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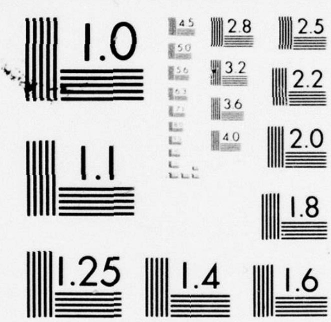

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Considerations in Selecting Wood as an Immediate Source of Reliable and Economical Energy for Military Installations

Steven A. Helms
US Army Facilities Engineering Support Agency
Technology Support Division
Fort Belvoir, Virginia 22060

1 December 1978

Notice

Comments

Comments on the contents of this report are encouraged, and should be submitted to:

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This report is an introduction to the state-of-the-art in wood harvesting, handling, procurement and combustion. Any decision to use wood as an energy source can only be made after careful consideration of the total system, i.e., stump to stack. This document contains or referenced sufficied back-up information that the reader can identify reliable sources of expertise.

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Table Of Contents

CONSIDERATIONS IN SELECTING WOOD AS AN IMMEDIATE SOURCE OF RELIABLE AND ECONOMICAL ENERGY FOR ARMY INSTALLATIONS

1.0 Purpose: This paper is an introduction to the state-of-the-art in wood harvesting, handling, procurement and combustion. Any decision to use wood as an energy source can only be made after careful consideration of the total system, i.e., stump to stack. This document contains or references sufficient back-up information that the reader can identify reliable sources of expertise.

2.0 Summary: The following subjects are discussed, with frequent reference to the sources of information:

Status of Wood Energy Utilization

Availability of supply

Economics of Wood fueled boilers

Direct combustion - Raw wood

Direct combustion - Densified wood

Gasification, Pyrolysis, alcohol production

Procurement and receiving of raw wood

Harvesting

Barriers to wood combustion

3.0 Status of Wood Energy Utilization: While wood alone will not solve this country's energy problems, there are large quantitites of renewable, underutilized wood that can be used as fuel at military installations (Appendix A, B, C). When compared to the cost of fossil fuels, wood is attractively priced.

In December 1977, a private utility in Michigan mixed wood with coal and achieved a reduction in pollutants. The US Air Force has converted a coal fired boiler to wood in order to meet pollution regulations. There are dozens of companies manufacturing wood fired boilers and thousands of these boilers are in use throughout the country.

Direct combustion is the only technology, in general usage across the country, for converting wood to energy. Gasification and pyrolysis are rapidly developing technologies that should offer distinct advantages when they mature.

Wood densification plants are not widely distributed in this country; therefore, the most likely fuel will be raw wood in the form of chips, sawdust or material that has been through a wood "hog."

Military installations can either harvest wood fuel or procure it on the open market. Design, procurement and utilization of efficient harvesting systems and resolution of institutional problems will require more lead time than installation of wood fired boilers.

If military installations install wood fired boilers and purchase fuel on the open market, procurement policies and receiving equipment must be similar to those prevailing in the immediate area; otherwise, wood fuel costs will increase.

4.0 Discussion:

4.1 Availability of supply: Wood alone will not solve this country's energy problem; however, there are large, renewable quantities of low grade wood that can be used to generate energy on a regional basis (Appendix A, B, C; Reference a). Sources of supply include wastes from woodworking industries and forest products industries, cull timber from forest management and land clearing operations, and low grade chips (limbs and bark) generated from whole tree pulpwood harvesting. There are large volumes of wood waste, either left on the ground or hauled to land fills, that would be used for fuel once the market develops. Specific sources would include contractors clearing land for re-forestation, subdivisions and utility right-of-way. While preparing this report, the author was offered one trailer load (approximately 22 tons) of sawdust and end trimmings per day from one plant.

Owners of wood fired boilers have found that mill residues are readily available for fuel; however, it generally conceded that this source will disappear as the number of these boilers increases. In anticipation of this shortage, boiler owners are turning to forest residue. This is an untapped resource and contract harvesters have found

a. Near Term Potential of Wood as a Fuel - HGP/T 4101-02 UC-61 Prepared for the Department of Energy by Mitre Corporation (Aug 78).

a buyers market. Forest experts project sufficient volumes of forest residue to support large numbers of wood fired boilers. These experts also see harvesting of forest residue as essential to proper forest management.

4.2 Economics - The following table is based on current prices for pulpwood grade chips and conventional fuel:

	Fuel Cost Per MBTU	Price (Delivered to Plant)	Energy Content
No. 2 Fuel Oil	$ 3.45	$ .48/gal	138,700 BTU/Gal
No. 6 Fuel Oil	1.94	.29/gal	149,690 BTU/Gal
Natural gas	2.42	2.40/KCF	1,000,000 BTU/KCF
Coal	1.97	50.00/T	12,700 BTU/Lb
Pelletized Wood	2.00	28.00/T	7,000 BTU/Lb
Wood Chips (Green)	1.33	12.00/T	4,500 BTU/Lb
Saw Dust (Green)	.89	8.00/T	4,500 BTU/Lb

See Appendix E, H and Reference b, c for more detail discussion and specific experience with the economics of wood as an energy source.

As the number of wood fired boilers increases, adjustments in fuel costs are to be expected. The ultimate, stable price of this fuel is subject to conjecture; however, an educated guess is in order. Within the next 3 - 5 years, the increasing popularity of wood fuel should increase the demand for underutilized wood. So long as the supply exceeds the demand, prices will be less than that of pulpwood chips. As the supply of underutilied wood diminishes, wood and coal should become competitive in terms of dollars per BTU. In other words, boilers and pulp mills will be bidding for the same raw material. Of course there are numerous, unquantifiable factors that could influence this projection, i.e., developments in coal and wood gasification, evolving pollution problems attributable to wood combustion, increased utilization of wood fiber by the pulp industry, etc.

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b. Morford, James V. Supplemental Wood Fuel Experiment - Interim Report, Board of Light and Power, Grand Haven, Michigan (9 Jan 78).

c. "Woodpower Generates Utility Savings," The American City and County (Mar 78).

A detail economic anaysis must precede any decision to install wood fired boilers. There will be applications where either coal or oil will be the most cost effective fuel.

4.3 Direct Combustion - Raw Wood

Wood fired boilers have been used for decades to produce process steam for industrial use (Reference a. and Appendix F). These boilers are commercially available from a variety of sources in the range of 1 - 150 MBTU/Hr. See Appendix G for a partial list of customers using these boilers. Appendix I contains a list of boiler manufacturers.

At least one New England utility is proceeding with plans to install a wood chip fired electric generating station (Reference c).

A utility in Colorado has been burning green sawdust mixed with coal for over four years. Benefits include less ash, reduced maintenance costs, lower fuel costs ($6 per ton for delivered sawdust) and less air pollution. Sawdust constitutes approximately 20% of the fuel burned at this power plant. (Appendix H and Reference d.)

A utility in Michigan successfully mixed wood chips with coal and found many benefits, including a significant reduction in stack emissions. This utility projects a $1,000,000 annual saving by using high sulfur coal and wood supplement in lieu of low sulfur coal (Reference b). The utility initiated this test in December 1977, and suspended the wood burning in the Spring of 1978. Unfortunately, during this period sulfur emissions could not be measured and the plant is now burning low sulfur coal at $45 per ton. As a result of this test and the publicity that followed, several new sources of fuel appeared. One supplier offered pulverized bark at $8 per ton. Reject seed corn at a low moisture content and 7,000 BTU per pound was offered. The utility has received many inquiries from individuals and companies who are considering wood fired boilers. Testing is scheduled to resume in the Spring of 1979. (Reference e.)

Disadvantages inherent to direct combustion are the difficulty of handling the solid fuel and controlling the particulate emissions.

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d. Private Communication from W. Burnham, Southern Colorado Power, Canon City, Colorado (27 Nov 78).

e. Private Communication from J. V. Morford, Board of Light and Power, Grand Haven, Michigan (16 Nov 78).

The most obvious handling problem results from the lower BTU content and lower density of wood relative to coal. For a given BTU content, wood chip volume exceeds coal volume by a factor of approximately eight. With only minor modifications, coal handling equipment will also handle wood (Reference c).

While wood is virtually sulfur free, particulate emissions can exceed allowable limits if burning is not closely controlled to assure complete combustion (Appendix F and Reference e). As previously noted, utilities have achieved reduced stack emissions when burning a mixture of wood and coal.

While wood offers economic advantages over fossil fuels, perhaps the greatest benefit is the possibility of operating a solid fuel system capable of burning either wood or coal. This advantage should be carefully evaluated in the design phase of new boiler plants. This dual fuel option can be used to increase price competition and assure continued plant operation during periods of curtailment.

4.4 Direct Combustion - Densified Wood

Densification of wood and other biomass is practiced commercially with several suppliers marketing a product (Appendix J).

Compared to raw wood, densified wood offers the advantages of increased BTU content, low moisture content and uniform size; however, this product must be stored under cover to protect it from moisture. Other characteristics are similar to raw wood as previously discussed.

Densification plants are not yet widely distributed in this country. If military installations are able to guarantee a market for densified wood there are manufacturers that will build a plant in the vicinity; otherwise, densified wood may not be a viable fuel for many military installations. There is considerable discussion as to the cost/benefit of densified wood when compared to raw wood chips. A final choice can only be made after careful analysis of price, availability, handling differences, and the combustion characteristics of the particular boiler. Any boiler designed for raw wood chips will burn densified wood efficiently.

To meet air pollution standards, the Air Force is burning densified wood at Kingsley AFB, Oregon. This has been a successful program and the Air Force is pleased with the results (Reference f).

For additional discussion of densified wood fuel, see Appendix K.

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f. _Operation with Woodex Pellets for the Period 9 - 16 February 1978._ US Air Force Test Report (Unpublished).

4.5 Gasification, Pyrolysis, Alcohol Production

4.5.1 Gasification - The thermal conversion of biomass or coal to a gas that can be used in producing heat, power or chemical synthesis is called gasification. Gasification is a rapidly developing technology with demonstration units being installed at several locations across the country (see Appendix L). When the technology is developed, gasification promises to be a retrofit option for existing gas and oil fired boilers. Thus, the operator can fuel his boiler with biomass, gas or oil, depending on availability and price. Gasification also offers the advantage of pollution control at the "front end" of the boiler rather than at the stack. For more detail discussion of gasification, see Appendix M, N and reference a.

Gasification technology is not commercially developed and, therefore, not a viable option at this time. It is expected that the technology will mature rapidly and will ultimately offer attractive benefits to owners of oil and gas fired boilers.

4.5.2 Pyrolysis - Pyrolysis is the decomposition of organic material, such as agricultural and forestry products, with heat. Pyrolysis differs from direct combustion in that "burning" is accomplished in the absence of oxygen. Low BTU gas, char and oil (all fuels) are produced by the process. One such system has been developed at the Georgia Institute of Technology and has been licensed to the Tech-Air Corporation. For additional information on pyrolysis, see Appendix O and reference a.

Pyrolysis is a rapidly developing technology without immediate application in the Department of Defense.

4.5.3 Alcohol Production - The Department of Energy is actively funding research projects in an attempt to develop this technology (References g and h). For a review of the current state-of-the-art, refer to Appendix P.

Production of alcohol from biomass is a developing energy option for the future.

4.6 Procurement and Receiving of Raw Wood

If a decision is made to install wood fired boilers and procure raw wood on the open market, an appreciation and understanding of the source of supply is necessary if price competition is to be achieved.

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g. Program Summary January 1978, Fuels from Biomass Program, DOE/ET-0022/1, UC-61.

h. Reference g, updated 20 Sep 78.

The most readily available wood fuel will be in the form of chips or sawdust produced by saw mills, residue from woodworking plants, and contractors operating whole tree chippers. In the area surrounding Fredericksburg and Richmond, Virginia there are easily fifty saw mills plus an unknown number of woodworking plants. The majority of these mills and plants are owner operated by individuals that are typically "entrepeneurs." Price competition can only be achieved if this broad base of suppliers is willing to compete for the military's buiness. While they may bid, they will compete only if the procurement policies and unloading equiment is quite similar to that of other buyers in the immediate area.

To illustrate, one Government agency routinely procures a forest product from suppliers in the states of Virginia and Maryland. This agency issues purchase orders for twice the number of units in a normal commercial procurement; however, the agency pays an additional 10 - 20% per unit. Price competition has not been achieved because few suppliers are willing to bid. This unfortunate situation exists because the agency requires 45 - 60 days to make payment and the procurement specifications are so restrictive that they cannot be met at twice the successful bid (Reference i).

It should be noted that this agency pays 40% more per unit than a large public utility in the same geographical area. This difference is attributed to the utility's realistic procurement practices and aggressive procurement personnel (Reference i).

If a decision is made to purchase wood chips or residue in the Fredericksburg - Richmond, Virginia area, truck scales would be required and truck dumpers or Scoop-Roveyors would be needed to unload the chips and residue. Truck dumpers (Appendix T) give the supplier a 15 minute turn-around on his tractor-trailer (easily a $40,000 investment). Mobile truck dumpers are available which could be moved from plant to plant on an installation operating several wood fired boiler plants. Government owned live bottom trailers (Appendix T) should be considered for use on those installations operating only one or two small wood fired boilers. In those areas of the country where live bottom trailers are in general use by mills and contract haulers, these trailers may well be the primary means of delivering wood for fuel. Scoop-Roveyors (TM) are a recently developed but proven means of unloading trailers. The Scoop-Roveyor costs less than a dumper but may take slightly longer to unload the trailer.

It is common practice for pulp and particle board mills in the southeastern US to pay suppliers at the end of each week for all chips delivered during that week. Chips, shavings and some sawdust are bought and sold in this area on the basis of verbal contracts not written contracts (Reference i).

i. Private Correspondence from Industry Source(s).

Owners of wood fired boilers are finding a different situation. The supply of mill residues (sawdust and bark) is so large and the demand is so small, mill operators are willing to sign two and three year fixed price (plus escalation) contracts for delivery of this fuel (Reference i).

A similar situation exists with the forest residues. The supply is large, approximately $700K is required to purchase the harvesting equipment and the demand is very low. Contract harvesters are ready to expand their operations if they can be assured of a market for their product. These contractors are willing to sign three year fixed price contracts for delivery of whole tree chips (Reference i).

Of course, procurement and handling practices will differ between geographical areas of the country; however, regardless of the location, price competition can be achieved only if the broad base of suppliers is willing to compete for the military's business.

In sumary, the economics of wood fired boilers will be a function of the procurement practices and handling equipment. Any justification to install these boilers must address these important aspects.

4.7 Harvesting - Reference j states that wood fired boilers are in the budget cycle for installation at Red River Arsenal Army Depot, Texas and Fort Steward, Georgia. References k and l address the advantages of harvesting wood fuel from Army timber holdings. Wood fired boilers and timber harvesting decisions should be treated separately because there are numerous installations located in regions of the country where large quantitied of attractively priced wood fuel are immediately available.

If consideration is given to harvesting timber for fuel, this can be done in-house or by contract. The discussion which follows is an introduction to timber harvesting for those persons who will be involved in the decision process (contract harvesting vs in-house harvesting) but have little prior exposure to the technology. The techniques and equipment described are not the only means available for harvesting wood.

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j. DAEN-MPO-U, Memorandum for LTG E. H. Johanse, Deputy Chief of Staff for Logistics, with Inclosures (undated).

k. Wilcox, Howard A., Trip Report for period 10-14 Jul 78 (28 Jul 78).

l. Wilcox, Howard A., Trip Report for period 18-29 Sep 78 (12 Oct 78).

In fact, there will be some timber stands where this discussion does not apply. The acceptable technique and equipment combination is a complex function of soil conditions, topography, timber species, timber grade, market condition, quality and quantity of labor, reputation of a particular piece of equipment, repair parts availability, availability of used equipment and owner/operator bias (to name a few). Seldom will two individuals assemble the same equipment combination to harvest the same tract of timber.

If wood for fuel is to be harvested from installations, this should be accomplished as part of the overall forest management program at the installation. Conversion of high grade saw and veneer timber to fuel is underutilization of a natural resource which could be politically and economically not feasible. Contractors operating whole tree chippers sort saw logs at the landing and sell them to saw mills (Appendix D and Q). Less energy is consumed in the manufacturer of lumber as a building material than in competing products such as steel, aluminum and concrete. The most likely source of wood fuel in the forest is the thinning or removal of cull timber from timber stands. Any remaining trees would be harvested later as saw timber and pulpwood.

Timber harvesting equipment is highly specialized, the technology is constantly developing and the efficient management of such an enterprise is not easily achieved. If the reader develops an appreciation of these facts, then the discussion will achieve its goal.

Appendix D, Q and R are typical of large number of recent articles that deal with whole tree chipping on the timber stand. This operation centers on the whole tree chipper first introduced in 1970. Typical equipment required in this harvesting operation would include:

a. A feller-buncher shear (Appendix T) which shears trees at the ground and piles them for pick-up by the grapple-skidder.

b. Two or three grapple-skidders (Appendix T) that pull the individual piles of trees to the whole tree chipper. The operator does not dismount to pick-up or release the trees.

c. A whole tree chipper (Appendix T) which chips the entire tree and blows the chips into a box trailer. Using this machine, high grade chips from the tree trunk can be blown into one van for pulp and low grade chips from the limbs can be blown into a second van for fuel.

d. A log loader will be needed to separate and load saw logs (Appendix T).

e. A bulldozer is required to clear a working area for the chipper, skidders and vans.

f. Road tractors and box trailers are required to deliver the chips to market. The exact number will depend on the haul distance; however, economics require that the chipper not be kept waiting for lack of empty trailers.

An equipment combination of this type can easily harvest 45,000 tons of chips per year (Appendix D). At 4500 BTU per pound for green wood and 67% combustion efficiency, this machinery could supply a 30 MBTU per hour boiler operating at full capacity for 168 hours per week. If the decision is made to operate harvesting equipment, economics will demand that this equipment not remain idle; therefore, the equipment selected will depend on boiler sizes and utilization, plus the factors mentioned earlier. Process boilers with year around steady loads would be best suited for firing with chips harvested from installations.

Appendix R is a presentation of the economics of whole tree chipping; however, in some cases, equipment prices have increased 25% since this article was published (Reference i).

The Hydro mower (TM) has been described by Reference l as an efficient harvesting machine. This machine clears land very well but does not harvest trees or chips (Appendix T).

The rate of change in timber harvesting technology is illustrated by the following table (Reference m):

Equipment	Approximate Year Introduced
Choker Skidder	1962
Tree Shear	1965
Grapple Skidder	1968
Whole Tree Chipper	1970
Feller-Buncher	1970
Mobile Chipper-Canter	1978

m. Private Communication from Dr. T. A. Walbridge, Virginia Polytechnical Institute (27 Nov 78).

The mobile chipper-canter allows the operator to improve utilization of low grade saw logs. Six to eight inch logs normally sent to the chipper will be sent to the canter which converts the logs to cants (4 x 4's, 6 x 6's, 6 x 8's, etc.) and chips. Thus, a log that would have been converted to chips at $12 per ton now will be converted to cants worth approximatley $60 per ton plus some chips. The first machine was recently sold to a logging company in Virginia (Reference n).

The Department of Energy, the Department of Argriculture and private industry are actively funding development of new harvesting machinery and techniques. New equipment is expected to reach the market place in the near future.

It is obvious that considerable time will be required to design, procure and efficiently manage a harvesting system for a given installation. While the design of wood fired boilers is relatively "off the shelf," the design of an efficient harvesting system is a function of many variables. Consideration should be given to utilization of wood for fuel, independent of the decision to harvest or not to harvest existing owned timber for fuel.

4.8 Barriers to Utilization of Wood for Fuel: Appendix S addresses several institutional and technical barriers to utilization of wood. Reference o addresses a rapidly developing barrier, i.e., environmental preservation in the forest. It would take 20-20 foresight to predict the extent of wood fuel utilization 20 or 30 years hence; however, in view of the rapidly increasing fossil fuel costs and the limited alternative fuels, it is reasonable to assume that a significant number of wood fired boilers will be operating for the foreseeable future. Evidence indicates there is enough wasted wood in the forest products and woodworking industries to support large numbers of additional wood fired boilers - all without harvesting a single additional tree. Private industry is utilizing wood fuel and the momentum is building rapidly. Every job created further insures the longevity of the industry. The Department of Energy and the Department of Agriculture are actively funding projects which will evaluate the efficiency of wood fired boilers and which will develop techniques for growing and harvesting wood fuel in the most efficient manner. State supported universities across the country are actively promoting wood fuel utilization. The military's utilization of wood fuel will be such a small percentage of the national consumption that we should simply monitor developments and "follow suit." At this point in time, all indicators are encouraging.

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n. Bryan, Richard W., "Mobile Canter Works at Landing to Improve Hardwood Utilization," Forest Industries, Vol 105, No 11 (Oct 78).

o. Wisdom, Harold W., "The Impact of the Environmental and Energy Crisis on the US Timber Supply," presented at the third World Pallet Congress (October 1977).

The barrier to harvesting fuel from military installations are more formidable. At present, funds from sales of merchantable timber must be placed in a special account at the Treasury Department and used to support the installation forestry program. Since this program is mandated by Congress (Referene l & p), the laws must first be changed if military timber lands are to be converted to energy plantations. As wood becomes a more popular source of energy, timber that is presently non-merchantable may very well become a valuable commodity; therefore, until the present law is changed the military may be unable to harvest any of its timber for in-house consumption. If the assumption is made that the law can be changed or that fuel wood can be harvested under the existing law, the military must then decide whether to harvest in-house or by contract. Unless the present trend of personnel and budget cuts is reversed, it is unlikely the military can justify in-house harvesting. Contract harvesting with the whole tree chipper is running approximately seven dollars per ton (Reference i). In view of the complexity of a harvesting operation, the capital investment required, the rate at which the technology is developing and the limited flexibility of a bureaucracy, the seven dollars per ton is most attractive. Perhaps the military's timber holdings could best be used as an efficiently managed source of forest products during peacetime and a fuel reserve during mobilization.

