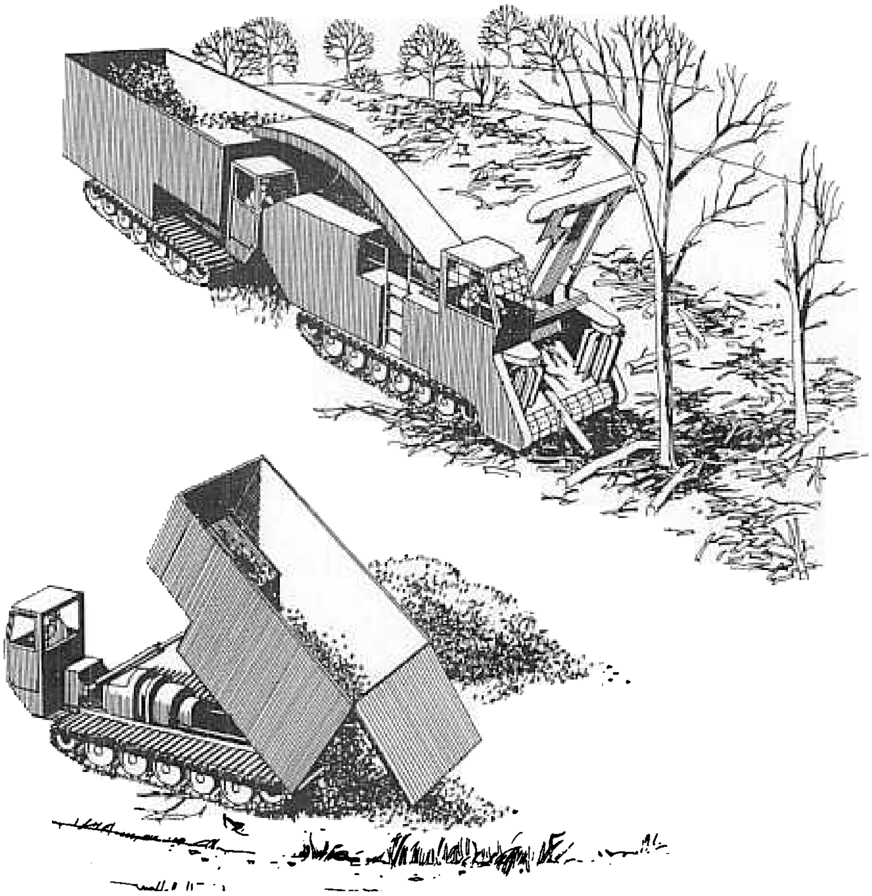


Figure 2. Felling bar extending width of machine and arranged to thrust butt-ends of severed stems toward drum chipper at upper center. Access door to felling-bar drive open to expose belt driven by hydraulic motor. Crowder bar shown partially depressed. Two toothed rolls set horizontally in lower surface of chipper throat will be replaced by a live bed.

Figure 3. Felling an 11-inch red alder. See cover photo for sequence.

Gross vehicle weight	72,000 lbs.
Approx. ground contact area with 2-inch penetration of tracks	6,740 sq. in.
Approx. ground pressure	10.7 psi
Drum chipper characteristics	
Cutting-circle diameter	48.0 in.
Spout width	47.5 in.
Number of knives	3
Rake angle of knives	52.5°
Drum speed	544 rpm
Nominal feed speed	136 ft./min.
Felling bar characteristics	
Cutting-circle diameter	16.5 in.
Length	93.5 in.
Number of knives	4
Rake angle of knives	38.5°
Rotational speed	0-600 rpm
Clearance above ground	2 to 7 in.
Diameter of side feed rolls	24 in.
Machine ground speed	Creeping to 3 mph.