If wood fuel is purchased on the open market, it must be recognized that existing marketing or brokerage practices require the buyer to take delivery as quickly as the fuel is manufactured. For example, the owner of a wood fuel heating plant will be expected to take delivery of fuel through the summer. As previously stated, process boilers with year around steady loads are best suited for firing with wood.

In summary, the military should follow industrial practice and consider installating wood fired boilers at those installations where wood fuel is economic and available on the open market.

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p. FLAME - Forestry Lands Allocated for Managing Energy, US Air Force Report CEEDO-TR-78-1 (Sep 78).

REFERENCES

a. Near Term Potential of Wood as a Fuel - HGP/T4101-02 UC-61. Prepared for the Department of Energy by Mitre Corporation (Aug 78).

b. Morford, James V. Supplemental Wood Fuel Experiment - Interim Report, Board of Light and Power, Grand Haven, Michigan (9 Jan 78).

c. "Woodpower Generates Utility Savings," The American City and County (March 1978).

d. Private Communication from W. Burnham, Southern Colorado Power, Canon City, Colorado (27 Nov 78).

e. Private Communication from J. V. Morford, Board of Light and Power, Grand Haven, Michigan (16 Nov 78).

f. Operation with Woodex Pellets for the Period 9-16 February 1978. US Air Force Test report (unpublished).

g. Program Summary January 1978, Fuels from Biomass program, DOE/ET-0022/1, UC-61.

h. Reference g, updated 20 Sep 78.

i. Private correspondence from industry source (s).

j. DAEN-MPO-U Memorandum for LTG E. H. Johansen, Deputy Chief of Staff for Logistics, with inclosures (undated).

k. Wilcox, Howard A., Trip report for the period 10-14 Jul 78 (28 Jul 78).

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o. Wisdom, Harold W., "The Impact of the Environmental and Energy Crisis on the US Timber Supply," Presented at the Third World Pallet Congress (Oct 77).

p. FLAME - Forestry Lands Allocated for Managing Energy, US Air Force report CEEDO-Tr-78-41 (Sep 78).

LIST OF APPENDICES

ACKNOWLEDGMENTS

Mr. Jerry L. Birchfield and his staff (Georgia Institute of Technology) provided appendices A, E, F, K, N, O, P and S which have been extracted from their publication "Wood Energy - Today and Tomorrow."

Mr. Larry G. Jahn (North Carolina State University) provided appendix R.

APPENDIX	SUBJECT
A.	Wood Energy Resource Base - Reviews the availability of wood as an energy source.
B.	Excerpt from the Congressional record containing remarks by Senator Baker in support of wood as an energy source.
C.	"Power Plants turn to good old wood," Business Week, 15 Mar 76.
D.	"Fuelwood harvesting, chipping operation encourages forestry," Forest Industries, Aug 78.
E.	Economics - Reviews the economics of wood as an energy source.
F.	Direct Combustion - Reviews the advantages and disadvantages of direct combustion of wood.
G.	List of customers using wood fired boilers.
H.	"Mix sawdust with coal for a cheap and clean boiler fuel," Electrical World, 1 Nov 78.
I.	List of manufacturers of direct combustion Systems (Taken from Reference a.).
J.	List of companies manufacturing densified fuel. (Taken from Reference a.).
K.	Densification - Reviews the advantages and disadvantages of densified wood fuel.

L. Wood Fuel System Users - Identifies users of densified wood fuel, pyrolysis, gasification and direct combustion (Taken from Reference a.).

M. "Gasifiers for retrofitting gas/oil combustion units to biomass feedstock," presented at the first world energy Congress, T. B. Reed et al, 31 Oct 78.

N. Gasification - Reviews the advantages, disadvantages and state-of-the-art of gasification.

O. Pyrolysis - Reviews the advantages, disadvantages and state-of-the-art of pyrolysis.

P. Alcohol production from wood - Reviews the advantages, disadvantages and state-of-the-art.

Q. "One Hundred Per Cent Timber Harvesting: A Dream Come True," Paper Trade Journal, 26 Jul 71.

R. "Economic Aspects of Low Grade Hardwood Utilization" Forest Products Journal, Aug 78.

S. Barriers to widespread wood use - Reviews technological and institutional barriers to the use of wood as a source of energy.

T. Manufacturers of timber harvesting and land clearing equipment (Partial list).

APPENDIX A

WOOD ENERGY RESOURCE BASE

U.S. Resource Base

The standing forests of the United States comprise over 700 million acres, about one-third of the contiguous U.S. land area. The total energy content of this resource is about 300 quads* -- 95 of which are in the Northwest, mostly in Oregon and Washington, 90 of which are in the Southeast and Southcentral states, and 45 of which are in the Northeastern states. Of these three major resource areas, the forest growth rate is highest in the Southeast, next highest in the Northeast, and slowest in the Northwest. Today the U.S. uses wood to supply about 2.1 quads of primary energy. Over 90% of that usage is concentrated in the forest products industry. The industry directly burns the fuel or black liquor for process steam and electricity (black liquor is a combustible by-product of the pulping process).

The theoretical maximum recoverable energy from wood per year is approximately 10 quads. A more realistic estimate of the amount of potential wood energy above what is already recovered today is 2.2 to 4.4 quads. This energy range is about 6% to 12% of the U.S. oil consumption or 12% to 24% to U.S. oil imports. This represents roughly $3.3 to $6.6 billion worth of energy.

Wood in the near term will be a regional energy source. Transportation costs outside a 30 to 50 mile radius from the harvest site quickly reduce the economic competitiveness of wood energy.

One potential problem is the harvesting of wood for energy is that if a stand of trees is cleared for fuel there is little or no incentive today to replant with trees for fuel. The landowner is more likely to raise sawtimber because it has 20 times the economic value of fuel trees. Only when crops can be raised in less than 12 years do the economics change in favor of fuel. More likely, however, the small private landowner will replant with a cash crop that pays in a year or two, rather than plant trees at all. Only the commercial industry with big landholdings and a stake in wood will replant with wood.

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*1 quad = 1 quadrillion BTU's = 10^{15} BTU's.

One strong plus for the harvesting of wood for energy is that if it is properly performed, much greater forest productivity will result. For example, in the Southeast it is estimated that the rate of production of wood in the forest can be doubled or perhaps even tripled if the cull (rough, rotten, or dead trees) or competing small material is removed from the forest. By having two cuts, one to thin out the cull and competing growth (which is used for wood energy) and the second to harvest sawtimber and pulpwood, higher yields and higher revenues may be produced for the landowner.

Resource Base of the South and Georgia

The South contains between 0.9 and 1.3 quads of realistically recoverable annual wood energy. This is equivalent to approximately 184 to 266 million barrels of #2 fuel oil. This represents between 3% and 4% of the annual U.S. petroleum consumption or between $1.3 to 2.0 billion worth of energy.

Georgia has a realistically recoverable energy potential of 120.6 to 277.4 trillion BTU's. This is equal to 42% to 97% of Georgia's total natural gas energy consumption in 1973 or 9%-22% of total energy consumption in the same year. This amount of annually recoverable wood energy also represents 5% to 11% of total energy demand projected for Georgia in 1990.

APPENDIX B

Congressional Record

United States of America

PROCEEDINGS AND DEBATES OF THE 95th CONGRESS, SECOND SESSION

Vol. 124 WASHINGTON, THURSDAY, JULY 20, 1978 No. 110

Senate

THE ENERGY PROGRAM

• Mr. BAKER. Mr. President, yesterday, the Congress embarked upon the final leg of passage for a comprehensive energy program for the United States of America. This is a task that has been long delayed and is sorely needed.

But, I am disturbed over the failure of the Department of Energy and the President's energy plan to address a source of domestic energy production that I think holds enormous potential, the burning of wood products to produce energy.

I am troubled by the low priority that has been given to wood fuel, or as it is more scientifically known, solar biomass energy. Considering the vast amounts of this potential energy source within the United States, and the fact that perhaps as much as 80 percent of our commercial forest yields go to waste, I am hard pressed to understand the Department of Energy's reluctance to devote more time and investigation to this energy source.

A number of companies have already committed themselves to increase utilization of this vital fuel source. In Michigan a number of companies have joined together in a firm commitment to developing wood fuel as a viable alternative for this country. The Michigan legislature and that State's public service commission have investigated this subject and have found wood fuel to be a credible source for future fuel production. In my own State of Tennessee, the Tennessee Valley Authority has committed itself to the study and development of wood-burning energy as a source of power generation.

This recognition by other segments of our society of the need to increase utilization of our domestic biomass potential, when compared with the efforts being made by the Department of Energy, leave me greatly concerned. I am therefore calling upon the Department to commit itself to greater utilization of this vital domestic fuel source.

I know that it is the desire of the American people to be free of our present dependence on foreign fuel sources. The only way this can be achieved is for us to make maximum use of all of our domestic productive capacity.

To underemphasize or ignore this vital and abundant domestic fuel source, is to ignore the wishes of the American public. That is something I do not wish to see happen.

Mr. President, I ask that the remainder of my remarks be printed in the RECORD following this statement.

The remarks follow:

REMARKS BY SENATOR BAKER

RATIONALE FOR WOOD ENERGY

The arguments that can be made for the increased commercial use of wood energy outside the forest products industry are indeed powerful. Most of these reasons have been around for a long time, and the positive characteristics can be summarized briefly as follows:

a. *Inexpensive price.*—Wood fuel in the form of whole tree chips cost less than $1.30 per million BTU's. Industrial wood wastes are even less expensive in the $.60 to $.80 per million BTU's.

b. Fuel availability.—The wood resources within the country are known to be significantly more than the U.S. Forest Service's commercial inventories. They have estimated over a billion tons of *unused* wood per year (1.3 billion barrels of oil equivalance), and even this estimate may also be conservative.

c. Established technology.—Commercial wood harvesting and combustion technologies have both been adequately demonstrated by the forest products industry for system technical feasibility.

d. Renewable and expandable.—Wood energy is one of the few renewable resources besides solar, ocean, wind, and other biomass. Moreover, it is here today while the other technologies require significantly more research. Good forest management has already demonstrated 50% increases in annual growth over the past 20 years.

e. Nonpolluting.—Wood contains less than 0.1% sulfur, far less than the lowest sulfur coal. Combustion temperatures are low enough that nitrogen oxides are not a problem. The stack particulates are easily captured by low cost, mechanical pollution control equipment; and the ash even has excellent soil nutrient value.

f. Land value improvement.—Harvesting by thinning or clear cutting increases the residual land value. Reforestation incentives have recently been dramatically improved. Whole tree harvesting also eliminates forest residues upon which forest fires thrive.

g. Jobs creation.—New jobs are created in the rural economy with a direct three person per 15,000 pounds of steam/hour new capability. The fuel supply is also not sensitive to labor disputes.

In addition to these stated benefits, there are also dynamic conditions which have evolved over the past few years which have helped to create the current potential for significantly increased wood fuel usage.

a. Conventional *fuel concerns.—The* costs of other combustible fuels is currently high ($1.40 per million BTU's for coal, $2.50 for oil, and $3.25 *for natural gas*), and they are all going higher. There is the ever present danger of fuel supply interruption due to strikes, *shortages*, and embargoes for coal, natural gas, and oil respectively while wood is not nearly so susceptible. There are also "*balance of payment*" implications for the giver state, region, or nation. Moreover, wood fuel is available just about everywhere in the United States.

b. Maturation of wood *harvesting techniques.*—The whole three chipping technology has matured over the past five years and is currently *recognized by loggers as a dependable* and economical harvesting technique for most forests.

c. Energy *independence by wood industry.*—There is an increasing move toward energy self sufficiency in the wood industry, *particularly in the* pulp and paper industry. Most of the wood energy system parameters have been proven within the wood industry *and are available* for commercial applications outside the wood industry.

d. Forestry endorsement of environmental/conservation benefits.—The U.S. Forest Service, State Forestry Officials, Forestry Schools, and Wood Industry Foresters are all pushing the value of good forest management through selective harvesting. There is also a growing recognition of the need for a comprehensive forest inventory for total biomass.

e. Continuing *unemployment.—There* is a recognized need for new jobs creation in rural areas as well as urban; and wood energy allows the creation of *healthy, productive* jobs in the forests or rural areas.

POTENTIAL DOE ROLE

Wood energy as an identifiable subject has existed in the Department of Energy (and its predecessors) in only two areas to date: Combustion Research and Biomass Fuels groups from the previous ERDA Conservation organization. Very little combustion research was done in the former, and emphasis was placed on synthetic fuels and biomass production in the latter. Wood has had a "*secondary alternate*" fuel status within DOE.

It is also generally agreed that wood energy *on these* bases is ready for commercialization outside the forest products industry, and yet it is not happening at a rapid rate. The question then is what should the Department of Energy do at this time to help increase the application of wood energy as a fuel alternative.

The DOE can confidently take three immediate steps:

1. Issue a policy statement on wood energy that clearly delineates those portions ready for commercialization and those portions still in the research/development stage.
2. Perform an immediate program definition for the commercialization program by either a DOE task force or a subcontracted

over

study or both. This unsolicited proposal addresses itself to this task.

3. Implement a follow-on DOE Wood Energy Commercialization Program which could contain the following features:

a. Sponsorship of a national wood energy data base for the country, i.e., how much wood is available for "energy uses," where is it available, and who is currently using it.

b. Study of the economic parameters that are involved in wood becoming a fuel "commodity" i.e., land ownership, harvesting, reforestation, transportation, supply contracts.

c. Provide broad publicity on advantages and disadvantages of wood energy to include endorsements from U.S. Forest Service as well as extolling environmental (less pollution, better forests) and economic (lower fuel costs, new jobs creation) benefits.

d. Highlight the elements in the National Energy Act that are already built in to help the commercialization/demonstration of wood energy (i.e. Investment Tax Credit, removal of cogeneration barriers, primary fuels tax, etc.).

e. Identify other incentives that are currently available (Forest Improvement Program) or needed (Harvesting Equipment Purchase Incentives) to further encourage wood energy conversions.

f. Implementation of commercial demonstration programs under the name of wood as a commercial biomass fuel. The program would mate wood supply and demand for industry, institutions, and utilities outside the forest products industry. The program baseline could be whole tree chipping for fuel supply and direct combustion for steam energy production. Other program variables could include wood wastes and pelletized wood as supply variables and electrical cogeneration as a demand variable. ●

APPENDIX C

Reprinted from **Business Week**

ENERGY

Power plants turn to good old wood

One utility in Vermont and several manufacturers are planning to do so

In energy, as in economics, there is no such thing as a free lunch. Still, experts searching for untapped fuel supplies seem to have discovered something almost as good: wood. The rising price of oil, coal, and natural gas has interested both electric utilities and industrial plants in the waste wood that is left in the forest or discarded at sawmills. Wood burns cleanly, is cheaper than fossil fuels, is often easier to get, and requires no new technology.

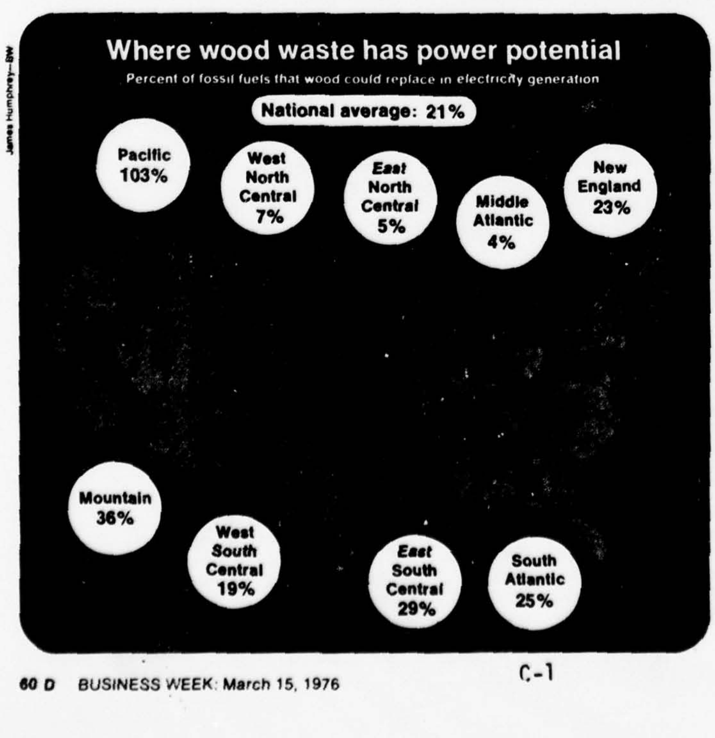
At least one utility—Vermont's Green Mountain Power Corp.—is already planning to build a wood-fired power plant. Several manufacturing plants that produce their own steam are converting boilers from fossil fuel to wood. Even the forest products industry, which has always used some of its wastes for fuel, is stepping up efforts to recover energy from wood.

So far no one is sure just how much waste wood could actually be used economically for fuel, but it is clear that this discarded resource represents an enormous amount of energy. Timber harvesting leaves behind a great deal of "slash"—unusable limbs, tops, and stumps, as well as diseased and otherwise unsalable trees. Sawmills also discard a fair amount of wood chips and sawdust. According to a draft report done by Battelle Memorial Institute for the Environmental Protection Agency, nearly three quarters of the wood harvested each year is lost somewhere on the trail from the forest to end products. This waste contains enough energy to replace 21% of the total fossil fuels—including 50% of the oil and gas—burned each year by U.S. utilities. In some areas of the country, such as the Northwest, there is even more energy available from waste wood than there is from all the fuels burned by utilities.

Supply. No one is suggesting that wood power is going to eliminate oil imports, but to Battelle, these facts are highly encouraging. Says senior researcher Elton Hall: "The implication is that in some areas of the country, incremental generating capacity using wood appears very attractive." Green Mountain Power heartily agrees. "We have to build a 50-megawatt base-load plant by the mid-1980s," says William H. Beardsley, assistant to the utility's president. "Wood looks extremely good." Beardsley says wood fuel would produce a kilowatt-hour of electricity for ½ mills less than the cost of electricity made from the low-sulfur coal that the company must burn. And supply is no problem. Green Mountain would use the slash left after harvesting, plus unmarketable species culled from the forest. "Half the trees in Vermont have no commercial value," notes Beardsley.

The fuel would be delivered in chip form. "We'd probably need about 400,000 tons of wood chips a year," says Beardsley, "That's no more than a medium-size pulp mill handles." The utility would have to order specially designed grates and stokers, though Beardsley claims the equipment would be very similar to coal-handling equipment. More sophisticated controls would also be needed because of the varying amounts of moisture in wood fuel. "But the technology for this is already here," he says. All in all, Green Mountain expects to pay about $50 million for the wood-burning plant, about as much as it would have to lay out for a coal-fired unit. "The wood-fired equipment costs more," explains Beardsley, "but pollution abatement equipment is considerably less."

The forest products industry is stepping up efforts to recover energy from wood



In fact, that may be one of wood's most alluring advantages. Most of the particulate emissions that burning wood gives off are large, obviating the need for costly electrostatic precipitators. Moreover, wood produces no sulfur dioxide at all. The amount of ash left over is very small compared to coal and may prove to be a salable byproduct because it can be used as a good soil conditioner.

Sawdust boiler. But there are limitations to wood as a utility fuel. For one thing, transportation costs rise rapidly as the volume needed increases. "It's unlikely that wood-burning plants larger than 100 Mw. would be built," says Beardsley, "because the fuel savings would be outrun by the added costs of trying to get more than 800,000 tons of wood within a reasonable distance of the plant." Even some areas rich in waste wood may find it uneconomical to use. In the Mountain States, for example, the abundance of low-sulfur coal would probably preclude much wood burning.

While these factors may inhibit growth of wood as a fuel in utilities, they should not do much to dampen acceptance elsewhere in industry. Last month Russell Corp., an Alexander City (Ala.) textile maker, replaced a coal-fired boiler capable of producing 180-million Btus an hour with a unit fired by sawdust. "We had to install pollution control equipment or go to oil," says Benjamin Russell, president of Russell Land Inc., an affiliate. "By using mill wastes instead, we'll cut our fuel bills about 40%. And it won't cause the cutting of one additional tree." Originally, Russell had planned to fire the boiler with chipped forest residue, but he found that sawdust was cheaper and more readily available. "We've got a number of sawmills in our area that are too small to use their own wastes," he explains. "They can't simply burn it, and it's not good landfill. They were glad to get rid of it."

As a result of his own experience, Russell has formed a subsidiary, Energy Conservation Inc., to market sawmill wastes to local industries. Although he has yet to make a sale, he reports dozens of inquiries. "It's like apple pie and motherhood," he says. "Everybody is in favor of it."

Russell claims his installation is the first use of waste wood for energy outside the forest products industry, which has been firing its boilers with leftover chips and sawdust for decades. Now, though, many pulp and paper companies are redoubling their efforts. "We want to keep those energy bucks from going to a third party," says James Rodgers, energy coordinator at Weyerhaeuser Co., in Tacoma, Wash. "In 1975 we shaved 6% off our $100 million energy budget, and we hope to shave another $10 million or more this year."

Weyerhaeuser is currently about 45% self-sufficient in energy; its goal is to become completely independent eventually. Right now the company gets most of its waste wood at its mills—bark, trim, and other residues are run through grinders and mixed with sawdust before being fired to produce steam. But Rodgers says he is analyzing the possibility of chipping slash left in the forest (and usually burned there) and transporting it to the mills.

Self-sufficiency. Weyerhaeuser is by no means alone. Many small lumber companies that found it uneconomical to use their wastes for fuel in the past are now reevaluating the idea. "I've got a healthy backlog of orders," beams one Seattle consultant who knows wood-burning boilers. "Smaller mills are being forced into using their wastes instead of throwing them away."

One example is Hanel Lumber Co., in Hood River, Ore. Until late last year the company incinerated some 20 tons of waste daily in a "wigwam" burner. At the same time, it was using 1,000 gal. a day of fuel oil to dry its lumber. But pressure from the state Environmental Quality Dept. made continued use of the wigwam impossible, and Hanel wanted to add a second kiln, which would have boosted fuel requirements by 50%. So the company decided to replace its oil-fired boiler with one that burned wood. "It's probably the best thing we've ever done," says President L. Sterling Hanel, "We're saving one heck of a fuel bill, and I expect we'll recover the $400,000 investment in a little over two years."

Enthusiasm like this leads Al E. Stevenson, manager of energy analyses for California-based Aerospace Corp. to conclude: "It's entirely feasible for the forest products industry to achieve energy self-suffiency in the near future." That, he adds, would provide an important national energy saving even if the idea of burning waste wood never spreads much beyond the lumber companies. Stevenson, who recently analyzed energy use in the forest products industry for the Energy Research & Development Administration, says the industry currently uses 2.2 "quads," or quadrillion Btus, a year but generates only 0.9 quads internally. Thus, if

Pollution control equipment costs less for wood than for coal, says Beardsley

the industry were entirely self-sufficient, it would trim the nation's need for fossil fuels by almost 2%. And because virtually all the saving would come in oil, the result would be to reduce the need for oil imports by 7%—an impressive amount.

Appealing as this sounds, however, waste wood will probably not prove to be a long-term source of energy. For one thing, pulp and paper mills are using more and more of their raw materials in end products, incorporating even bark into some papers. Lumber mills, too, are making greater use of previously discarded wood by increasing production of such items as chip board. And integrated companies such as Weyerhaeuser are using more of their sawdust for pulp. "As we learn how to use more fiber for products," sums up Rodgers, "a smaller amount of waste will be left for energy purposes." Beardsley of Green Mountain Power agrees. "We'll be working ourselves out of a source of supply," he says. "The rough trees we use will be replaced by more valuable ones worth too much to burn."

Still, every little bit helps these days, and the experts seem to think that wood has a place in the complex solution needed for the nation's energy problems. Says Beardsley: "We look at wood as a 30-year bridge to breeder reactors, fusion, and solar power." ■

APPENDIX D

Fuelwood harvesting, chipping operation encourages forestry

Brick and tile company established woods operation to meet projected energy needs; removal of low-grade hardwood makes it feasible to undertake reforestation efforts

By RICHARD W. BRYAN
Associate Editor

GOLD HILL, N.C.—How does a non-forest products company go about developing a fuel harvesting operation? For Isenhour Brick and Tile Co. of Salisbury, N.C. the answer is: very systematically.

After thoroughly investigating wood fuel for energy, the company came to the conclusion that three ingredients were needed: a previously untapped source of raw material, a half million dollar equipment investment and the managerial skills to put it all together.

Since these requirements could be met, company officials established Isenhour Forest Products Corp., a wholly-owned subsidiary with responsibilities for carrying out a previously initiated sawdust purchase program and starting the fuel logging operation. Ernest Safrit Jr., administrative manager of Isenhour Brick and Tile Co., was named vice-president/general manager of the new company.

Next, Garry Morris, long-time pulpwood dealer, producer and equipment representative, was hired as woods supervisor.

Then, Morris and other company officials spent a great deal of time talking to people in the forest products industry and looking at other operations.

The result was the formation on March 1 of a very efficient, 9-man logging crew which is producing approximately 250 tons of chips a day at about two-thirds the cost of No. 2 fuel oil. At the same time, the crew is helping local land owners improve their lands by providing site preparation benefits and utilizing cull material which previously had little or no market value.

"We discovered that the country within a 30-mi radius of Salisbury contained a great volume of low grade hardwood for which there was very little market," Safrit said. "In fact, the volume is great enough to meet our needs almost indefinitely.

"The land is privately owned, for the most part, and has been high-graded through the years until very little sawlog hardwood remains. Our discussions with North Carolina Forest Service officials and others in the industry led us to believe that we could derive the fuel we needed and at the same time promote better forest management. Very few of the land owners are willing to spend the money necessary to remove the cull material. But it was felt that if a harvest operation provided a little return and at the same time provided most of the site preparation needed many of them would be willing to reforest their holdings," Safrit explained.

Equipment for the crew consists of a Liebherr 940 feller-buncher, three John Deere 640 skidders (two are grapples, one a cable skidder), a Morbark model 22 Total Chiparvestor with dirt separator, Prentice 210 hydraulic loader, and an Owens log trailer. Four International road tractors and 11 open top and conventional 40-ft chip vans are normally assigned to the logging crew. However, hauling is under the direction of the company's transportation manager and the number of trucks and vans can be varied to meet production needs. A fleet of 11 International trucks and 45 vans have been assigned to this and the sawdust procurement program. In addition, a flatbed trailer is being converted into a second log trailer.

Crew members include an operator for each piece of equipment, plus a combination mechanic/utility man and crew foreman David Speer, a former North Carolina Forest Service assistant county ranger.

The feller-buncher operates in a straight line, making a swath from one boundary to the other, taking everything from 3-in. in diameter up. There is very little in the way of tops or debris left as a result. Trees are bunched in skidder payload-sized bundles and the skid distance is held to 1,500 ft or closer.

The feller-buncher operates six days a week to maintain production. As a normal rule the two grapple skidders pull the bulk of the wood, with the cable skidder used to pick up dropped or scattered trees, and as a spare.

At the landing, the small amount of sawlog sized material is high-graded out, bucked and loaded on a waiting log trailer by the loader operator. It has been averaging about a trailer load every day. When FOREST INDUSTRIES visited, Isenhour had not yet started utilizing chips from the logging operation so pine chips were going to Champion International at Roanoke Rapids, N.C. and hardwood chips to a local fiberboard concern.

The tracts being logged have varied from 30 to 800 acres, although at least 40 acres is desirable to minimize the number of times the crew must be moved. It is anticipated that tracts will probably range from 40 to 150 acres in the future, Morris said. The terrain consists mostly of well-drained red clay.

In explaining Isenhour's decision to enter the wood fuel business, Safrit said: "We fired our brick kilns primarily with natural gas until October, 1976, when we were informed that the day of uninterrupted supply was over. We couldn't afford to be without a constant source of fuel so we switched to No. 2 fuel oil that same month and in 1977 we established contracts with sawmills within a 30-mi radius to obtain sawdust.

"However, developments in the energy field led us to believe that sawdust will become a competitively priced fuel and perhaps a scarce fuel within a year. This led to our entering the fuel harvesting business." ■

RICK BRYAN PHOTOS

Clockwise, from top: (1) Liebherr 941 feller-buncher with 22-in. shear places multiple stems in bundle for grapple skidder. Shear has over 110 tons of cutting force. Undercarriage is equipped with 24-in. triple-rib pads. (2) Ernest Safrit Jr., left, and Gary Morris. (3) Temporary arrangement uses Morbark Scooproveyor and chip screen plus mobile belt conveyor to unload trucks and store fuel. (4) The set is arranged with the Morbark 22-in. Total Chiparvestor on one side and the Prentice 210 hydraulic loader and trailer on the other. Trees can be skidded to either side of the landing; sawlogs are bucked out and transferred to the loader side. Chiparvestor is powered by 600-hp Cummins diesel; has dirt and bark separator. (5) John Deere 640 grapple skidder brings payload of trees to landing beside Chiparvestor.

APPENDIX E

ECONOMICS

Utilization of wood as an energy source will provide a definite economic boost to the area in which it is developed. It has been conservatively estimated that, for the state of Georgia, a comprehensive wood utilization program can provide $180 to $420 million in direct fuel sales revenue. Applying macroeconomic theory's multiplier effect to this spending increase would indicate a magnification of business activity by a factor related to the public's inclination to spend versus save this additional income. A conservative multiplier value of 3 would predict that the $180 to $420 million range in energy sales translates to $540 million to $1.2 billion dollars worth of annual economic activity.

Harvesting and transportation operations would be stimulated in this process with resulting employment benefits. Property values would most probably increase as well, since many acres currently standing idle with non-commercial grade timber would become a resource.

To give a clearer picture of the cost of wood compared to the costs of other more conventional fuels, the followign table was constructed.

Fuel Cost per Million BTU

No. 6 fuel oil	$1.90
Natural gas	1.75
Coal	1.75
Pelletized wood	1.75
Wood chips	1.45

These costs were developed using data from the southeastern U.S. and while generalized, are felt to be representative values. They represent price to the user, delivered within a 50 mile radius. Wood certainly appears to be in a comparatively favorable cost position. Future conventional fuel availability and costs would only be speculative, but these factors again seem to favor wood.

In terms of original new installation costs, wood fired sytems have been found comparable to coal systems. In situations where a retrofit of existing equipment is mandated, wood gasifiers appear to hold economic promise.

In summary, wood looks economically viable as a fuel. Much work remains to be accomplished in developing appropriate technologies and obtaining reliable fuel, equipment, and operating costs, but these points are rapidly being addressed.

APPENDIX F

DIRECT COMBUSTION

Direct combustion in the burning of fuel in the presence of oxygen for use as a direct heat source. In the case of wood, the fuel can be logs, chips, pellets, bark, sawdust, or wood waste from manufacturing operations. The forest products industry has used wood to produce energy for many years. As a waste product, wood was readily available at little or no cost. Consequently, direct combustion is a proven technology for large scale operations.

One disadvantage of direct combustion, as with all wood systems, is the handling of a solid fuel. A chipper may be required to reduce the wood to usable size. A screw conveyor or front end loader is needed to move the chips from covered storage to a metering feed system. Then a grate is needed to catch the oversize pieces; and finally, ash removal and disposal can be a problem.

Another disadvantage of direct combustion is air pollution. Wood is virtually free of sulfur, but particulate emissions can exceed allowable limits if the burning process is not closely controlled to ensure complete combustion. Existing technology to control particulate emissions includes cyclones, bag-houses, and electrostatic precipitators.

As prices for gas and oil increase, direct combustion of wood for energy will become more economical for small scale operations where wood is readily available. Furniture, picture frame, and other wood product manufacturers need to be educated on wood as a fuel. Farms with woodlots can use wood to heat animal shelters. In the residential sector, more and more people are turning to woodstoves as a supplementary heating source in their homes and workshops. Central wood burning furnaces are now available, some even with multi fuel capabilities, in sizes small enough to heat average homes efficiently.

The key to increased usage of direct combustion for wood energy will be education. Let the public know what is available and how to use it properly; encourage woodstove and furnace manufacturers to design more efficient systems.

APPENDIX G

Fyr-Feeder
REG. U.S. PAT. OFF.

INSTALLATIONS LIST [redacted]

ALABAMA	
Mobile River Sawmill Company	Mount Vernon
Bacon McMillan Veneer Company	Stokton
Decatur Box & Basket Company	Decatur
Scott Paper Company	Mount Vernon
ALASKA	
Ketchikan Pulp	Ketchikan
ARKANSAS	
Anthony Williams Lumber Company	Calion
Desoto, Inc.	Fort Smith
W. S. Fox Lumber Company	Pine Bluff
Joseph Seagram	Pine Bluff
Potlatch Corporation	Warren
ARIZONA	
Fort Apache Timber Company	Whiteriver
CALIFORNIA	
Kroehler Manufacturing Company	Fremont
California Cedar Products Company	Stockton
COLORADO	
San Juan Lumber Company	Durango
CONNECTICUT	
Eagle Pencil Company	Danbury
O. F. Mossberg & Sons, Inc.	New Haven
GEORGIA	
Communicable Disease Center	Atlanta
U. S. Public Health Service	Atlanta
HAWAII	
Royal Hawaiian Nut Company	Hilo
IDAHO	
Northwest Timber Company	Coerd'Alene
Clearwater Forest Products	Kooskia

ILLINOIS

Intercraft Corporation	Chicago
Turner Manufacturing Company	Chicago
W. W. Kimball Company	Chicago
Jasper Wood Products	Newton
Rock Island Mill Works	Rock Island

INDIANA

Union Furniture Company	Batesville
Indiana Hardwood Lumber	Chandler
Dale Manufacturing Company	Dale
Craddock Furniture Corporation	Evansville
Evansville Veneer & Lumber Company	Evansville
Jasper Office Furniture Company	Evansville
Jasper Chair Company	Jasper
Jasper Corporation	Jasper
Jasper Office Furniture Company	Jasper
Kimball International	LaPorte
Indiana Moulding & Frame Company	LaPorte
B. L. Curry Company	New Albany

IOWA

Manchester Industries	Manchester
Flour City Box & Manufacturing Company	Waterloo

KENTUCKY

Young Manufacturing Company	Beaver Dam
Scott Lumber Company	Henderson
Green River Chair Company	Livermore

LOUISIANA

H. D. Foote Lumber Company	Alexandria

MAINE

Indian Head Plywood, Inc.	Presque Isle

MARYLAND

Beaver Dam Veneer Mills, Inc.	Cockeysville
Veneer Manufacturing Company, Inc.	Cockeysville
Williamson Veneer Company	Cockeysville
Mulco Products	Indian Head

MICHIGAN

Calumet & Hecla, Inc.	Calumet
L. L. Johnson Lumber Company	Charlotte
Birds Eye Veneer Company	Escabana
Goodman Staniforth Div.	Escabana
Northwest Veneer & Plywood Corporation	Gladstone
Thureson Lumber Company	Howell
John Widdicomb Company	Grand Rapids
Ahonen Lumber Company	Ironwood
Forest Center Sawmill	Munising
Hartho Saw Mill (Cleveland Cliffs)	Munising
Paramount Furniture Company	Sturgis

MINNESOTA

Rajala Mill	Big Fork
Rajala Mill	Deer River
Durkee Manufacturing	Pine River
Marvin Lumber & Cedar Company	Warroad
Marvin Mill Works	Warroad

MISSISSIPPI

The Wurlitzer Company	Corinth
Rudolph Wurlitzer Company	Holly Springs
Mengel Wood Industries, Inc.	Laurel
U. S. Plywood Corporation, Inc.	Laurel
Kroehler Manufacturing Company	Meridian
La-Z-Boy Chair Company	Newton
Pascagoula Veneer Company	Pascagoula

MISSOURI

La-Z-Boy Chair Company	Neosho
Leggett & Platt	Springfield

MONTANA

Diehl Lumber Company	Plains
Thompson Falls Lumber Company	Thompson Falls

NEW YORK

Ellenville Handle Works	Ellenville
Frewsburg Furniture Company	Frewsburg
Maddox Table Company	Jamestown
Chautauqua Cabinet Company	Mayville
Reliance Pencil Company	Mount Vernon
Racquette River Paper Company	Potsdam
Fancher Furniture Company (Mos. 1 & 3)	Salamanca
Jamestown Table Company	Salamanca
Columbia Box Board Mills	Wallomsac
Whitestone Wood Products Company	Whitestone

NORTH CAROLINA

Southern Furniture Company	Conover
Cary Lumber Company	Durham
Fairfield Chair Company	Lenoir
Abitibi Corporation	North Wilkesboro
Edinburgh Hardwood Lumber Company	Washington

OHIO

Trailmobile, Inc.	Cincinnati
Kroehler Manufacturing Company	Cleveland

OREGON

Ellingson Plywood	Baker
Rickini Lumber Company	Cottage Grove
Hanel Lumber Company, Inc.	Hood River
Hestern States Plywood, Inc.	Port Orford
Hudspeth Pine, Inc.	Prineville

PENNSYLVANIA

Sensenich Corporation	Lancaster
General Interiors Corporation	Lewisburg
Colonial Products Company	Mifflinburg
Mifflinburg Industries	Mifflinburg
Merchants Box Company	Dallastown
Williamson Veneer Company	New Freedom
Eberhard Faber Pencil Company	Wilkes-Barre
West Virginia Pulp & Paper Company	Williamsburg
Seiling Furniture Company	Railroad
Stewartstown Furniture Company	Stewartstown

SOUTH CAROLINA

Roundwood Products Company	Florence
Stuckey Lumber Company	Manning
Marion Lumber Company	Marion

TENNESSEE

Cavalier Corporation	Chattanooga
La-Z-Boy Chair Company	Dayton
Dyer Fruit Box Company	Dyer
Roy Johnson Lumber Company	Huntland
Ashby Veneer & Lumber Company	Jackson
Tennessee White Oak	Jackson
Jasper Corporation	La Fayette
Rockford Textile Mills	Mc Minnville
Chapman Dewey Lumber Company	Memphis
Ivers & Pond Piano Company	Memphis
Memphis Furniture Manufacturing Company	Memphis
Prest Manufacturing Company	Memphis
Gluck Bros., Inc.	Morristown
Rhyne Lumber Company	Newport
Wood Products, Inc.	Newport

TEXAS

Curtis-Matches Manufacturing Company	Athens
Olive-Myers Furniture Company	Athens
Southern Pine Lumber Company	Diboll

VERMONT

Weyerhauser Company	Hancock

VIRGINIA

Great American Industries	Bedford
Berryville Basket Company	Berryville
U. S. Gypsum Corporation	Banville
Interstate Veneer Company, Inc.	Emporia
Quality Furniture Products Company	Newport News
Dixie Veneer Company	Portsmouth

WASHINGTON

Kinnear of Washington	Centralia
Simpson Timber Company	McCleary
U. S. Plywood Corporation	Morton
Peninsula Plywood	Port Angeles
Burke Millwork Company, Inc.	Seattle
Seattle Boiler Works (Export - Malaysia)	Seattle
Tyee Lumber Company	Seattle
Long Lake Lumber Company	Spokane
Buffelen Woodworking Company	Tacoma
Coast Sash & Door Company	Tacoma
Mutual Fir Column Company	Tacoma
White Swan Lumber	White Swan

WISCONSIN

Vulcan Corporation	Antigo
Birchwood Lumber & Veneer Company	Birchwood
Northern Hardwood Veneer, Inc.	Butternut
Cradwick Manufacturing Company	Coleman
Chippewa Lumber Ind., Inc.	Glidden
Kern Furniture Division of De Soto	Hoquiam
A. A. Laun Furniture Company	Kiel
Donald Duncan, Inc.	Luck
Marion Plywood	Marion
Hurd Mill Work Corporation	Medford
Moclips Cedar Manufacturing Company	Moclips
American Woodworking Company	Montello
Hardwood Products Corporation	Neenah
Menominee Ineian Mills	Neopit
Edison Wood Products Company, Inc.	New London
Simmons Company	New London
Birchwood Manufacturing Company	Rice Lake
Marathon Corporation	Rothschild
Weber Veneer & Plywood Company	Shawano
Cecraft Manufacturing Company	Stoughton
G. B. Lewis Company	Watertown

WISCONSIN - Continued

Underwood Veneer Company	Wausau
Connor Forest Industry	Wausau
Pukall Lumber Company	Woodruff

PHILLIPINE ISLANDS

St. Cecilia Sawmills, Inc.	Manila
Sta. Ines Logging Enterprises	Mindanao

CANADA

Columbia Forest Products Company	Sprague, Manitoba
Staniforth Lumber & Veneer Ltd.	Kiosk, Ontario
Goodman-Staniforth	Rutherglen, Ontario
Volcano Ltd.	St. Hyacinthe, Quebec

SAMOA

Coconut Processing Corporation	Island of Samoa

SINGAPORE

Seattle Boiler Company
Boise Cascade Corporation

MALAYSIA

Seattle Boiler
Boise Cascade Corporation

COSTA RICA

Brenda Company

NICARAGUA

Plywood, Inc.

INDUSTRIAL BOILER CO.

Post Office Box 936 - 221 Law Street - Thomasville, Ga. 31792 - 912-226-3024

"WOOD FIRED BOILER SYSTEMS"

CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
Dixon Plywood Andalusia, AL Mr. John Vick Mr. Bill Benson (205) 222-4163	700 BHP 24,150 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Ames-McDonough Co. Parkersburg, W.V. Mr. Max Wright (304) 422-6431	400 BHP 13,800 PSPH	Slip Form Silo w/Flying Dutchman	Hardwood, bark, sawdust, chips, dry shavings and sawdust.
Escambia Treating Co. Camilla, GA Mr. Tom Hayes (912) 336-0181	300 BHP 10,350 PSPH	Open Storage w/Drag Chain	Pine bark, sawdust and chips.
Florida Plywoods Greenville, FL Mr. John Maltsby (904) 948-2211	500 BHP 17,250 PSPH	Slip Form Silo w/Flying Dutchman	Hardwood, bark & sawdust, pine bark & sawdust, dry shavings & sanderdust.
Rhyme Furniture Marianna, FL Mr. Glenn Groves (904) 526-2811	300 BHP 10,350 PSPH	Wood House w/Drag Chain	Dry shavings and sawdust.
Stilley Plywoods Conway, S.C. Mr. Sonny Stilley (803) 248-4241	300 BHP 10,350 PSPH	Peerless	Dry shavings and sanderdust.
Schoolfield Industries Mullins, S.C. Mr. John Adams (803) 464-6485	400 BHP 13,800 PSPH	Slip Form Silo w/Flying Dutchman	Dry shavings and sanderdust.

INDUSTRIAL BOILER CO.
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CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
Butler Land & Timber Co. Creedmoor, N.C. Mr. Max Butler (919) 528-1612	1000 BHP 34,000 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Coastal Lumber Co. Havana, FL Mr. Jerry Williams (904) 539-6443	1200 BHP 41,400 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Robbins Lumber Co. Searsmont, Maine Mr. Jenness Robbins (207) 342-5221	400 BHP 13,800 PSPH	Stave Silo w/ Sprout Waldron	Pine bark, sawdust & dry shavings.
Florida Veneer Co. Hosford, FL Mr. Ed Odom (904) 379-8675	300 BHP 10,350 PSPH	Slip Form Silo w/Flying Dutchman	Hardwood bark & sawdust, pine bark & sawdust.
Newton & Tebbets, Inc. West Bethel, Maine Mr. Archie Young (207) 836-2336	150 BHP 5,175 PSPH	Steel Silo w/Camron Unloader	Shavings, bark and sawdust.
American Forest Products Lumpkin, GA (Plant) Mr. Jim Kent (912) 838-4358	725 BHP 25,000 PSPH	Open Storage w/Drag Chain	Pine bark and sawdust.
Willamette Industries Minden, LA Mr. Ivan Debben (318) 377-1030	600 BHP 20,000 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Harden Furniture McConnellsville, N.Y. Mr. Gordon Babcock (315) 245-1000	435 BPH 15,000 PSPH	Stave Silo w/ Sprout Waldron	Hardwood bark, sawdust and shavings.