This commercial prototype was first tested in the field during the summer and early fall of 1979 in stands of red alder north of Seattle, Washington. The trees were closely spaced, and the machine functioned best when operated in a race-course pattern on the stand periphery. When it penetrated directly into a dense stand, severed stems could not fall forward (tree crowns became entangled) and so

Figure 4. Mobile chipper and companion forwarders retrieve logging slash as chips and deposit them in roadside inventory piles. The three machines in combination should be mechanically functional (available) at least 62 percent of the time, and they should all operate at least 75 percent of the time they are available; non-operating time should therefore be 46.5 percent of scheduled time (i.e., 0.75 × 0.62 = 0.465). If the machine is scheduled 7 days per week, 9.6 hours per day, 48 weeks per year, actual operating time should total about 1,500 hours during which time it should harvest about 1,500 acres. If 20 tons (green basis) are delivered to the mill fuel pile from each acre, annual harvest should be about 30,000 tons of fuel chips.

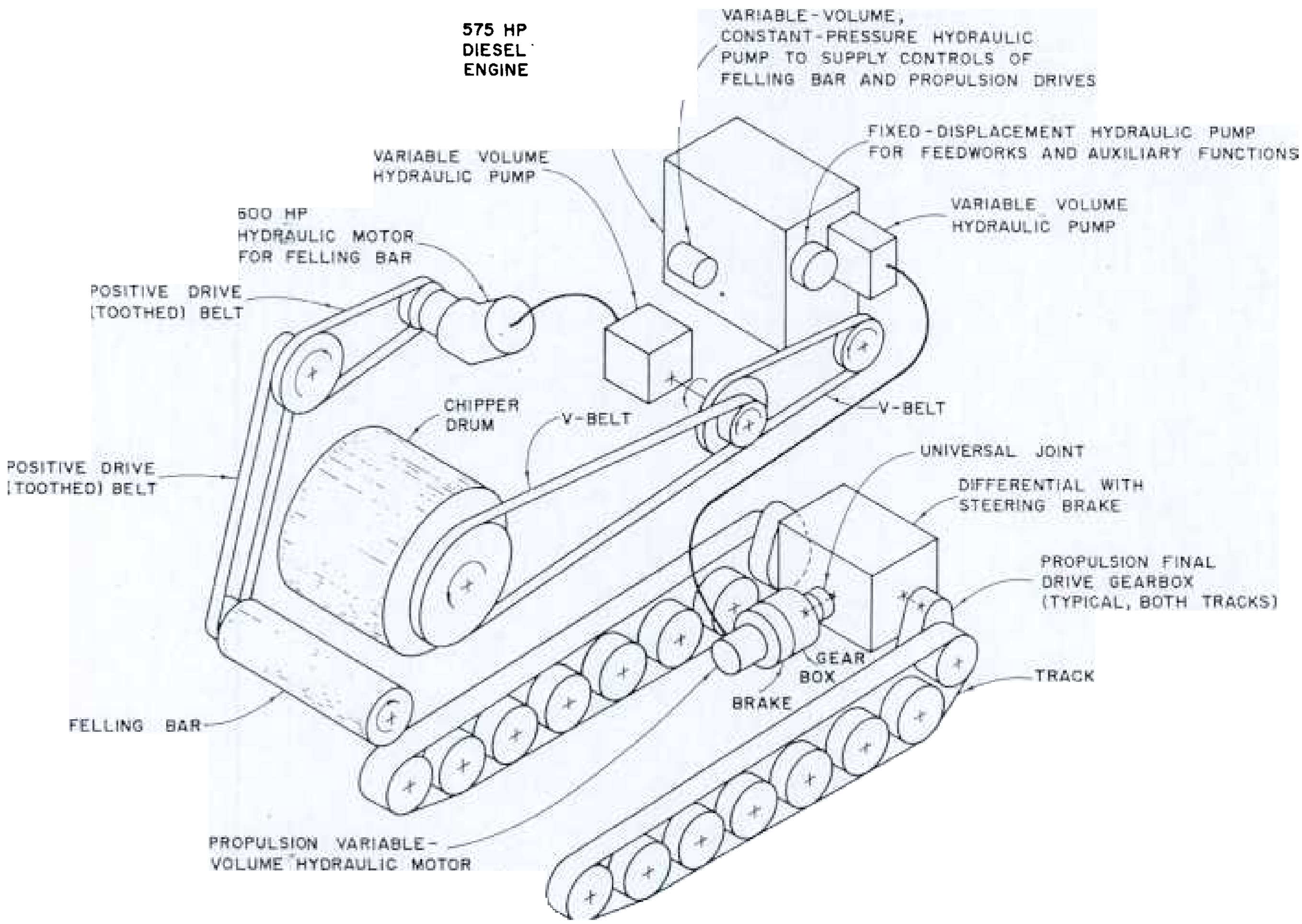


Figure 5. Drive train from diesel engine to felling bar, drum chipper, and tracks. The hydraulic motor is powered primarily by the diesel engine, but its short-term peak load capacity is increased by the flywheel effect of the chipper drum.

failed to get oriented for self-feeding into the chipping drum.

The felling bar, revolved at low speed, effectively picked up woody debris from the ground and delivered it to the chipping drum (*fig. 2*). When picking up logging slash and down trees, the machine worked best if stems were aligned parallel with machine travel. Pickup was least successful when stems lay transverse to machine travel. The crowder bar proved able to break 6-inch alder stems that lodged across the feed rolls, but its effectiveness will be enhanced by increasing its stroke speed. The crowder bar successfully thrust clumps of wood and brush toward the drum chipper.

Horsepower and speed were adequate for alder; when harvesting southern oaks and hickory the speed will be slower. Large-diameter stumps not visible to the operator may cause unplanned overloads. If the operator sees such stumps in time, he can slow forward travel or raise the felling bar a few inches (7 inches is the maximum) to clear some of them. Turning radius is large (about 40 feet) and steering control needs some improvements through more positive braking action, rearrangement of the steering-brake shoes, or addition of a system to lock the inside track during turns.

The cooperators were well impressed by chipper power, by the appearance of the site after harvesting (*fig. 6*), and by chip quality (*fig. 7*). Stump height—1 to 7 inches—was generally considered acceptable, although several observers felt that these stumps would require use of dibble-type planters rather than the simple and inexpensive coulter-type planters more common in the South. This is a critical issue, as a credit for site preparation of about $75 per acre seems needed to economically justify use of the machine. Stumps, even when cut flush with the ground, interfere with coulter-type planters. If stumps are not over 6 or 7 inches high and not too numerous, a coulter-type planter with short turning radius can circumvent them. Resulting tree rows will not be straight, and spacing will vary, depending on number and size of stumps.

Figure 6. Site after harvest. Performance goals call for pickup, in chip form, of 85 percent of the cull wood present on each acre harvested.