INDUSTRIAL BOILER CO.

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CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
Sullivan Lumber Co. Preston, GA Mr. Collins Sullivan (912) 828-3555	1200 BHP 41,400 PSPH	Open Storage w/Drag Chain	Pine bark and sawdust.
Lewittes Furniture Taylorsville, N.C. Mr. Joe Meister (704) 632-4271	200 BHP 6,900 PSPH	Slip Form w/Laidig	All dry wood waste.
North Anson Reel North Anson, Maine Mr. Henry Hinman (207) 635-2101	600 BHP 20,700 PSPH	A.O. Smith Glass Silo w/ Sprout Waldron	Bark & sawdust.
American Forest Products Vredenburgh, AL (Plant) Mr. Jim Kent (205) 337-4321	600 BHP 25,000 PSPH	Open Storage w/Drag Chain	Pine bark and sawdust.
Coulee Region Enterprises Bangor, Wisconsin Mr. Dennis Wood (608) 486-2882	200 BHP 6,900 PSPH	Stave Silo w/ Laidig	Sawdust & dry wood waste.
Producers Lumber Co. Boise, Idaho Mr. Dallas Harris (208) 344-2573	270 BHP 9,315 PSPH		Pine bark & sawdust.
Salem Frame Morehouse, MO Mr. Al Jones (314) 667-5291	400 BHP 13,800 PSPH	Slip Form w/ Van Dale Unloader	Dry fuel.
Burley Smith Lumber Co. Yazoo City, MS Mr. Bobby Smith (601) 746-4054	400 BHP 13,800 PSPH	Stave Silo w/ Laidig Unloader	Dry fuel.

INDUSTRIAL BOILER CO.
Post Office Box 936 - 221 Law Street - Thomasville, Ga. 31792 - 912-226-3024

WOOD FIRED BOILER SYSTEMS

CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
J. R. Mains Co. Bridgton, Maine Mr. Joe Mains (207) 647-3782	75 BHP 2,580 PSPH	Live Bottom Screws	Bark, sawdust & dry shavings.
Bailey Mfg. Co. Fryeburg, Maine Mr. Bob Robillard Mr. David James (Clarks Summit, PA) (717) 586-1811)	600 BHP 20,700 PSPH	Slip Form w/ Flying Dutchman	Pine bark & sawdust.
Durgin & Crowell New London, N.H. Mr. Peter Crowell (603) 763-2562	200 BHP 6,900 PSPH	Metal Silo w/ Laidig Unloader	Pine bark, sawdust & shavings.
Tara Materials Lawrenceville, GA Mr. Wally Klarman (404) 963-5256	400 BHP 13,800 PSPH	Existing Peerless Bin w/Screws	Dry wood waste.
Dickson Treating Co. Canton, MS Mr. Hugh Dickson (601) 859-1135	350 BHP 11,550 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark.
Stanley Tools Pulaski, TN Mr. Steve Swain, Plant Mgr. (203) 225-5111	315 BHP 10,458 PSPH	Slip Form Silo w/Flying Dutchman	Medium M.C. Hardwood Hogged Fuel.
Stakmore Co., Inc. Owego, N.Y. Mr. David Niermeyer (607) 687-1616	100 BHP 3,450 PSPH	A.O. Smith Glass Silo w/ Sprout Waldron	Dry wood waste.
R. Leon Williams East Eddington, Maine Mr. Leon Williams (207) 843-7331	200 BHP 6,900 PSPH	Metal Silo w/ Laidig Unloader	Pine Bark & sawdust.

INDUSTRIAL BOILER CO.
Post Office Box 936 - 221 Law Street - Thomasville, Ga. 31792 - 912-226-3024

CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
Sprowl Bros. Searsmont, Maine Mr. George Sprowl (207) 342-5211	400 BHP 12,800 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Levesque Lumber Co. Ashland, Maine Mr. Paul Levesque (207) 435-3011	600 BHP 19,200 PSPH	Slip Form Silo w/Flying Dutchman	Pine bark and sawdust.
Southern Wood Piedmont Co. Spartanburg, SC (Augusta, GA Plant) Mr. H. I. Warrington (803) 576-7660	850 BHP 29,325 PSPH	Slip Form Silo w/Flying Dutchman	Green hogged fuel.
Fort Apache Timber Co. White River, Arizona Mr. Hal Butler (602) 338-4304	1450 BHP 50,000 PSPH	Clark's Live Botton Bin	Green hogged fuel.
Curtiss Lumber Co. Balston Spa, NY Mr. Bob Curtiss Mr. Bob Robinson (518) 885-5311	154 BHP 5,313 PSPH	Open Storage	Green bark and sawdust.
Union Camp Corp. Building Products Div. Seaboard, NC 23851 Mr. Garland E. Gravely (804) 569-4321	1,292 BHP 44,584 PSPH	Slip Form Silo w/Flying Dutchman	Green sawdust.
Holmes and Co. Columbia City, Indiana Mr. David Holmes (219) 244-6149	195 BHP 6,728 PSPH	Slip Form Silo w/Flying Dutchman	Green sawdust and bark.
Duke City Lumber Co. Winslow, Arizona Mr. Ed McCausland (505) 842-6000	650 BHP 22,425 PSPH		Green bark and sawdust.

INDUSTRIAL BOILER CO.
Post Office Box 936 - 221 Law Street - Thomasville, Ga. 31792 - 912-226-3024

CUSTOMER	CAPACITY	STORAGE	TYPE FUEL
The Fairbanks Co. Rome, GA Mr. Freddy Ergle (404) 234-6701	323 BHP 11,144 PSPH	Slip Form Silo w/Flying Dutchman	Mixture Dry and Green Wood Residues
Universal Veneer Mill Newark, Ohio Mr. Carlo Iseli Zurich, Switzerland	465 BHP 200 PSIG Hot Water	Slip Form Silo w/Flying Dutchman	Green Hardwood Residues
TMA Forest Products Andalusia, Alabama 36420 Mr. James Forbes (Evergreen Plant)	600 BHP 20,000 PSPH	Existing Shed Type	Bark Sawdust

Guaranty Performance Co., Inc.

P.O. Box 748
1120 East Main Street
Independence, Kansas 67301
(316) 331-0020

CUSTOMER REFERENCE LIST

BASSETT FURNITURE INDUSTRIES Bassett Fiberboard Plant P.O. Box 646 Bassett, Virginia 24055 703-629-7511 Jim Minter, V.P./Engineering	ROEMMC solid fuel burner installed for a new boiler system with waste heat recovery. Equipment in operation 9/77.
BERT & WETTA SALES, INC. P.O. Box 317 Maize, Kansas 67101 316-722-0240 Ray Bert, President	Two complete rotary drum drying systems for forage crops. Equipment in operation 5/74.
BOISE CASCADE CORPORATION Box 610 LaGrande, Oregon 97850 503-963-3141 John Schuh, Particleboard Plant Manager	Two fuel economizing systems converting two boiler stacks into four rotary dryers complete with electronic controls. One system utilizing steam-heated furnace for a rotary dryer.
CELOTEX CORPORATION Division Jim Walter Homes P.O. Box 8 Sellers, South Carolina 29592 803-423-5053 Bob Jennus, Plant Manager	Engineering and equipment for furnace modifications to steam heat in combination with boiler stack heat into fiber tube dryers.
DOMINION TAR & CHEMICAL CO., LTD. 396 de Maisonneuve Montreal, Quebec, Canada 514-282-5400 Herb Johnson, Central Engineer 418-285-2121 G. A. Paquin, Plant Manager	Two rotary drum dryer systems, one 100-320 triple pass and one 100-400 single-pass, complete with negative air system. Predryer is heated from wet fuel boiler system. Equipment in operation 6/76.
EL CAMPO RICE MILLING CO. Box 110 El Campo, Texas 77437 713-543-2741 John Hancock, Jr.	Complete design and engineering for par-boiled rice drying systems. Three-pass rotary drums with mechanical dryer discharge, primary and secondary air and particulate collecting system.
GEORGIA PACIFIC CORP. Box 520 Crossett, Arkansas 71635 501-567-8111 Harold Rutledge, Operations Manager Particleboard Division Jerry Ozmant, Project Engineer	One complete ROEMMC wood burning (sanderdust) conversion firing two rotary drum dryers, complete with Allen Bradley programmable process controller system.

HAMBRO FOREST PRODUCTS P.O. Box 129 Crescent City, California 95531 707-464-4355 Hal Hamilton, President	One single-pass rotary drum dryer complete with air system fired from a wet wood waste boiler system. Equipment in operation 6/75.
HUDSON BAY DEHYDRATORS MUTUAL Box 901 Hudson Bay, Saskatchewan, Canada 306-865-3969 Lockie Bracken, President	Design, engineering, equipment and construction management for a complete alfalfa dehydrating plant. Equipment includes a 120-400 triple-pass rotary drum dryer, 250 HP pellet mill, 300 HP hammermill and 6,000 ton pellet storage. Equipment in operation 12/75.
LOUISIANA PACIFIC P.O. Drawer CC Arcata, California 95521 707-822-5961 Robert Johnson, Plant Manager	Two complete rotary drum drying systems with sanderdust burning system.
MACMILLAN BLOEDEL INC. Particleboard Plant Pine Hill, Alabama 36769 205-963-4391 Werner Westphal, Plant Manager	Four complete rotary drum drying systems. Heavy oil burners with boiler stack heat and steam pre-heaters. Negative air system with particulate control equipment. Equipment in operation 2/75.
MASONITE CORPORATION P.O. Box 378 Waverly, Virginia 23890 804-834-2201 Clyde Ratcliff, Plant Manager Carl Shaw, Manufacturing Manager	One complete wood drying system. Replacement of one Heil drum only. Equipment in operation 3/74.
NAVAJO FOREST PRODUCTS INDUSTRIES Box 1280 Navajo, New Mexico 87328 505-777-2211 Horst Strumlinger, Particleboard Manager	Two complete rotary drum dryer systems, one with sanderdust burner and one steam heated furnace system. Equipment in operation 6/76.
NU-WOODS INC. P.O. Box 706 Lenoir, North Carolina 28645 704-758-4463 Fred Fulmer, Executive Vice President and General Manager	One complete rotary drying system for a particleboard plant. Negative air system. Vertical combustion tube.
OCCIDENTAL RESEARCH CORP. 1001 West Bradley Avenue El Cajon, California 92020 714-449-3910 Dale Barnhill, Sr. Process Engineer	One complete rotary drying system fired with regenerative gas for municipal waste pyrolysis system.

PLUM CREEK LUMBER COMPANY Box 188 Columbia Falls, Montana 59918 406-892-3222 Bill Black, Plant Manager	Two sanderdust burner conversions to existing fiber tube dryers. Equipment in operation 2/76.
PRODUCER'S RICE P.O. Box 461 Stuttgart, Arkansas 72160 501-673-2551 Charles Chastain, Plant Engineer Ron Bailey, Vice President	Complete rotary drum dryer with pollution abatement package for pre-cooked, par-boiled rice. A quality controlled drying process.
SOUTH COAST CORPORATION P.O. Box 8036 Houma, Louisiana 70361 504-868-1990 Albert Guidry, Vice President Engineering	Two complete rotary drum drying systems, bagasse fuel preparation, boiler using boiler flue gas, system complete with conveying and handling.
TEMPLE INDUSTRIES, INC. Particleboard Division Diboll, Texas 75941 713-829-5511 Bill Oates, Divisional Manager Richard Krull, Plant Superintendent	ROEMMC solid fuel burner conversion into four existing rotary dryers for particleboard plant. Including boiler stack heat utilization.
UNION CAMP CORPORATION P.O. Box 178 Franklin, Virginia 23851 804-569-4321 Garland Gravely, Vice President Bruce Jones, Plant Manager	ROEMMC solid fuel burner conversion into two existing rotary dryers for particleboard plant. Including boiler stack heat utilization.
U.S. PLYWOOD P.O. Box 558 Gaylord, Michigan 49735 517-732-5151 Lee Evans, Corporate Purchasing Max Stehman, Project Manager	Four 120-400 triple-pass rotary drum dryers complete with fossil fuel and wood dust burners, negative air systems and particulate abatement equipment.
VERHOFF ALFALFA MILLS P.O. Box 87 Ottawa, Ohio 45875 419-523-4767 Ray Verhoff, President	One complete rotary drum drying system for forage crops. Equipment in operation 5/74.
WAIALUA SUGAR COMPANY P.O. Box 665 Waialua, Oahu, Hawaii 96791 808-637-4520 Chester Shishido, Project Engineer George Fraser, V.P./Production	Boiler fuel preparation system, equipment and engineering, for bagasse handling, three-pass rotary drum drying system utilizing power boiler stack flue gas for rotary drum dryer energy.

WEYERHAEUSER COMPANY
P.O. Box 547
Adel, Georgia 31620
912-896-2215
Royce Stanford, Plant Manager
Tony Moore, Production Manager

Two complete rotary drum dryers with combination gas/sanderdust burners, negative air systems and product moisture analyzer and controls. Equipment in operation 2/75. Two existing dryer energy conversions from fossil fuel to boiler flue heat and excess steam utilization.

WEYERHAEUSER COMPANY
Craig Box
Broken Bow, Oklahoma 74728
405-584-3318
Jim Simon, Complex Manager

Fuel economizing system converting boiler stack into fiber tube dryers complete with electrical controls. Equipment in operation 10/75. One complete fiber tube dryer fired with solid fuel (sanderdust) and electrical control system. Equipment in operation 2/76.

WEYERHAEUSER COMPANY
P.O. Box 135
Doswell, Virginia 23407
804-876-3331
Henry Ragar, Plant Manager
Gary Holmquist, Project Engineer

One complete designed and engineered ROEMMC solid fuel suspension burning system with hot gas dampered control into two fiber tube dryers. Complete fuel preparation consisting of grinding, screening, storing, reclaiming and burning.

WEYERHAEUSER COMPANY
118 S. Palmetto
Marshfield, Wisconsin 54449
715-384-2141
Guenter Hennig, Project Engineer

Conversion of existing No. 1 rotary dryer system with new controls and furnace, to solid waste burning (sanderdust). Equipment in operation 1/77. Modified and relocated No. 3 rotary dryer system with new controls, furnace, and air system and converted to solid waste burner (sanderdust).

WEYERHAEUSER COMPANY
Box 168
Moncure, North Carolina 27559
919-542-2128
Bill Peek, Plant Engineer
Jim Knoles, Plant Manager

Fuel economizing system utilizing boiler stack heat into two fiber tube dryers complete with electronic controls. Equipment in operation 6/75.

WEYERHAEUSER COMPANY
P.O. Box 275
Springfield, Oregon 97477
503-746-2511
Richard Crabb, Project Manager
Bill Perry, Particleboard Manager

Particleboard plant dryer systems, pollution controls, engineering and equipment.

APPENDIX H

Mix sawdust with coal for a clean and cheap boiler fuel

Bill Burnham is blazing new trails with sawdust from local-area lumber mills—he's feeding the wood waste to the boilers at Southern Colorado Power Div's electrical generating station in Canon City. The sawdust, which is mixed with coal before burning, is cheaper than conventional energy sources. Currently, the two boilers (18- and 24-MW units) are burning an average of about 120 tons of sawdust a day.

Burnham, the plant superintendent and an electric-utility specialist with 31 years of experience with SCP, (a subsidiary of Chicago-based Central Telephone & Utilities) says in describing the project, "The sawdust simply falls out from the back of a truck and down through a grating into a hopper with the coal. Then it's conveyed as a mixture with the coal into the boiler and burned. It's nothing extravagant," he says.

The sawdust is hauled in specially equipped semitrailers with canvas tops that keep the dusty bits from flying away when the loads are in transit to the power station. Instead of dumping the sawdust, each trailer has a full-width conveyor belt on the floor, which pulls the sawdust out of the truck's back door. The trailer is parked on the grate over the hopper at the plant.

Burnham says that, in the beginning, he burned about five tons of sawdust a day. "I just wanted to burn small amounts and see how it worked." And four years and a few thousand tons of sawdust later, Burnham has had no problems. In fact, he's found that the process can increase the life of the boilers.

He explains: "Burning a ton of our coal produces about 200 to 600 lb of ash in the boiler. The ash is abrasive and erodes the metal. Sawdust, on the other hand, produces about 60 lb of ash. Anything you can do to cut down the amount of ash just lengthens the life of everything. Also, with the quantity of ash reduced, there's less ash-handling labor and equipment involved.

Since 1974, Burnham gradually increased sawdust consumption at the plant to 10, 20, 30, 40 and 50 tons a day. The plant has burned as much as 120 ton/day, and is now averaging about 100 ton/day.

"About 120 tons per day is the maximum we can burn," Burnham says. "If we were to burn more sawdust than that, we'd have to make equipment conversions, and that takes dollars."

Sawdust, hauled to plant in trailer, is dumped into grated hopper and mixed with Colorado subbituminous low-sulfur coal

He points out that each truckload of sawdust varies in quality. "Some varieties of sawdust don't burn as well as others. Sawdust with a high moisture content burns less efficiently. Our contract is based on a 35% moisture content. The higher the moisture content, the lower the Btu rating. One ton of contract-quality sawdust produces about 10-million to 11-million Btus, so when we get drier sawdust it's a bonus," he says.

Burnham says that one ton of sawdust costs about $6, while a ton of the coal used at SCP (about 20-million Btu/per ton) costs about $13.50. "I'm paying a little less per-million-Btus for the sawdust. In January 1978, the savings amounted to 11.3¢ per 1-million Btus.

"Anytime you can buy a cheaper fuel it's a saving for the customer and the company, and this makes everyone happy," Burnham says.

Another plus is that burning sawdust causes less air pollution than coal not only because it contains less ash, but also because the sulfur content is one fifth that of the Colorado subbituminous coal used in the plant. This is despite the fact that Colorado coal is a low-sulfur coal with an average sulfur content of only 0.55%. ■

APPENDIX I
MANUFACTURERS OF DIRECT COMBUSTION SYSTEMS

American Fyr-Feeder Engineers
1265 Rand Road
Des Plaines, IL 60026
312-298-0044

Atlas Boiler & Equipment Co.
W. 29 Spokane Falls Blvd.
Spokane, WA 99211
503-747-6001

Automated Combustion
PO Drawer 9
Lake Oswego, OR 97304
503-636-4569

Babcock & Wilcox Company
20 S. Van Buren Avenue
Barberton, OH 44203
216-753-4511

Bagot (Herman) and Company
3143 N. Nottingham
Chicago, IL 60634
312-637-6037

Basic Environmental Engineering, Inc.
21 Hill Street
Glen Ellyn, IL 60137
312-469-5340

Bigelow Company
PO Box 706
New Haven, CT 06503
203-772-3150

Bumstead Woolford Company
PO Box 448
Woodinville, WA 98072
206-485-9646

Burnham Corporation
PO Box 27
Lancaster, PA 17604
717-397-4701

Burt Power Inc.
6405 New Tampa Highway
Lakeland, FL 33802
813-876-5329

Combustion Engineering, Inc.
900 Long Ridge Road
Stamford, CT 06902
203-688-1911

Copeland Systems, Inc.
200 Spring Road, Suite 300
Oak Brook, IL 60521
312-654-2820

Detroit Stoker Company
Monroe, Michigan 48161
313-241-9500

Eclipse Lookout Company
PO Box 4756
Chattanooga, TN 37405
615-265-3441

Energex, Ltd.
PO Box 4208
North Portland, OR 97208
503-286-8231

Energy Control Engineering Corp.
PO Box 3064
Charlotte, NC 28203
704-375-1701

Energy Products of Idaho
PO Box 153
Coeur d'Alene, ID 83818
208-667-6439

Environmetrix
4725 University Way NE
Seattle, WA 98115
206-524-6350

European Woodworking Machinery Co.
PO Box 452
Franklinton, NC 27525
919-494-7455

Foster Wheeler Energy Corporation
110 South Orange Avenue
Livingston, NJ 07039
201-533-1100

Gaskell Company, Inc.
PO Box 13225
Memphis, TN 38113
901-775-3222

Harvey Engineering and
Manufacturing Corp.
Route 2, Box 478
Hot Springs, AR 71901
501-262-1010

Industrial Boiler Company
221 Law Street
Thomasville, GA 31792
912-226-3024

International Boiler Co.
E. Strousburg, PA 18301
717-421-5100

Irvington-Moore Division of USNR
PO Box 40666
Jacksonville, FL 32203
509-747-7965

Johnston Boiler Company
Ferryburg, MI 49409
616-842-5050

Keeler (E.) Company
238 West Street
Williamsport, PA 17701
717-326-3361

Kewanee Boiler Corporation
101 North Franklin Street
Kewanee, IL 61443
309-853-3541

Kipper and Sons Engineers, Inc.
2616 Western Avenue
Seattle, WA 98121
206-622-4545

Lamb-Grays Harbor Company
Hoquiam, WA
206-532-1000

Lasker Boiler & Engineering Corp.
3201 S. Wolcott Avenue
Chicago, IL 60608
312-523-3700

Marden, Inc.
3129 E. Washington Avenue
Madison, WI 53704
608-244-3331

McBurney Corporation
PO Box 47848
Atlanta, GA 30362
404-448-8144

McConnell Industries
Box 26210
Birmingham, AL 35226
205-942-3321

Mechanical Equipment Company
7212 Woodlawn Avenue, NE
Seattle, WA 98115
206-523-8526

Moore-Oregon-Canada
PO Box 4208
Portland, OR 97208
503-286-8231

Peabody Engineering Company
Stamford, CT
203-327-7000

Peabody Gordon-Piatt, Inc.
Box 650
Winfield, KS 67156
316-221-4770

Pyrotechnic Industries, Ltd.
Box 629
Cochrane, Alberta, Canada
403-932-2274

Ray Burner Company
1303 San Jose Avenue
San Francisco, CA 94112
415-333-5800

Riley Stoker Company
9 Neponset Street
Worcester, MA 01613
617-852-7100

Rogers (John) Co.
4605 Illinois Avenue
Louisville, KY 40213
502-458-5400

Seattle Boiler Company
5237 Marginal Way
Seattle, WA 98134
206-762-0737

Smith (Perry) Co., Inc.
PO Box 21282
Chattanooga, TN 37421
615-982-7130

Stearns-Roger, Inc.
PO Box 5888
Denver, CO 80217
303-758-1122

Steel Craft Corporation
Box 12408
Memphis, TN 38112
901-452-5200

Vogt (Henry) Machine Company
PO Box 1918
Louisville, KY 40201
502-634-9411

Woodamation, Inc.
PO Box 1365
Chalmette, LA 70044
504-279-1010

Wyatt Engineers, Inc.
3214 16th Avenue, SW
Seattle, WA 98134
206-682-2501

York-Shipley Inc.
PO Box 349
York, PA 17405
717-755-1081

Zurn Industries, Inc.
2214 West 8th Street
Erie, PA 16512
814-455-0921

APPENDIX J

COMPANIES MANUFACTURING DENSIFIED FUEL

Agnew Environmental Products
211 S. E. 10th PO Box 1168
Grants Pass, OR 97526
503-479-3396

Bio-Solar Corporation
PO Box 762
Eugene, OR 97401
503-686-0765

Bonnot Company
805 Lake Street
Kent, OH 44240
216-673-5829

California Pellet Mill Company
1800 Folsom Street
San Francisco, CA 94013
415-431-3800

Fourply, Inc.
PO Box 890
Grants Pass, OR 97526
503-479-3301

Guaranty Performance Co., Inc.
PO Box 748
Independence, KS 67301
316-331-0027

Hobbs (C. B.) Company
Elk Grove, CA 95624
916-685-3925

Papakube
931 East Harbor Drive
San Diego, CA 92101
714-231-1490

Sprout Waldron and Co., Inc.
Muncy, PA 17756
717-546-8211

APPENDIX K

DENSIFICATION

A fuel with high mass energy density and volume energy density is preferable to a fuel with low values because it is more efficient to store, ship, and burn. Combustion efficiency increases with increasing fuel density and decreasing moisture content.

The first U.S. Patent for densification was issued in 1880; it describes a process where sawdust or other wood residues are heated and then compacted to the "density of bituminous coal" with a steam hammer. Since then, a number of additional patents have been issued for processes that make dense forms of biomass. At first, the process were primarily used to produce animal feed; several companies are now using various forms of the same basic idea to produce fuel for the energy market.

There are now five forms of biomass densification being practiced commercially: pelleting, cubing, briquetting, extrusion, and rolling-compressing. The products vary considerably in size and appearance, from 1/4" diameter pellets to 8" long by 7" diameter rolls.

The densification process is dependent on heat input. The heat both softens the lignin (a "waterproof glue" that holds the cellulosic material, or biomass, together) in the material so that it can be molded, and reduces the moisture content to somewhere between 10% and 25%.

The process of densifying biomass shows promise of providing a dry, uniform, easily stored and conveniently shipped fuel from the wide variety of residues produced in agriculture, forestry, and food processing. Compared to coal, densified biomass is clean, easy to handle, and burns with low ash and sulfur emissions. The process of densification consumes about 7% of the energy in the feedstock. Depending on the cost of feedstock, the cost of densified wood runs from $1.20 to $3.40 per million BTU.

Widespread use of densification could generate a commodity fuel market capable of supplying both small and large fuel users. Pellets are also suitable for use in gasifiers.

APPENDIX L

WOOD FUEL SYSTEM USERS

Densification

Applied Engineering Company
Box 1337
Orangeburg, SC 29115
803-534-2424

Collins and Aikman
701 McCullough Drive
Charlotte, NC 28232
704-596-8500

Edward Hines Lumber Company
Hines, OR 97738
503-573-2091

Minnesota, State of
Department of Corrections
Metro Square Building
Seventh and Robert Streets
St. Paul, MN 55101
612-296-3529

Sierra Power Corporation
9893 N. Blockstone Street
Frenso, CA 93710
209-439-6601

Pyrolysis

California, State of
Solid Waste Management Board
PO Box 160908
Sacramento, CA 95810
916-322-3330

Maryville College
Maryville, TN 37801
615-982-6412

Rockwell International
Marysville, OH 43040
513-644-3015

Weyerhaueser Company
Tacoma, WA 98401
206-259-0425

Gasification

Interpine Lumber Company
Picayune, MS 39466
601-798-5912

Kearsarge Reel Company
Warner, NH 03278
603-938-2266

Direct Combustion*

American Fyr-Feeder Engineers
1265 Rand Road
Des Plaines, IL 60026
312-298-0044

Ray Burner Company
1303 San Jose Ave.
San Francisco, CA 94112
415-333-5800

*These companies are among many which will provide on request list of facilities using wood-fired boiler equipment.

APPENDIX M

Presented at First World Energy Congress, Atlanta, GA, Oct. 31, 1978

GASIFIERS FOR RETROFITTING GAS/OIL COMBUSTION UNITS TO BIOMASS FEEDSTOCK

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Solar Energy Research Institute
Golden, Colorado

ABSTRACT

As oil and gas become more costly and less available, there is increasing incentive to use biomass sources such as mill wastes, municipal wastes and densified biomass. Yet installation of completely new equipment for biomass combustion is expensive (typically $25/lb steam/hr). An attractive alternative is the use of close-coupled gasifiers to produce a gas of typically 160 Btu/cf. This gas can be burned in existing equipment with minor modifications which permit return to gas/oil when available.

Various types of close-coupled gasifiers will be described with conversion requirements, typical energy balances and cost figures for conversion and biomass fuels. Problems encountered in conversion will be discussed.

INTRODUCTION

Industrial concerns will need 20-20 foresight to cope with the increasing energy problems in our society. Many, who converted from coal to natural gas or oil during the last decade to meet more stringent emission requirements are faced now with much higher fuel prices and the possible curtailment or total interruption of supply. The most obvious course is conversion of those boilers originally using coal back to coal or wood or the replacement of the new oil/gas package boiler with a new coal/wood installation. Both of these options are relatively expensive and will also require new emission controls.

A less obvious option is the use of a biomass (or coal) gasifier to retrofit the existing gas/oil boiler to an intermediate energy gas generated in-situ, using the "close-coupled gasifier". In this paper we examine the technology and economics of gasifiers and compare the economics of retrofit with installation of new solid fuel installations.

HISTORY AND STATUS OF GASIFIERS

The term "gasification" refers to the thermal conversion of biomass (or coal or petroleum) to a gas to be used for heat, power or chemical synthesis. "Pyrolysis" usually implies production of char and oil as well. A recent worldwide survey lists 55 commercial or demonstration gasification and pyrolysis projects in North America.(1)In the 1930's, most cities of the United States had a "gasworks", gasifying either coal or occasionally wood to provide gas for cooking and lighting. These units have been closed down in the U. S. due to the availability of low cost natural gas and oil, but gasification of biomass has been widely used in other parts of the world.(2) Small portable gasifiers were widely used during both World Wars to drive cars and trucks. (3,4)

Although we will probably not use gasifiers for transportation in the U.S. in the near future, we can use these simple devices to provide gas for retrofitting gas or oil fired boilers, thus eliminating the necessity of replacing the entire system, which would be required for conversion to a solid fuel such as wood or coal. Many industries in fact have waste biomass which is presently a disposal problem, but which would provide necessary process heat if suitable size gasifiers are installed.

TYPES OF GASIFIERS

There are dozens of types of gasifiers ranging in size from 100,000 Btu/hr to 100 MBtu/hr and yielding a gas with energy content from 90 Btu/scf to 1,000 Btu/scf. The various methods for gasification are shown in Fig. 1. We wish to focus here on the simplest type of gasifier, the air-blown, close-coupled gasifier accented in Fig. 1 in which a relatively low energy content gas is manufactured on site and burned in existing equipment a few feet away. This is the so-called "close-coupled" mode of operation. In this case there is no need to cool and scrub the oils from the gas as would be required for use in engines or for pipeline use. This greatly reduces the cost and increases the simplicity and efficiency of the apparatus.

The two principle types of close-coupled gasifiers are the updraft gasifiers and the downdraft gasifier, shown diagramatically in Fig. 2, (a) and (b). (Other types include crossdraft and dual mode-gasifiers.) In an updraft gasifier, air first contacts a bed of buring charcoal, generating hot CO and CO_2. These gases pass successively through the incoming biomass, first pyrolysing it to form volative oils and finally drying it. The gas is diluted by any moisture in the feedstock, but the energy content is enhanced by the high molecular weight oil vapors which also improve the burning characteristics.

In a downdraft gasifier, the air is injected through nozzles into the hottest portion of the charcoal fire and is drawn down through the charcoal bed along with the tars and moisture from the fuel in the higher regions. This causes the oil vapors to crack into gases, primarily CO and H_2. Downdraft gasifiers are especially useful for prodUcing gas to be used in engines, because the oil vapors will clog the engine intakes. At present, both types are being used for retrofitting gas/oil boilers to biomass.

A preliminary list of manufacturers of gasifiers suitable for conversion of gas/oil boilers is given in Table I. This Table also shows the type of gasifier, the size, and some preliminary costs obtained from the manufacturer. (Costs will be discussed below.) The authors are continuing a larger study of gasifiers and would appreciate more data from these and other manufacturers.

GASIFIER FUELS

In prinicpal, gasifiers can operate on any carbonaceous solid fuel such as coal, lignite or biomass. In practice, however, the satisfactory operation of any particular gasifier will depend on its design relative to the fuels used, and depends in particular on the fuel density, moisture, ash fusion temperature, particle size, etc.

The satisfactory operation of a gasifier depends on a free and uniform passage of the gas through the fuel bed. Therefore, satisfactory biomass fuels should be relatively uniform in particle size so that the gases do not form channels. Particle size should be greater than about 1/4" so that there is not too much back pressure, particularly in updraft gasifiers. Dusts and fines are particularly troublesome. The char which forms on pyrolysis should have moderate physical integrity to prevent collapse and plugging of the bed.

For these reasons wood chips and bark make excellent fuels for gasifiers. Gasifiers have been run satisfactorily also on shells, pits and corn cobs. However, other fuels such as straw, cotton gin trash, food residues, etc, may require densification (cubing, pelleting, briquetting, extrusion, etc.) in order to be used satisfactorily in gasifiers.

Biomass has many attractive features as a fuel, including very low sulfur, renewability, low cost in many cases and no increase in long-term atmospheric CO_2. However, biomass occurs in a wide variety of forms and is often too wet to burn and too bulky to ship. Recently a number of companies have begun to make densified biomass fuels, "DBF", to overcome this handicap and create a uniform commodity fuel selling for \$20-\$30/ton. The cost of drying and densifying runs from \$6-\$15/ton and must be weighed against the value of the biomass with and without densification. A recent report summarizes the energetics and economics of densification.(5) A number of gasification tests have been run on pellets and they are found to be quite satisfactory fuels.(6-8)

DBF has typical particle densities of 0.8-1.3, while wood chips (dry basis) have densities of 0.4-0.5 and most other biomass is even less dense. Therefore, a further advantage of densification before gasification is that the capacity of the gasifier is increased due to the higher energy density at the grate.

The energy content of the gas produced in gasifiers is low because of the nitrogen content of the air used in gasification. In addition, it may be even lower due to water vapor in the gas. Therefore it is desirable to keep the water vapor in fuel to a minimum. Some gasifiers can operate with up to 30% moisture content , but gas quality is degraded at higher moisture levels. It is necessary to reduce moisture content to 10-20% before densification and as a consequence has an attractively low moisture content.

PROPERTIES OF PRODUCER GAS

The gases produced in the gasifiers shown in Table I contain CO, H_2 and hydrocarbon as their principle fuel ingredients. In addition, they contain N_2, CO_2 and H_2O as diluents. If the gases are cooled and scrubbed for use in engines or a pipeline, they have a typical energy content of 90 Btu/scf and are called by the names low Btu gas (LBG), producer gas, Gen-gas or generator gas. A typical analysis (Davis gasifier, walnut shells) show: CO = 20.5%; H_2 = 15.3%; CO_2 = 7.4% O_2 = 1.4%; hydrocarbons = 8.1%; N_2 = 47.4%.

If these gases are to be used for heating only, it is not desirable to remove the pyrolysis oil vapors and the sensible heat, and then these same gases have an effective heat content of 140-200 Btu/scf, depending on temperature, feedstock, type of gasifier, etc. We propose the name "intermediate Btu gas" (IBG) for gas with this energy content.

OVER-EFFICIENCY OF GENERATION OF IBG

The energy content of a gas is very important to the economics of shipping by pipeline. However, the energy content has little effect on the flame temperature and mass of flue gas produced, because large quantities of air must be added for combustion. The combustion efficiency of gases in boilers is shown in Fig. 3 (after reference 9) as a function of energy content of the gas. Here it can be seen that effciency is slightly higher for the medium Btu gas (MGB) with energy content around 350 Btu/scf than it is for high Btu gas (HBG) with energy content about 1,000 Btu/scf. Efficiency begins to fall below about 200 Btu/scf and it can be seen that there is little efficiency loss for close-coupled gas (IBC), but there is a 10-15% loss for low Btu gas (LBG).

SCALE OF CLOSE COUPLED GASIFIERS

It can be seen from Tables I and II that there are a number of close-coupled gasifiers being developed in the range 1-100 MBtu/hr. There may also be some need for even smaller gasifiers, for instance for heating apartments and shopping installation. At present there are no proven biomass gasifiers for operation above 100 MBtu/hr and there would seem to be a need for this size for large process steam installations, especially in the paper industry. However, coal gasifiers have been built at this larger scale and there seems to be no technical barrier to building a very large close coupled gasifier.

EFFICIENCY OF CLOSE COUPLED GASIFIERS

Since all of the gas generated is burned and the sensible heat of the gas stream is also conserved, close coupled gasifiers can have very high efficiencies. Essentially complete combustion is achieved, as a result of the two stage combustion in the gasifier and the boiler. The only losses are the heat losses from the outer surfaces and heat to the ash which is negligible. The Century gasifier is reported to have a thermal efficiency of 90% (10) while the Davis Gasifier operates a typical efficiency of 85% (8). The early gasifiers used for transport in Europe has thermal efficiencies of 80% even after scrubbing the gas and removing tars.

TECHNOLOGY OF RETROFITTING EXISTING BOILERS TO CLOSE COUPLED GASIFIERS

The gases produced in the gasifiers of Table I can be burned in existing oil/gas installations, and a number of commercial installations have been made. The gas is somewhat more difficult to burn than natural gas and will require insulated pipes to prevent condensation of pyrolysis oils and tars. A gas pilot flame or a flame holder is used to insure combustion. However, the conversion problems are minimal.

In general the modifications needed for retrofitting existing boilers are not documented, but a recent feasibility study at the California State Central Heating and Cooling Plant in Sacramento has used the Davis gasifier to power one of their boilers for 158 hours.(7) The gasifier is 8 ft. in diameter and 15 ft. tall and produced 16 MBtu/hr. Tests were run using three fuels; kiln dry wood chips purchased for \$9/ton, or \$12.50/ton delivered; demolition chips purchased for \$9/ton or \$12.50/ton delivered; and pelleted white fir sawdust purchased for \$25.50/ton or \$35.00/ton delivered. The heating value of the gas varied from 182 to 206 Btu/scf. Emissions were: 0% SO_2 observed (0.2% allowable); 130 ppm NO_x (200 ppm Federal Standard); and 0.703 lbs/hr particulates (4.09 lbs/hr allowable). There was some condensate, tar and char collected. The Division of Water Quality concluded that they would not be a serious disposal problem.

Minor problems were encountered during the test runs, such as burning out of an auger motor and some tar buildup on the delivery line. Most of the problems were associated with the temporary nature of the hookup for testing and should be no obstacle to commercialization. There was no noticeable deterioration of the metal parts and it is expected that gasifiers will have a long lifetime. (Gasifiers are still in operation that were built 60 years ago.) During these tests the gasifier production rate was controlled manually by controlling intake air. It is expected that gasifiers will be characterized by fast response time to changes in load, since they have been used to operate trucks, cars and tractors.

COSTS OF RETROFITTING TO EXISTING BOILER

Two manufacturers with commercial experience have projected costs for commercial size units and these are compared in Table II. (8,10)

From these costs it can be seen that
- Gas costs are very low compared to current natural gas costs
- Capital costs of gasification are in the range of 0.13 to 0.40 $/MBtu
- Fuel costs are highly variable, but are the major costs in producing IBG

Costs are given in detail for the test operation of the Sacremento gasifier. From this experience, costs projected for a permanent 50 MBtu/hr gasifier system add to a total of $2.5 million, including a 25% contingency fund. Operating costs are expected to be $150,000/yr including labor, electricity and maintenance. The present cost of gas/oil fuels is $340,000 /yr and would escalate to $758,000 by the year 2000 at a 4%/yr escalation rate. Over the 20 year period 1980 to 2000 this would cost $10 million. Fuel costs for biomass gasification would be $110,000 and $220,000/yr, assuming that residue biomass costs $10 or $20/ton. However, inclusion of capital and operation and maintainance costs would bring the 20 year cost to $7.7 million or $9.9 million for the 20 year period, assuming $10 and $20/ton for residue biomass fuel. (Sacremento is the hub of a large timbershed and wood processing and exporting economy generating over a million tons of residu/ur at costs from $0 to $50/ton. This facility would use 10,000 tons/yr). (7)

COMPARISON OF CONVERSION ECONOMICS

If it is difficult to establish cost guidelines for retrofitting gas/oil boilers with close-coupled gasifiers, it is even more difficult to compare these costs with other options in a time of repidly changing costs and availability of fossil fuels and combustion equipment. Therefore we limit ourselves at this point to listing factors which affect the relative economics of various options and comments on these factors.

The options available for conversion away from gas/oil today are:

1. Reconversion of an originally solid-fueled installation which has been converted to gas/oil back to solid fuel. Where possible, this is probably the most economical conversion - yet often the solid fuel handling equipment will have been scrapped, new emission control equipment will have to be added, and the existing boiler is likely to be old and inefficient.
2. Removal of the existing gas/oil boiler (often relatively new) and installation of a new solid fuel system burning coal or wood or other biomass. This will cost on the order of $10-30/lb st/hr and will require installation of new emission control equipment.
3. Installation of a close-coupled gasifier to operate the existing gas/oil equipment. This will cost on the order of $4-9/lb st/hr (see Table I and II) and makes use of much of the existing installation. It also permits using gas/oil where and when they are available and economic. It permits use of biomass wastes that would not have other value as fuels.

In an early study for some wood industries of Maine, the advantages of close coupled gasifiers for retrofitting existing boilers were compared to installation of new wood-fired equipment. It was concluded that the gasifier would permit retrofit at a cost of $5-10/lb st/hr, while new installations would cost on the order of $25/lb st/hr. (11)

On the other hand a recent study by Mitrek (13) concludes that direct combustion will probably be the most economical method of burning wood at least in large installations. However they do not appear to have considered close-coupled gasifiers nor are they taking credit for retrofitting existing installations.

There will sometimes be a requirement for additional capacity. Although the economics in this case do not so clearly favor the use of a close-coupled gasifier, in certain size ranges the low cost and high heat release rates of package boilers for gas/oil and the low emissions from gasifiers suggest that this option should be closely studied for new biomass installations as well. A recent study shows that installation of a medium Btu gasifier plus package boiler is comparable in cost to installation of solid fuel equipment, even though an BMG gasifier is considerably more expensive than the close-coupled gasifiers described in this paper. (13)

CONCLUSION

The addition of a close-coupled gasifier to an existing gas/oil boiler appears to be considerably more economical than substitution of solid fuel combustion equipment. A number of manufacturers are developing equipment for retrofitting existing boilers.

REFERENCES

(1) J.L. Jones, R.C. Phillips, S. Takaoka, and F.M. Lewis, "Pyrolysis, Thermal Gasification and Liquefaction of Solid Wastes and Residues: Worldwide Stutus of Processes", Presented at ASME 8th Biennial National Waste Processing Conference, Chicago, IL, May, 1978. (Available SRI International)

(2) R. Overend, "Wood Gasification: An Old Technology with a Future?" in Proceedings Forest and Field Fuels Symposium, The Biomass Energy Institute, Inc. Box 129, Postal Stn. "C", Winnipeg, Canada R3M 357 October 12, 1977. (Also contains discussions of various gasifiers by R.E. Chant, E.R. Mellinger, W. Stohlgren, G. Finnie, R.C. Bailie and F.Buckley)

(3) "GENGAS" The Swedish Academy of Engineering, Stockholm, Sweden (Available in translation from Solar Energy Research Institute, Golden, CO about September 1978)

(4) Brian Horsfield, "Current European Activities in Gasification," 1976. Available from University of California, Agricultural Engineering Department, Favis, CA 95616 along with 12 publications 1976-77 from B. Horsfield, JR. Goss, F. Jenkins, H. Doster, R. Peart, R.D. Williams, and R. Hodam.

(5) T.B. Reed and B. Bryant, "Densified Biomass: A New Form of Solid Fuel." SERI Report #35, The Solar Energy Research Institute, Golden, CO (July 1978).

(6) R.O. Williams and J.R. Goss, "An Assessment of the Gasification Characteristics of Some Agricultural and Forest Industry Wastes," Manuscript from Department of Agricultural Engineering, University of California, Davis, November 1977.