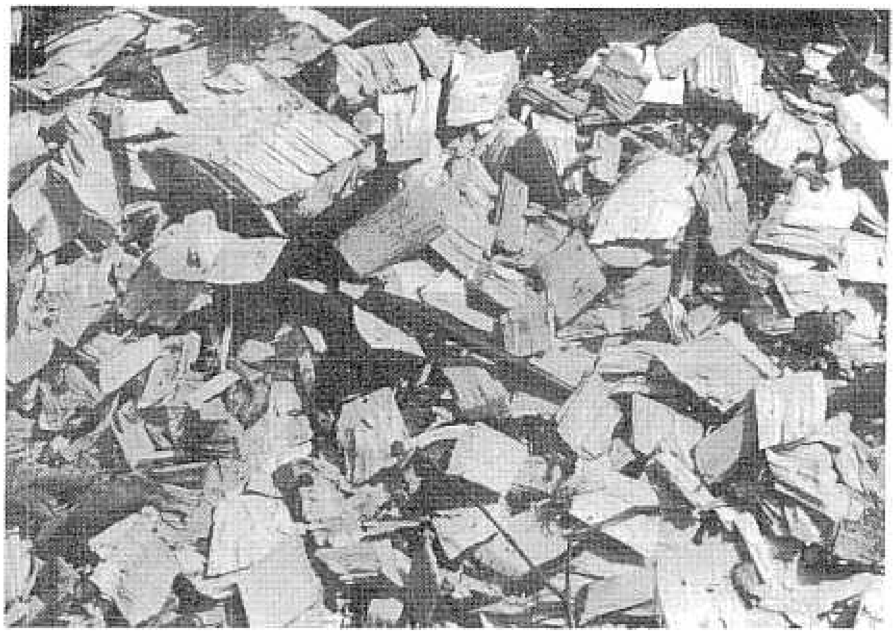


Figure 7. Red alder chips from drum chipper. Pen in center of photo is 5.5 inches long.

During the Seattle trials, frames were added to the front of the machine to help in directing the forward fall of severed trees (*fig. 3*). It also became evident that a live bed is needed to form the lower surface of the chipper throat between felling bar and drum chipper (*fig. 1*); such a bed would help thrust the butt of a severed tree toward the drum chipper. Additionally, knife geometry on the drum chipper must be designed to promote aggressive self-feeding.

The cooperators now plan extended field trials in the South. These southern trials, which will include extensive evaluation by Forest Service engineers, should begin during early 1980 near Auburn, Alabama. The manufacturer will then modify the design to improve performance and Forest Service engineers at Auburn will again test the machine. After these shakedown trials, performance will be studied during the spring, summer, and fall of 1980 on the cooperators' lands in the Carolinas, Louisiana, and Arkansas. Also, its effectiveness in site preparation will be evaluated by Forest Service silviculturists at Auburn, who will study nutrient leaching losses, woody and herbaceous vegetation control, and forage growth.

Overall weight of the machine—72,000 pounds—is cause for concern, for resulting ground pressure of 10.7 psi is too great for winter operation on many southern soils. Some redesign and material substitutions on later production models should reduce ground pressure to an acceptable 8 psi.

Economics

Trials conducted through September 1979 have not determined whether performance goals can be met under southern conditions, but with incorporation of revisions planned for early 1980, the outlook seems promising.

The earlier article (Koch and Nicholson 1978) projected that the harvested wood could be delivered to the mill for $13.57 per ton (green-weight basis), including a 30-percent pre-tax profit on an equipment investment of $470,000 per machine team (one mobile chipper, two self-powered chip forwarders, and support equipment). This cost is for harvesting logging slash and cull wood from 1,500 acres annually and simultaneously preparing the site. Recovery from these acres should be about 30,000 tons (green weight basis) of chips.

Inflation has increased these costs, which include profit, to about $18 per ton delivered to the mill (green basis). At the same time, oil costs have increased greatly. Though the price of $18 may appear high, a ton of these chips is worth about $36 if their heat content (taking into account boiler efficiency) is priced comparably with the heat content of No. 2 fuel oil costing $0.70 per gallon. And fuel oil prices may well reach, or exceed, $1 per gallon.

Perhaps certain classes of cull wood can be harvested more economically by existing methods than by the swathe-felling mobile chipper. For example, the central stump-root portions of southern pines 5 to 12 inches in d.b.h. can be harvested with tree puller-bunchers and grapple skidders at about $10 per green ton (Koch 1977). Also, throughout the South, tree-shear feller-bunchers teamed with grapple skidders can economically harvest cull trees 6 to 12 inches in d.b.h. at about $10 per green ton. But neither the tree puller-buncher nor the tree-shear feller-buncher can operate economically on a steady diet of logging slash or standing culls 5 inches and smaller in d.b.h. Such small material seems to invite use of the swathe-felling mobile chipper.

The southern field trials during 1980 should provide information on which to base more precise economic assessments. Data will be obtained on terrain for which the machine is best suited, percentage of available cull wood recovered as chips, machine operating time as a percentage of scheduled time, and acreage harvested per operating hour. ■

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The Authors—Peter Koch is chief wood scientist, Southern Forest Experiment Station, USDA Forest Service, Pineville, Louisiana. Thomas E. Savage is project engineer, Nicholson Manufacturing Company, Seattle, Washington.

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