(7) Feasibility Study: "Commercial Biomass Gasifier at State Central Heating and Cooling Plant", prepared by Fuels Office Alternatives Division, California State Energy Commission, Sacramento, (April 1978).

(8) J.R. Goss, "Food, Forest Wastes = Low Btu Fuel". Agricultural Engineering, p. 30, (January 1978).

(9) H.R. Amundsen, "The Economics of Wood Gasification", in Chaparral for Energy Information Exchange Conference, Pasadena, CA sponsored by PSW Experiment Station, Angeles National Forest, July 22, 1976 (p. 118); also various publications available from Century Research, Gardena, CA 90247.

(10) E.P.R.I., "Fuels from Municipal Refuse for Utilities: A Technical Assessment," EPRI report 261-1, March 1975 (Prepared by Bechtel Corp).

(11) T.B. Reed and W.A. Stevenson, "Energy From Wood," Maine Wood Study Group, November 1975.

(12) D. Salo, L. Gsellman, D. Medville, and G. Price, "Near-Term Potential of Wood as a Fuel," Mitre Technical Report MTR-7860 (July, 1978).

(13) R. Bailie and C.A. Richmond, "Economics Associated with Waste or Biomass Pyrolysis Systems," presented at ACS Symposium, Anaheim CA Mar 10-12, 1978.

Table I

PARTIAL LIST OF BIOMASS GASIFIER MANUFACTURERS IN THE U.S.

Name:	Type	Status(1)	Size(2) MBtu/Hr	Install. Cost(3) $MBtu/Hr	$/MBtu	Biomass Cost $/ Dry Ton
Applied Engineering, Orangeburg, SC	Updraft	D	8	--	--	--
Biomass Fuel Conversion, Yuba City, CA	Downdraft	D	14	--	--	--
Century Research, Gardena, CA	Updraft	C	85	4100(4)	1.05(4)	10
Davis Gasifier, U. of Calif., CA	Downdraft	D	14	8920(4)	0.73(4)	4
Dekalb Agricultural Research, DeKalb, IL	Updraft	D	1.7	--	--	--
Forest Fuels, Keene, NH	Updraft	C	1-12	5000	--	--
Foster-Wheeler, Livingston, NJ	Updraft	D	50	--	--	--
Halcyon, E. Andover, NH	Updraft	C	8	--	--	--
Pioneer Hi-Bred Inst., Johnston, IA	Updraft	D	7	--	--	--
Woodex Corp., Eugene, OR	Updraft	C	10	--	--	--

(1) Status of project: C, Commercial - at least one unit in field
D, Demonstration, Testing

(2) Fuel Consumption in tons/hr is approximately MBtu/hr ÷ 16 MBtu/dry ton

(3) Installation cost in \$/lb steam $hr^{-1} \sim 10^{-3}$ (\$MBtu-hr)

(4) Depends on many factors, see Table II and References

Table II

OPERATING COST OF GASIFICATION

	Davis Gasifier(1)		Century Gasifier(2)	
Fuel	Walnut Hulls		Chaparral	
Rated Gas Production (B /hr)	14.1 M		85 M	
Rated Feed Rate (Ton/Hr)	1.19		7.87	
Capital Cost	$125,800		$350,000	
Efficiency	85%		90%	
Annual Operating Costs:				
Depreciation	(10%)	$12,580	(10%)	$35,000
Repairs & Maintenance	(3%)	3,774	(3%)	10,500
Utilities (Water, Power)		--		38,795
Operating Labor	(250 days)	6,000	(365 days)	14,600
Taxes & Insurance	(2%)	2,516		--
Interest	(7%)	8,806		--
Profit		--		--
Gasification Cost		$33,676		$98,895
Fuel Cost	($4/Ton)	28,571	($10/Ton)	$689,450
Total Operating Cost		$62,247		$788,345
Annual Gas Production (MBtu)		85,000		744,600
Gasification Cost ($/M BTu)		$ 0.40		$ 0.13
Gas Cost ($/M BTu)		$ 0.73		$ 1.06

(1) Data from Goss, J.R., "Food, Forest Wastes = Low B Fuel," Agricultural Engineering, p. 30, January 1978.

(2) Data from Amundsen, H.R., "The Economics of Wood Gasification," in Chaparral For Energy Information Exchange Conference, Pasadena, CA, sponsored by PSW Experiment Station, Angeles National Forest, July 22, 1976, p. 118.

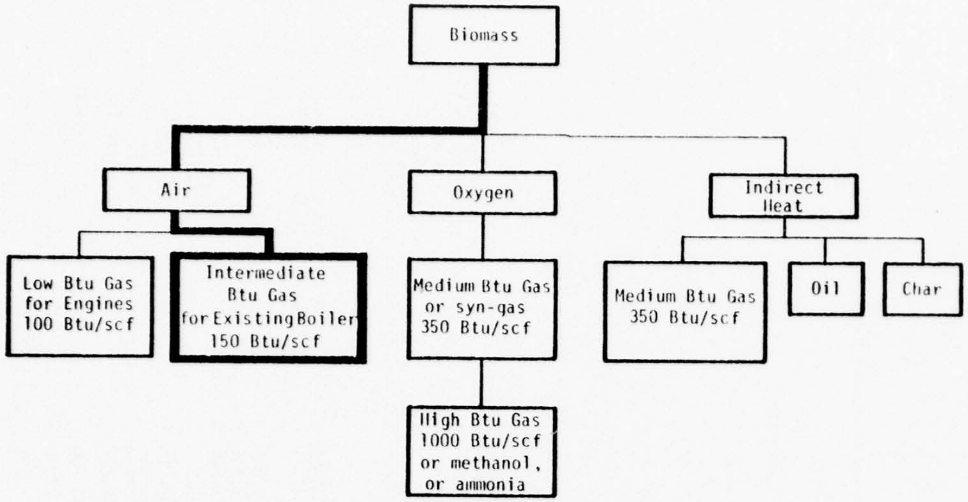


Fig. 1. Close-Coupled gasification and other gasification paths

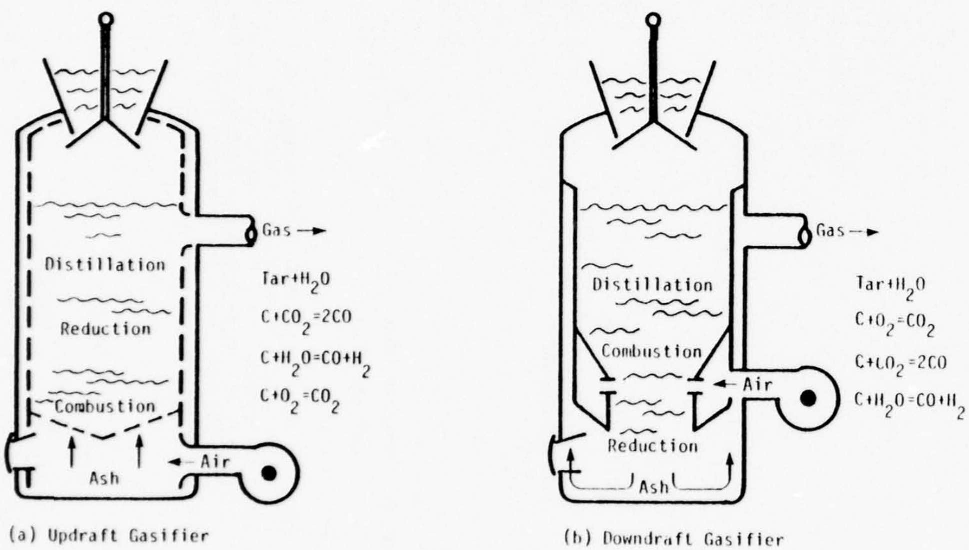


Fig. 2 Updraft and downdrat gasifiers and their associated reactions

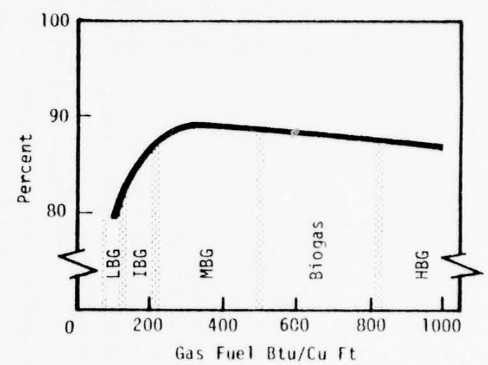


Fig. 3 Boiler efficiency vs Gas energy content

APPENDIX N

GASIFICATION

Gasification is the term for the thermal conversion of biomass (agricultural or forestry products) or coal to a gas that can be used in producing heat, power, or chemical synthesis.

The first gasifiers were built around 1860 and steadily developed through the 1940's. Both stationary and portable gasifiers were manufactured and sold to power ships, automobiles, electric power plants, and tractors. During World War II, over 700,000 vehicles in Europe were adapted to run on gas from small gasifiers attached to the vehicle.

Feedstock for these original gasifiers included nearly every conceivable form of cellulose including wood, coconut husks, rice hulls, and olive pits. With the advent of inexpensive natural gas and fuel oil, however, this technology diminished. It is now being revived.

Gasifiers can be retrofitted to existing natural gas and oil-fired boilers. This eliminates the need to replace the entire system, as required for conversion to direct combustion of a solid fuel such as wood or coal.

Although gasifiers can theoretically use any carbonaceous solid fuel such as coal, lignite, or biomass, proper operation depends on its design relative to a given fuel as well as the fuel density, moisture, and particle size. Due to these and other considerations, wood chips and bark make excellent gasifier fuels. Various shells and pits, as well as corn cobs, are also being used satisfactorily; but fuels such as food residues, straw, and cotton gin trash would normally require some form of densification prior to use.

The energy content or the gas produced in gasifiers is comparatively low (typically 140 to 200 BTU per cubic foot), due in part to the nitrogen content of the air used in gasification. However, overall combustion efficiency can reach 80% to 90%.

The close-coupled gasifier arrangement is one of the simplest and least expensive. It entails manufacturing gas on-site for use in nearby equipment. While the relative economics of retrofitting an existing gas/oil system with a gasifier versus installation of a new solid fuel system have not been defined, several studies place the cost of the former option in the range of $4 to $10 per pound of steam an hour, compared to $15 to $30 for the latter alternative. Emission control equipment in an additional cost factor for solid systems (particularly coal). As in pyrolysis, gasification is a relatively clean process environmentally.

In summary, gasification provides the various advantages of biomass waste disposal, fuel production, and maximum use of existing systems. It appears that gasification will be a real factor in the switch away from conventional fossile fuels.

APPENDIX O

PYROLYSIS

Pyrolysis is the decomposition of organic material, such as agricultural and forestry products, with heat. Pyrolysis differs from direct combustion in that the "burning" is accomplished in the absence of oxygen. The intense heat, ranging from 1100^{o} to $2200^{o}F$ depending on the process, causes both a physical and chemical decomposition. In practice, pyrolysis units often utilize small amounts of oxygen to support the process, but this is typically only 5% of that necessary for direct combustion.

The products of pyrolysis include carbon char, pyrolytic oil, combustible gases, and water containing soluble organic compounds. The relative proportions of the products, or yield, can be varied by controlling the type of feed material and regulating operating parameters such as bed temperature and rate of char recirculation. While it is possible to provide indirect heating to supply the necessary heat, it is generally considered more efficient to use a portion of the feed material as a fuel. After absorbing a relatively small amount of heat to initiate the process, the pyrolysis action is then self-sustaining.

Most of the development work on pyrolysis was originally motivated by a need for environmentally sound methods of waste disposal; the process also appears to have a real potential for fuel production. Solid waste is reduced to a fraction of its original volume while a clean-burning fuel is produced.

Pyrolysis is not widely used commercially at this time. However, char from the pyrolysis of wood waste is being used in the manufacture of charcoal briquettes. Char also has fuel value as a low sulfur coal extender or substitute and can be used in the production of activated carbon. Pyrolytic oil has been demonstrated as both a fuel and chemical raw material. The gas from the pyrolysis system, in addition to its use as a direct combustion fuel, has been tested as a fuel for an internal combustion engine. Preliminary studies show some promise in this direction.

In summary, pyrolysis seems a likely candidate for commercial applications beyond the current level. The technology appears to be available for large scale use, although additional research will no doubt bring refinements.

APPENDIX P

ALCOHOL PRODUCTION FROM WOOD

Production of chemicals from wood is an old concept, and a number of commmerical plants have been operated in the past. These plants, which were handicapped by single product production, proved to be noncompetitive with chemical plants based on an abundant supply of cheap petroleum as the feedstock. However, the recent increases in the costs of crude petroleum and the continuing prospects for further increases as petroleum resources diminish has resulted in better prospects for the economical viability of producing chemicals from a renewable resource, wood.

Alcohol is a chemical of primary importance that can be produced from wood. It can be mixed with gasoline to form gasohol, a transportation fuel, or it can be used as a chemical feedstock.

Methanol, often called wood alcohol, can be made from the gas that is produced from the pyrolysis of wood. However, methanol is not as desirable for use as a fuel as is another form of alcohol, ethanol. Methanol does not mix well with gasoline, and the gasoline-methanol mixture does not combust properly without engine modification. Ethanol is not as difficult to mix or combust as methanol. Also, according to recent work at Georgia Tech, producing ethanol from wood is cheaper than producing methanol. Making ethanol involves hydrolysis, which converts the cellulosic material into sugars, and fermentation, which converts the sugar into ethanol. Most fermentation processes presently use corn or wheat to produce ethanol. Though feasible, using agricultural products does not presently produce an economical fuel. The key to making fermentation competitive is in finding low-cost sources of sugars. Cellulosic biomass such as wood is the most abundant potential source.

Georgia Tech is developing a pilot plant to test the technical feasibility and economic viability of producing ethanol from wood. The best approach is an integrated plant that would utilize the whole tree to produce chemicals.

The non-structural components of wood such as fatty acids and resin acids can also be recovered and marketed.

The structural parts -- cellulose, hemicellulose, and lignin -- can be separated and processed into various chemicals. The cellulose, about 50% of the structural part of wood, is hydrolyzed via either acids or enzymes into sugars which are fermented to produce ethanol. Hemicellulose, 25% of the wood, is hydrolyzed to xylose which is converted into furfural. Lignin, the remaining 25% of the wood, is pyrolized to produce phenols, char, oils and a combustible gas. The char, oils, and gas can be used to reduce the energy requirements of the process while the phenols can be sold as by-product credit.

The economics of a large scale production facility appear promising particularly if a multiple product plant is considered. Economic analyses indicate that, with the credits available for the by-products, such a plant can produce ethanol at competitive costs.

Georgia Tech analyzed the costs for a plant capable of producing over 406 tons per day of enthanol (123,000 gallons plus many other products from 1500 tons per day of wood input. The capital investment for a plant this size would be $65,299,000. The cost of producing ethanol in this plant is estimated to be $1.29 per gallon for a wood cost of $34 per ton. If the cost of wood is $20 per ODT (oven dry ton), then the cost of ethanol drops to $1.01 per gallon. If by-product credits equivalent to 65% of the market price of phenol and furfural are assumed, the selling price of ethanol from a softwood processing plant becomes $0.50 per gallon and $0.78 per gallon for wood prices of $20 per ODT and $34 per ODT respectively. For a hardwood processing plant the price of ethanol is estimated to be $0.30 per gallon and $0.58 per gallon for wood prices of $20 per ODT and $34 per ODT.

These prices can compare favorable with gasoline production costs of roughly $0.40 per gallon and are more attractive than the costs of producing ethanol from grains which are $0.75 to $1.50 per gallon. Also, this process is a net energy producer whereas fermentation of ethanol from grain is often not.

APPENDIX Q

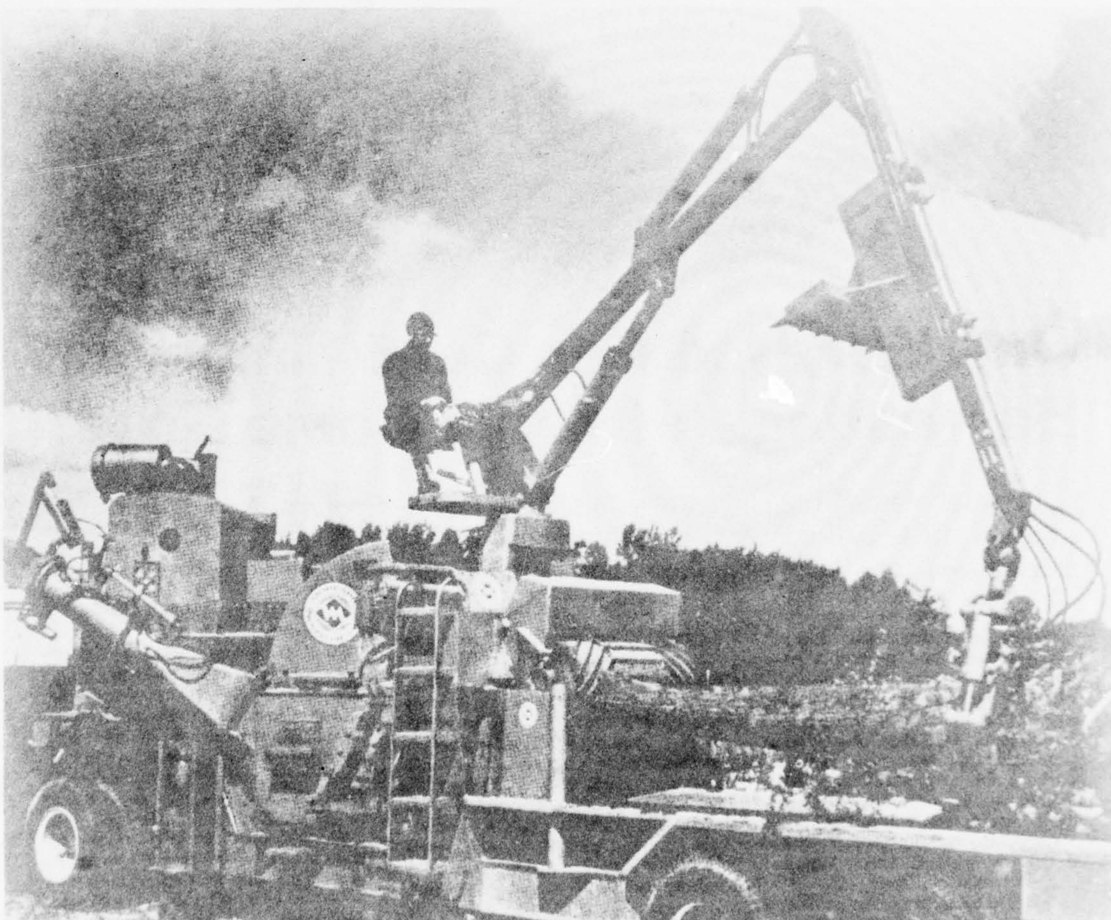
PAPER TRADE JOURNAL

JULY 26, 1971

Improved Technology, Economics and Better Quality for Mechanical Pulps

Computer Control Applications from Stock Preparation through Shipping—II

Orr's Triplex: A New Unique Three-Fabric Concept in Paper Makers' Felts



Total Timber Harvesting Plan Features Morbark's Chiparvestor

One Hundred Per Cent Timber Harvesting: A Dream Come True?

Field experiments in Michigan and Mississippi demonstrate that the concept is achievable. Highly mechanized, low manpower operation is the key.

Realization of the goal of 100 per cent harvesting and utilization of a standing timber crop may be in sight, with the results coming from several parts of the country on experiments conducted by a Michigan-based company, Morbark Industries, Inc. Despite the name, Morbark is actually in the process of demonstrating a highly mechanized harvesting system that produces "total" wood chips out of everything from small branches to 20-inch diameter trees.

Designed to supply wood chips at a cost significantly lower than any other method now in use, this system exemplifies two basic principles: use of machines will increase harvesting productivity, and 100 per cent harvesting of standing timber utilizes the forest resource to best advantage. Four machines do the work. They are a feller/buncher, two skidders, and a portable chipper. The last unit is Morbark's own Metro Chiparvestor.

The field experiments conducted to date have been in Michigan and Mississippi, and the timber sites have been clear-cut. The chipper literally eats up whatever the other machines supply, including trees, saplings, branches and leaves. No attempt is made to remove bark. Chips are blown directly into adjacent vans to be trucked to the mills. If desired, screening can be added to the system between the chipper and the vans.

Only six people run the operation, a result of the high degree of mechanization. Yet the total utilization concept has permitted unusually high yields of wood chips from the experimental plots.

How the system works

Four men operate the major pieces of equipment. The feller/buncher cuts all timber from a few inches up to 20 inches in diameter. Trees are chopped off close to the ground and placed in piles. Two grapple skidders then take over and haul the felled timber to the chipping unit. There the trees are fed into the chipper by a single operator manipulating an articulated grapple boom. Three other men operate the skidders and the felling machine.

Two more men make up the six-man crew. One is a maintenance man who services the machines and doubles as a sawman. In the latter capacity he trims branches off the larger trees before they go to the chipper. The same function may be required if these bigger trees are to go to a sawmill instead of being chipped. The sixth man supervises the screening operation and acts as trailer spotter, directing the chip vans to parking locations and overseeing the chip blowing equipment.

Since all sizes of timber are felled and chipped, the harvested area is then more amenable to planned reforestation programs. In addition, the utilization of branches, tops, trimmings and bark means virtually no slash or litter left behind. This has definite benefits from the point of view of re-seeding the site, and greatly reduces the fire hazard that slash often presents.

Total harvesting makes better use of the existing timber resource, and has already proven more productive than conventional methods. The chips so produced are suitable for pulping operations, and can also be used for making particle board, pressed board and hardboard. Even the bark on some of the chips going to a kraft mill appeared to have no effect on the finished paper product.

Field demonstration

A well-documented study was run in early May this year on a 40-acre timber plot near Winn, Michigan. (Winn is the home of Morbark Industries). The object of the experiment was to produce 2,500 tons of "total" chips from the site in five days using a six-man crew. Before cutting began, professional paper company woodsmen surveyed the area, and estimated a yield of 60 to 75 tons per acre if conventional pulpwood operations were used.

Over the five-day test period, a total of 2512 tons of chips was produced and loaded into vans. Forty-five hours of actual operating time were involved. In all, only slightly over 18 acres of the plot were harvested, resulting in a yield of approximately 136 tons per acre. Thus the yield was twice what the foresters expected from conventional techniques, and with a much smaller operating crew.

The acreage harvested contained 3,235 trees under six inches in diameter at the base, 3,468 trees six to twelve inches in diameter, and 1,198 trees larger than 12 inches. The timber was predominantly poplar, with lesser quantities of oak and other hardwoods. From these a total of 95 trailer loads of chips was produced. The equipment used in the harvesting project included a Drott Feller/Buncher, two Timberjack Grapple Skidders, and Morbark's "Super Beever" Metro Chiparvestor. Tree diameters ranged from two inches and less up to 20 inches. All the trees were chipped, with no sawlogs being taken.

Chips were blown out of the Chiparvestor directly into an on-site screen which culled out fines (consisting mainly of bark) and oversize chips. The screen was diesel-powered and hydraulically operated; it had a capacity of one and a half tons of chips per minute. The screened chips went into the waiting vans.

Chip screen rejects left at the harvesting site were spread out by bulldozer. However, if the chipper is to be operated at one location for a longer time, a large volume of rejects could accumulate. Hence the screen can be equipped with an auger conveyor to deliver the off-size material to a storage bin or truck to be hauled away.

The chips so harvested were trucked to a near-by paper company in Michigan where they were mixed into the stream of conventional chips entering the pulping plant. Several test runs of a few hours each were made; the chips went through the standard kraft cook and the final bleached pulp was used to produce paper. The paper company reported no difficulties in using the "total" chips, and finished paper showed no abnormalities from the usual product. The normal chip furnish to the mill is short-fibered hardwood, and during the test period the "total" chip contribution to the digester in-feed ran as high as 35 per cent.

Further proof

Late in June, Morbark provided another demonstration of the 100 per cent harvesting concept at a hardwood timber plot near Ellisville, Miss. This time the experiment was a cooperative adventure with Masonite Corp. which operates the largest hardboard plant in the world at Laurel, Miss.

In this case all felled timber suitable for lumber was segregated out and sent to the sawmill. The remaining trees, tops and branches were chipped, screened and blown into vans to be transported to Laurel. At the Masonite mill the chips were to be used for experimental production of hardboard. At present the report is still not in on the results of the study.

The latest exhibition of Morbark's system was held June 28 through July 2, once again in Michigan. This time the cooperating company was U.S. Plywood-Champion Paper. The site, near Gaylord, Mich., belonged to the paper company, and only chips were produced. They subsequently went into the production of particle board. Again, the final evaluation is not in yet on the board that was made, but the harvesting project was considered a decided success.

The last word

J. H. McLeod, log and chipwood processing manager for the Masonite mill in Laurel, liked what he saw and said of the underlying concept: "Most companies are going to 'clear cutting' of forest areas. It leaves a clear area that you can replant and get an even-age stand of timber, just like sugar cane or any other crop."

And Norval Morey, chairman and chief executive of Morbark, pronounced the experiments a success now and for the future. "Wood harvesting is one of our oldest industries," he said, "but with new machanics and systems such as those in our experiments, it may soon be among the most progressive. With the constantly rising costs of timberland and of doing business in general, we must institute the most efficient systems using highly productive, labor-saving machines, so we can keep this industry healthy and profitable."

Chipping unit blows chips to this screen; accepts go directly into vans to be transported to the mill.

Q-3

APPENDIX R

Economic Aspects of Low-Grade Hardwood Utilization

Irving S. Goldstein

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Abstract

For this discussion, low-grade hardwoods are defined as the material remaining in high-graded stands of mixed hardwoods, or the hardwood component of pine stands, containing very few quality trees and generally unmerchantable due to low value and excess supply. Such material is suitable neither for structural applications nor for pulping because of size, species, defects, or bark content. Three potential applications for this material, *independent of these limitations*, include use as fuel, conversion into chemicals, and conversion into fiberboard. The delivered cost of such hardwood material at a central location is currently less than $20 per ton of dry wood. This material cost is compared to the potential value returned by the various utilization schemes. The potential availability of such material at a specific site in the Piedmont of North Carolina is described.

A MAJOR PROBLEM in the U.S. South is the utilization of low-grade hardwoods. As Anderson (1) has pointed out most traditional products that could be made from low-grade hardwoods could be made more cheaply from better hardwoods. Consequently the 70 million acres of sites suitable for pine plantations in the U.S. South, but that are now covered with a mantle of unwanted hardwoods, cannot be economically converted to pine unless some new uses can be found for this hardwood material.

For this discussion, low-grade hardwoods are defined as the material remaining in high-graded stands of mixed hardwoods, or the hardwood component of pine stands, containing very few quality trees and generally unmerchantable due to low value and excess supply. Such material is suitable neither for structural applications nor for pulping because of size, species, defects, or bark content. Three potential applications for this material which are independent of these limitations include fuel, chemicals, and fiberboard. Low-grade hardwoods which are otherwise of little or no value can be converted into chips in the forest for ultimate processing by one of the above schemes. Unlike conventional harvesting systems, in-woods chipping converts tops, limbs, noncommercial species, small trees, defective trees, and bark into usable material for these processes leaving very little residue in the forest.

Important economic aspects of the utilization alternatives proposed involve the delivered cost of such hardwood material at a central location, the potential value of the products, and the availability of the material. These are considered in detail below. Other important factors are capital requirements and plant operating costs. While rough estimates of capital needs will be presented, operating costs are dependent on specific process configurations and plant location and are beyond the scope of this preliminary discussion.

Cost of Raw Material

Whole-tree in-woods chipping has increased rapidly in the U.S. South with approximately 100 operations in existence. This system is ideal for the applications under consideration. The presence of bark, objectionable for pulp chips (3), does not interfere with burning or conversion to chemicals. Bark does cause some strength reduction in fiberboard, but boards of good quality can be made from barky hardwoods provided resin distribution is adequate (10).

Since whole-tree chips are conventionally marketed on a green basis, and the yields of products depend on dry weight, economic projections require the cost of the wood on a dry basis. The average moisture content (MC) needed for this calculation is derived in Table 1 based on species data from the Southern Forest Experiment Station (7) and MC data compiled by Smith (8). The calculated MC of 82 percent is somewhat greater than the value of 78.6 percent actually determined for upper coastal plain hardwoods containing more oak (6), and provides a more conservative basis for cost calculations.

The authors are, respectively, Professor of Wood and Paper Science, Associate Professor of Forestry, and Extension Specialist, School of Forest Resources, North Carolina State Univ., Raleigh, N.C. Helpful discussions with R. C. Allison, L. G. Jahn, and M. W. Kelly are gratefully acknowledged. This paper was presented at Session 2—Economics & Financial Management—of the 31st Annual Meeting of the Forest Products Research Society, July 4, 1977, in Denver Colo. It was received for publication in September 1977.

R-1

TABLE 1. — *Composition by volume, green weight, and dry weight of southern hardwoods (per 100 ft.³).*

Species	Volume* (%)	Green weight** (lb.)	Dry weight** (lb.)
Sweetgum	21	1,343	612
Hickory	10	645	393
Black tupelo	9	514	268
Post oak	9	607	361
Southern red oak	9	586	339
Water oak	8	527	298
White oak	8	539	321
Yellow-poplar	4	198	94
Sweetbay	3	164	80
Black oak	3	195	113
Cherrybark oak	2	130	75
Ash	4	208	138
Red maple	1	50	29
Elm, hackberry	3	159	85
Red oaks (5)	5	326	188
Others***	1	63	34
Total	100	6,254	3,428

Average moisture content = 82 percent
* Southern Forest Experiment data for pine sites
** H. D. Smith, North Carolina State University
***Green and dry weights average of species listed

TABLE 2. — *Estimated delivered cost of whole tree hardwood chips.*

	Production rate (tons/crew hour)			
	23.81 (380 hp chipper)		32.74 (600 hp chipper)	
A. Production cost				
Hourly cost: Equipment	$124.43		$144.26	
Labor	36.04		40.25	
	$160.47		$184.51	
Cost/ton		$ 6.74		$ 5.64
B. Stumpage cost				
Assume: — $4.50/cord				
— 3 tons/cord				
Cost/ton		$ 1.50		$ 1.50
C. Trucking cost				
Assume: — 50 mile haul				
— 24 tons/load				
— $1.00/double mile				
Cost/ton		$ 2.08		$ 2.08
Delivered cost/green ton		$10.32		$ 9.22
Delivered cost/ton dry wood		$18.78		$16.78

Table 2 presents the estimated delivered cost of whole-tree hardwood chips for two production rates. The estimated labor costs are shown in Table 3, the assumptions used in the calculation of equipment costs in Table 4, and the estimated equipment costs at the higher production rate in Table 5.

TABLE 3. — *Estimated labor cost per crew hour.*

Function	Production rate (tons/crew hour)			
	23.81 (380 hp chipper)		32.74 (600 hp chipper)	
	No. of men	Rate/crew hour	No. of men	Rate/crew hour
Foreman	1	$ 7.00	1	$ 7.00
Feller buncher operator	1	3.85	1	3.85
Skidder operator (3.50)	2	7.00	3	10.50
Chipper operator	1	3.85	1	3.85
Deck hands (3.00)	2	6.00	2	6.00
Supervisor	1/3	2.34	1/3	2.34
Subtotal		$30.04		$33.54
Payroll benefits (20%)		6.00		6.71
Labor cost/crew hour		$36.04		$40.25

TABLE 4. — *Assumptions for whole-tree harvesting equipment.*

Equipment	Initial cost ($)	Salvage value ($)	Life (yr.)
Whole tree chipper (380 hp)	115,000	25,000	5
Whole tree chipper (600 hp)	132,000	27,000	5
Feller buncher	100,000	25,000	5
Grapple skidder	55,000	10,000	4
Used skidder	10,000	2,000	3
Lowboy trailer	10,000	2,500	10
Used crawler	30,000	6,000	5

Straight line depreciation — 18 percent cost of invested capital
Insurance — $3.00/$100 — taxes — $1.50/$100
Operating 8 hours/day, 210 days/year
Equipment moving truck $1.00/mile, 1,680 miles/year
3/4 ton crew cab pickup $0.20/mile, 200 miles/day
1/2 ton pickup $0.15/mile, 250 miles/day

The estimated delivered costs in Table 2 are in good agreement with actual market prices of $10 to $12 per green ton of whole-tree chips (2). Delivered cost per ton of dry wood of less than $20 for whole-tree hardwood chips is considerably less than the values commonly cited for bark-free pulpwood chips or secondary mill residues (2).

Potential Value of Products

If the hardwood chips are used to fire a boiler to provide process steam or space heating for small manufacturing plants, the relative fuel cost compared to the use of No. 2 fuel oil is shown in Table 6 to be 40 percent as great. The wood cost cited is equivalent to about $1 per thousand cubic feet (Mcf) for natural gas

TABLE 5. — *Estimated equipment cost per crew hour for 600 hp whole-tree harvesting system.*

Item	Average** investment ($)	Depreciation ($)	Cost of capital (18%)	Insurance and taxes ($)	Total fixed cost ($)	Total operating* cost ($)	Total cost per hour ($)
Whole-tree chipper	80,375	12.50	8.61	2.21	23.32	24.80	48.12
Feller buncher	63,125	8.93	6.76	1.70	17.39	13.00	30.39
Grapple skidders (3)	68,910	20.10	7.38	1.86	29.34	11.07	40.41
Used skidder	6,111	1.58	0.65	0.16	2.39	0.74	3.13
Lowboy trailer	6,281	0.45	0.67	0.17	1.29	0.19	1.48
Used crawler	18,200	2.86	1.95	0.50	5.31	2.94	8.25
Equip. moving truck							1.00
3/4 ton crew cab pickup							5.00
1/2 ton pickup							4.68
3 chainsaws							1.80
						Total	144.26

*Includes repairs, fuel, lubrication, etc.

$$\text{**Avg. invest.} = \frac{(\text{initial cost-salvage})\ (\text{life in mths} + 1)}{2(\text{life in mths})} + \text{salvage}$$

R-2

TABLE 6. — *Value of steam produced from hardwoods in place of No. 2 fuel oil.*

Assume — 400 hp boiler 20,000,000 Btu/hr.
8,400 Btu/lb. for southern hardwoods
140,000 Btu/gal. for No. 2 fuel oil

Net heating value of wood = 8,400 − (.82 × 1,210) = 7,400 Btu/lb. for 82% moisture content

2,700 lb. dry wood/hr. = 32.4 tons/day

Daily wood cost = 32.4 tons × $16.78/ton = $543.67

Equivalent gallons No. 2 fuel oil = 24 × 142.9 = 3,428.6 gallons

Daily oil cost = 3,428.6 gal. × $0.40/gal. = $1,371.43

Value of oil replaced per $1.00 of wood used = $2.52

TABLE 7. — *Value of fiberboard produced from hardwoods.*

Assume — 48 lb./ft.^{3} density and $225/1,000 ft.^{2}
8% resin content at $0.20/lb. resin solids
90% yield from wood

1,000 ft.^{2} of 3/4-in panel = 62.5 ft.^{3}/1,000 ft.^{2}

48 lb./ft.^{3} × 62.5 ft.^{3} = 3,000 lb./1,000 ft.^{2}

$225/1,000 ft.^{2} = $7.50/100 lb.

100 lb. board contains 92 lb. wood + 8 lb. resin

Value of 100 lb. board less resin cost = $7.50 − (8 × 0.20) = $5.90

92 lb. wood in board require 102.22 lb. raw material at cost of $0.858

Product value of board (excluding resin cost) · per $1.00 of wood used = $6.88

and about $30 per ton for bituminous coal. Capital investment for a 400 hp fire-tube boiler, combustion furnace, metering bin, storage silo, particulate collector, fuel handling conveyor, and instrumentation, including freight and installation costs, is estimated to be about $300,000 (11).

Conversion of the chips to fiberboard is shown in Table 7 to return $6.88 in product value excluding resin cost for each $1 of wood used for raw material. Capital cost for a 500-ton-per-day plant was estimated at $30,000,000 in 1975 (11).

If the hardwood chips are converted to chemicals (4, 5), the product value per $1 of wood used rises to $8.36 as shown in Table 8. Furfural production would represent a significant fraction of present total capacity so a discounted price is used. Phenol and ethanol production would influence total capacity only slightly. Improvement of ethanol yields by more effective hydrolysis of the wood could raise this product value to over $11. Capital cost for a plant converting 1,500 tons of wood per day was estimated at $90,000,000 in 1975 (9).

In Table 9 the values added by each utilization scheme are compared and normalized for capital costs. Operating costs aside, the best rate of return on capital would be obtained from direct combustion if oil were being replaced. However, alternative use of coal, depending on its price and availability, would have to be considered here. Furthermore the small size of the steam boilers would require many installations to attain

TABLE 8. — *Value of chemicals produced from hardwoods.*

Assume—Wood is 55% hexose, 20% pentose, 25% lignin
50% hydrolysis to hexose
50% yield of furfural from pentose
30% yield of phenol from lignin

100 lb. of wood costing $0.839 will yield		
14.9 lb. ethanol at 0.175 ($1.15 gal.)	=	$2.61
9.8 lb. furfural at 0.25*	=	2.45
7.5 lb. phenol at 0.26	=	1.95
		$7.01
Product value per $1.00 of wood used	=	$8.36

*Approximately half of current market price.

TABLE 9. — *Comparison of product values from hardwood processing schemes.*

	Steam	Fiberboard	Chemicals
Daily capacity, tons dry wood	32.4	500	1,500
Capital investment	$300,000	$30,000,000	$90,000,000
Investment/ton capacity	$9,260	$60,000	$60,000
Product value per $1.00 of wood used	$2.52	$6.88	$8.36
Value added/day/$1,000 invested capital	$2.75	$1.64	$2.06
Value added/360 day year/ $1,000 invested capital	$990	$590	$742

equivalence in invested capital or total wood consumption to the other schemes. Depending on the objective, i.e., maximum rate of return on limited capital or maximum utilization of low-grade hardwoods, a different scheme would be chosen. Manufacturing plants seeking cheaper fuel, large landowners, or investors would all choose the utilization scheme most suitable for their needs.

If it is assumed that operating and energy costs for fiberboard and chemical plants would be comparable, the chemical plant seems to have a slight advantage. Other considerations which might have to be taken into account in this comparison involve government incentives or disincentives for the conservation of petroleum from which the chemicals would otherwise be made, or even the ultimate depletion of the petroleum resources.

Availability of Wood

Inventories of low quality hardwoods are accumulating in North Carolina as across most of the South. Hardwood pulpwood stumpage averages only $3 per cord compared to $7 for pine. A case study approach has been used to explore the potential supply of hardwood chips for the processes under discussion. Detailed forest survey data provided on special request by the Forest Survey Project at the Southeastern Forest Experiment Station were analyzed for a 50-mile radius centered on Roxboro, North Carolina, in the North Central Piedmont.

Within this area 59 percent of the land is commercial forest owned by private nonindustrial landholders (89%), forest industry (7%), and the public sector (4%). Hardwoods comprise 56 percent of the growing stock. Only 12 percent of the forest land is less than 60 percent

R-3

TABLE 10. — *Potential availability of hardwood chips within 50-mile radius of Roxboro, North Carolina.*

A. Total inventory of hardwood growing stock*		2,281,150,000 $ft.^3$
B. Net annual growth*		112,827,000 $ft.^3$
C. Current annual removals*		61,178,000 $ft.^3$
D. Excess growth over removals		51,649,000 $ft.^3$
E. Potential harvest conventional measure/day		141,504 $ft.^3$
F. Potential harvest chips/day (E×2)		283,008 $ft.^3$
G. Potential harvest/day (F×34.28 lb./$ft.^3$)		9,701,522 lb. (dry)
H. Potential harvest/day (G÷2000)		4,851 tons (dry)
I. No. of plants supportable		
Steam	(H÷32.4)	150
Fiberboard	(H÷500)	10
Chemical	(H÷1500)	3
J. Average procurement radius for one plant		
Steam	4.1 miles	
Fiberboard	16.0 miles	
Chemical	27.8 miles	

*Customized data from forest survey project Southeastern Forest Experiment Station

stocked with trees, and only 4 percent is in deep swamp or steep slopes so barriers to harvesting are minimal.

Table 10 summarizes the potential harvest of hardwoods over and above the volume currently being removed by existing mills. The potential harvest for new processes is defined as the balance of hardwood growth over current removals so that the existing inventory of hardwood growing stock is not depleted. While the saw log portion of high quality hardwood stems would likely be sorted out, thus reducing the potential volume of whole-tree chips, a compensating addition would be the inevitable use of scattered and low quality softwood species.

The Forest Survey inventory data summarized in Table 10 are based on conventional utilization standards. Experience has shown repeatedly that the tonnage yield of whole-tree chips is between two and three times the volume that would be expected from conventional cruise inventory data. A factor of two is conservatively used in Table 10 in going from E to F. The chip overrun comes from noncommercial hardwood species, rough-rotten-cull trees, tops and limbs normally left in the woods, and trees below the conventionally merchantable diameter at breast height (DBH) limit. These sources are more significant in hardwood stands than in pine.

It is especially noteworthy that this small region is capable of supporting three large plants for converting wood into chemicals. This conclusion is in marked contrast to the concern shown in a previous report (9) that 1,500 tons per day of hardwood wastes would be difficult to assemble for such a plant.

Even if none of the cutover land goes back into hardwoods, the total annual harvest given in Table 10 including current and potential removals would reduce the current inventory by only 6.5 percent in 20 years. However, ample physical availability of wood is only one necessary condition. In view of the high percentage of private nonindustrial ownership would the wood be made available for harvest, or would environmental concerns and opposition to clearcutting militate against its use?

Although there is a theory that some private owners will refuse to sell timber, the literature indicates that the average length of tenure for private owners is only 15 years more or less. Even though a given owner may preserve his timber, the probability that harvest will occur increases every time the property changes hands. The new owner may have attitudes different from those of the previous owner; the volume available for harvest would have been built up in the meanwhile making a timber sale more attractive; and the new owner may need to recoup some of his investment in land and timber. Indications are that all categories of ownership in the study area now make their lands available for harvest.

The economic incentives for supplying wood to the processes under consideration could be very high relative to what the market has offered in the past. The average volume of hardwood growing stock on the predominantly hardwood sites is 16.6 cords per acre by conventional merchantability standards or at least twice that volume in terms of whole-tree chips. At $4.50 per cord for green whole-tree chips this is an attractive return of $150 per acre for wood, much of which was previously considered worthless and unmerchantable.

Furthermore the whole-tree chipping logging system results in a well prepared site with all culls removed and ready for planting with minimum additional preparation. Ordinarily the task of cull tree removal would cost $50 per acre or more, and some of the site would be taken up with windrows. With this logging system site preparation comes almost free, another valuable incentive to the landowner.

Summary

Whole-tree chips from low-grade hardwoods can be delivered within a radius of 50 miles for less than $20 per dry ton. These chips are suitable for direct combustion, conversion into chemicals and into fiberboard, and such processes appear to offer attractive returns on investment. An example is given of the availability of sufficient low-grade hardwoods within a 50-mile radius of Roxboro, North Carolina, to supply 150 steam plants, 10 fiberboard plants, or 3 chemical plants while returning exceptionally attractive income to the landowners as well.

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R-4

APPENDIX S

BARRIERS TO WIDESPREAD WOOD USE

There are two major institutional barriers preventing a more widespread use of wood in the industrial commercial sector. The first is supply and lack of knowledge about the technology, its costs, and its availability. The second relates to the long term availability of the resource. To the extent that fuel is the least valuable economic use of wood, there is no incentive to replant land cleared for fuel with new growth. This is complicated by the ownership pattern of the forests. In Georgia, with a large forest of 25 million acres, 24 million are privately owned. Strong incentives may be needed to encourage the small landowner to contract with a fuel collector and utimately replant with trees for future use.

A less difficult, but still important, barrier relates to the current regulatory climate. A favorable climate and a responsive bureaucracy can measurably impact a corporate decision to convert or not to convert to wood systems. An example will serve to illustrate the point. A textile mill held up a scheduled increase in their wood burning capacity for almost a year because they could not get a clear response from DOE on whether such a conversion would fall under guidelines that had been written for oil and gas conversions. When assured by DOE that they did not fall under their guidelines, they committed instantaneously to the conversion, thereby nearly doubling their woodburning capacity.

A major institutional barrier for utilities is the acceptance of a new technology. Regulatory and/or federal incentives can nudge the utilities into a more aggressive position. Another important barrier for utilities is the assurance of a long term wood energy supply. In addition, the high costs of collection pose a problem. Finally, the increasing value of wood chips and sawmill residue in the manufacture of pulp and particle board is seen as a deterrent.

Besides the availability of a technology suitable for home installation and use, the major barriers in the residential sector involve the acceptability of a new fuel form by a market that has been accustomed to never seeing its heating fuel. Will the homeowner accept the fact that he or she needs a bin for wood — like the old coal bins that most people were delighted to get rid of? Is he or she likely to accept a product that is wet and potentially moldy in the basement? Will the wood have to be dried or pelletized? Does a distribution system exist or can one be created that is as reliable as today's oil, gas, and electricity system? These and many more questions on wood availability must be answered before any major switch to wood occurs in the residential sector.

APPENDIX T

MANUFACTURERS OF TIMBER HARVESTING AND LAND CLEARING EQUIPMENT (PARTIAL LIST)

Feller-Buncher Shears

Morbark Industries, Inc.
Winn, Michigan 48896

Deere and Co.
Industrial Division
Moline, Illinois

Florida Machine and Foundry
PO Box 2370
Jacksonville, Florida 32203

Skidders

J. I. Case
Construction Equipment Division
700 State Street
Racine, Wisconsin 53404

Clark Equipment Co.
Benton Harbor, Michigan 49022

International Harvester Company
Payline Group
Schaumburg, Illinois 60196

Caterpillar Tractor Co.
Government Sales Office
1815 K St., NW
Washington, DC 20006

Whole Tree Chippers

Morbark Industries, Inc.
Winn, Michigan 48896

Strong Manufacturing Co.
498 8-mile Road
Remus, Michigan 49340

Truck Dumpers

Screw Conveyor Corporation
700 Hoffman Street
Hammond, Indiania 46327

Air-O-Flex Equipment Co.
3030 E. Hennepin Ave.
Minneapolis, Minnesota 55413

Live Bottom Trailers

Bocats, Inc.
Box 1021
Garden City, Kansas 67846

Hydro Mowers

Pettibone Corporation
4700 West Division Street
Chicago, Illinois 60651

Log Loaders

Barko Hydraulics
Superior, Wisconsin

US Military Academy
ATTN: Dept of Mechanics
West Point, NY 10996

US Military Academy
ATTN: Library
West Point, NY 10996

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WASH DC 20314

HQDA (DAEN-MPO-B)
WASH DC 20314

HQDA (DAEN-FEP)
WASH DC 20314

HQDA (DAEN-MPO-U)
WASH DC 20314

HQDA (DAEN-MPZ-A)
WASH DC 20314

HQDA (DAEN-MPZ-F)
WASH DC 20314

HQDA (DAEN-MPZ-E)
WASH DC 20314

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Ft Monroe, VA 23651

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Alexandria, VA 22332

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Ft McPherson, GA 30330

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Civil Engineering Laboratory
Naval Construction Battalion Center
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USA Construction Engineering
Research Laboratory
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Ft McPherson, GA 30330

Commanding General, 5th USA
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Ft Sam Houston, TX 78234

AFCE Center
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Commander, DARCOM
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Research Division
Kirtland AFB, NM 87117

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Engineering
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Center for Building Technology
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Commander
Eighth US Army
APO San Francisco 96301

Commander
US Army Facility Engineer
Activity Korea
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Commander
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Facility Engineer
Fort Benning
Fort Bennning, GA 31905

Facility Engineer
Fort Bliss
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Facility Engineer
Carlisle Barracks
Carlisle Barracks, PA 17013

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Fort Chaffee
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Facility Engineer
Fort Dix
Fort Dix, NJ 08640

Facility Engineer
Fort Eustis
Fort Eustis, VA 23604

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Fort Gordon
Fort Gordon, GA 30905

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Fort Hamilton
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Facility Engineer
Fort A.P. Hll
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Facility Engineer
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Fort Jackson, SC 29207

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Facility Engineer
Fort Monroe
Fort Monroe, VA 23651

Facility Engineer
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Facility Engineer
Fort Pickett
Blackstone, VA 23824

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Fort Rucker, AL 36362

Facility Engineer
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Fort Sill, OK 73503

Facility Engineer
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Fort Story, VA 23459

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Louisiana Army Ammunition Plan
Fort MacArthur, CA 90731

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Warren, MI 48089

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Pine Bluff, AR 71601

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Radford Army Ammunition Plant
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Facility Engineer
Rock Island Arsenal
Rock Island, IL 61201

Facility Engineer
Rocky Mountain Arsenal
Dever, CO 80340

Facility Engineer
Scranton Army Ammunition Plant
156 Cedar Ave.
Scranton, PA 18503

Facility Engineer
Tobyhanna Army Depot
Tobyhanna, PA 18466

Facility Engineer
Tooele Army Depot
Tooele, UT 84074

Facility Engineer
Arlington Hall Station
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Arlington, VA 22212

Facility Engineer
Cameron Station, Bldg 17
5010 Duke Street
Alexandria, VA 22314

Facility Engineer
Sunny Point Military Ocean Terminal
Southport, NC 28461

Facility Engineer
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Fort Wainwright, AK 99703

Facility Engineer
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New Cumberland, PA 17070

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Pacific Northwest Outport
Seattle, WA 98119

Facility Engineer
Oakland Army Base
Oakland, CA 94626

Facility Engineer
Fort Ritchie
Fort Ritchie, MD 21719

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New Brighton, MN 55112

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Volunteer Army Ammunition Plant
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Watervliet, NY 12189

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Fort Monmouth
Fort Monmouth, NJ 07703

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Facility Engineer
Detroit Arsenal
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Aberdeen Proving Ground, MD 21005

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Madison, IN 47250

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White Sands Missile Range,
NM 88002

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Natick, MA 01760

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Fort Campbell, KY 42223

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Facility Engineer
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Anniston, AL 36201

Facility Engineer
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Corpus Christi, TX 78419

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Red River Army Depot
Texarkana, TX 75501

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Sacramento, CA 95813

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Sharpe Army Depot
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Presidio of San Francisco,
CA 94129

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Facility Engineer
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510 Title Bldg
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USA Engr Div, Norfolk
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Norfolk, VA 23510

USA Engr Div, Missouri River
ATTN: Chief, Engr Div
PO Box 103 Downtown Station
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USA Engr Div, South Pacific
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Cincinnati, Ohio 45201

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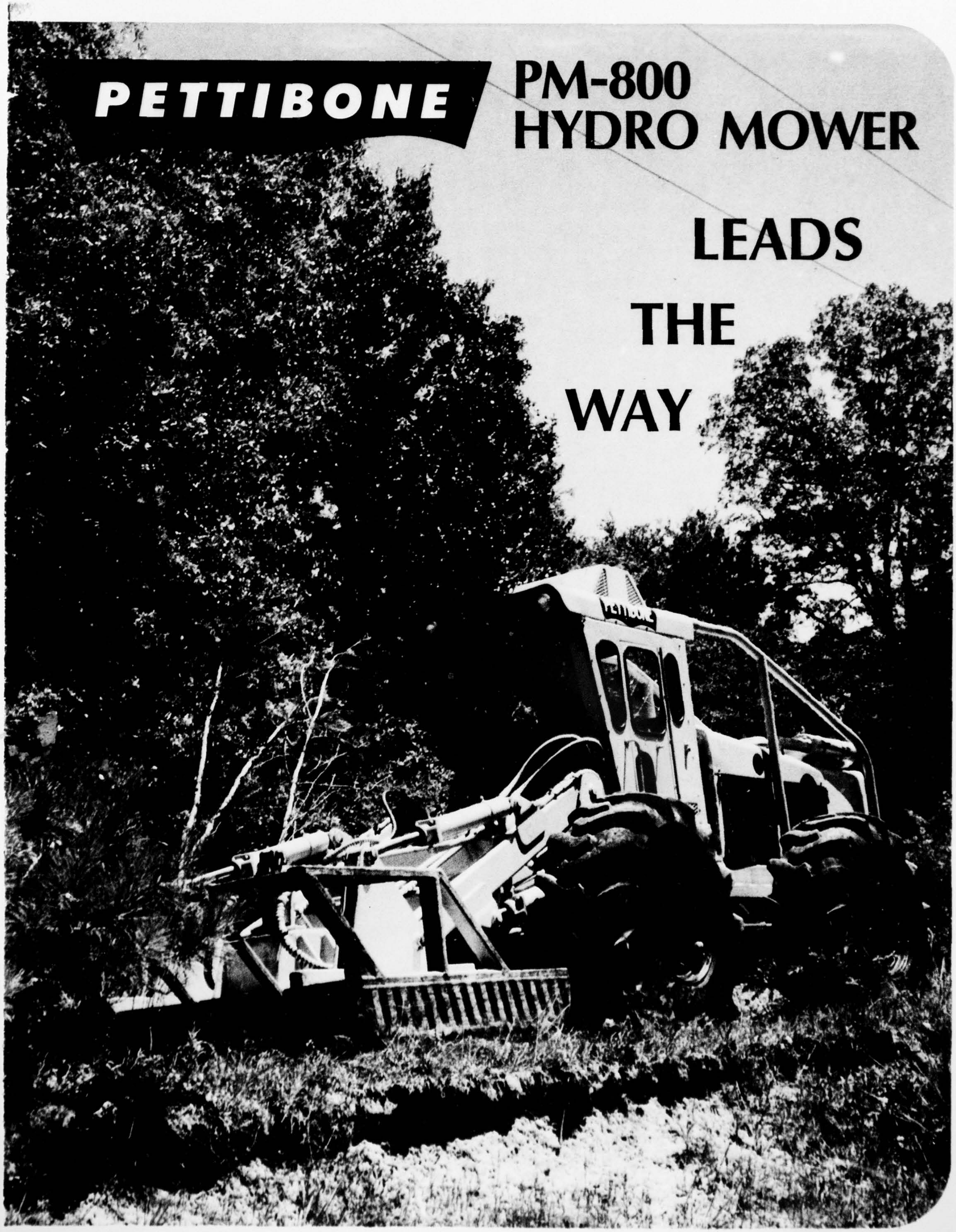
Dist 9


PETTIBONE
PM-800
HYDRO MOWER
LEADS
THE
WAY

IS THIS ONE OF YOUR NEEDS?

Right-of-way, Site preparation, Slash reduction, Pre-commercial thinning or Land clearing.

Here's why it's Pettibone.

Pettibone's PM-800 Hydro Mower with its many advantages has become one of the most valuable pieces of equipment in land reclamation. Important environmental advantages include the ability to minimize soil disturbance. This results in more erosion control and brings the survival rate of new plantings up. Greatly reduced time spent on site preparation and pre-commercial thinning brings about reduced costs.

Top Photo: With the PM-800's extended cutter head and 4-1/2" cylinders reaching an extended height of 13'6", the felling of trees is accomplished with relative ease.

Bottom Photo: Demonstrates how oscillation of frame maintains balanced weight distribution and vertical positioning of cab in rough hilly terrain. This is accomplished by the cab being positioned by means of a hydraulic sway control cylinder.

WHY THE PM-800?

Utility companies throughout the country are finding the PM-800 Hydro Mower a dual asset, saving both time and money. The control of brush around power and distribution lines has been a constant problem, involving cost and time consuming manual labor.

Increased production is one of the mainstays of the PM-800, and in this time of increased costs, that is important. Depending on the types of brush or trees to be cleared and the density of the acreage and the terrain, the capability can climb up to 4 acres per hour.

Durability and power provide the 800 with ability to climb hilly terrain and still maintain a maximum amount of power to cut and clear brush. Whether it's clearing hundreds of acres or just a path, its operating power provides top efficiency, and in any business that's found and saved dollars.

Top Photo: High ground clearance and front and rear floating cradles, together with 4-wheel drive and planetary type axles provide unusual stability under all working circumstances.

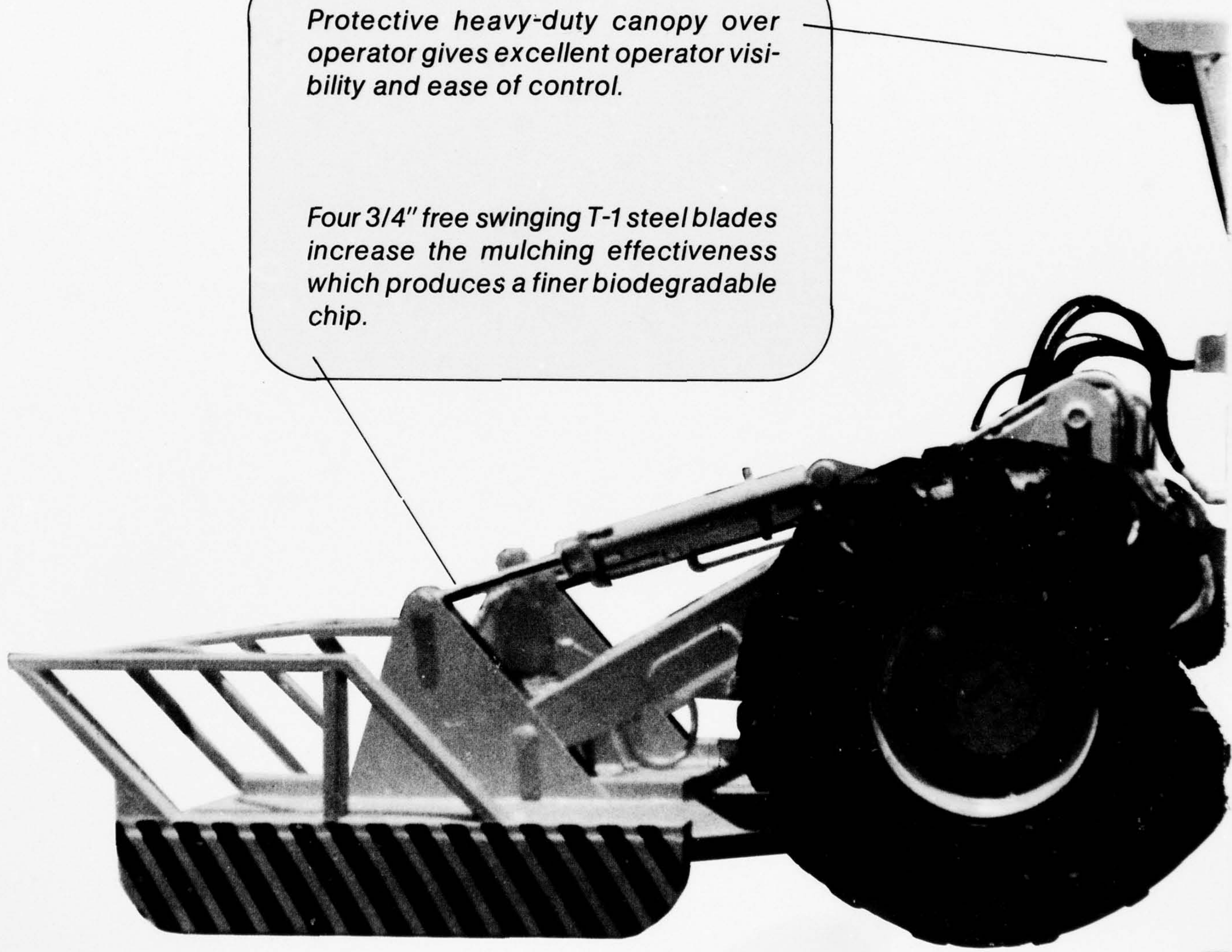
Center Photo: Multi-job versatility is the PM-800's trademark. Utility companies, for example, are finding the Hydro Mower an invaluable asset in maintaining brush control around and under transmission and distribution lines.

Bottom Photo: After felling a large tree, the cutter head is then lowered on the remaining trunk, easily shredding it to ground level.

A FEW OUTSTANDING FEATURE

Protective heavy-duty canopy over operator gives excellent operator visibility and ease of control.

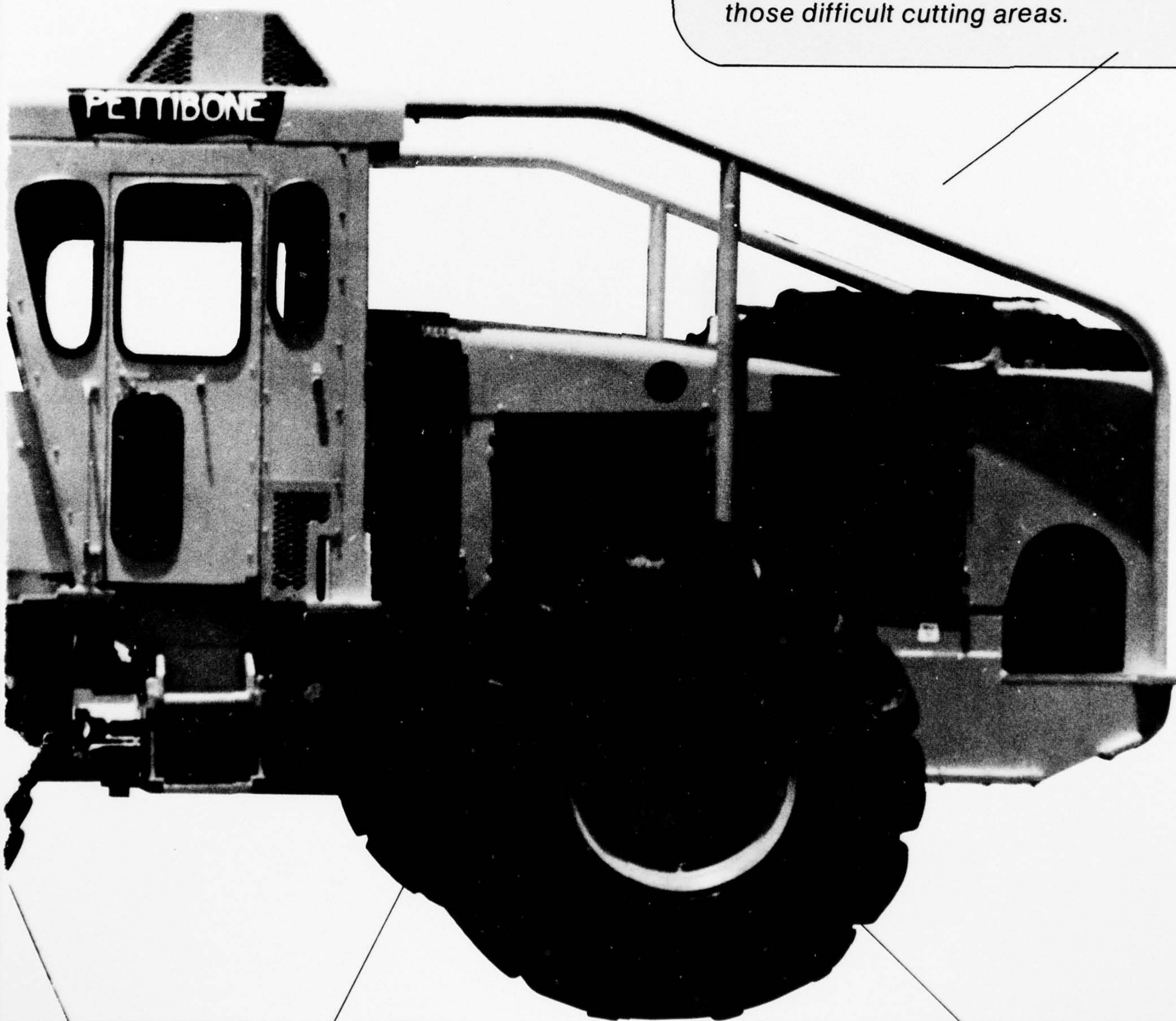
Four 3/4" free swinging T-1 steel blades increase the mulching effectiveness which produces a finer biodegradable chip.



ES

PETTIBONE

Pettibone, with its fully-articulated frame, reduces the turning radius, giving it greater maneuverability in those difficult cutting areas.



ettibone planetary front and rear axles
ith 5 to 1 gear ratio for better trac-
ion available.

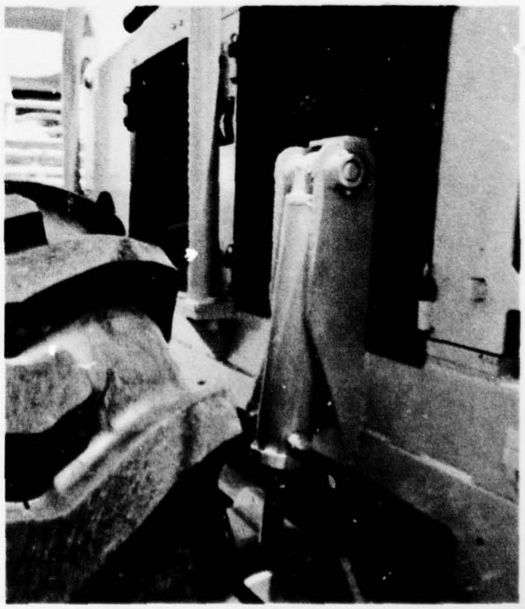
Standard equipped with interchangeable 23.1 X 26-10 ply wire reinforced logger specials. Note: Shown here with optional swamp type 67 X 3400 X 25.

PETTIBONE

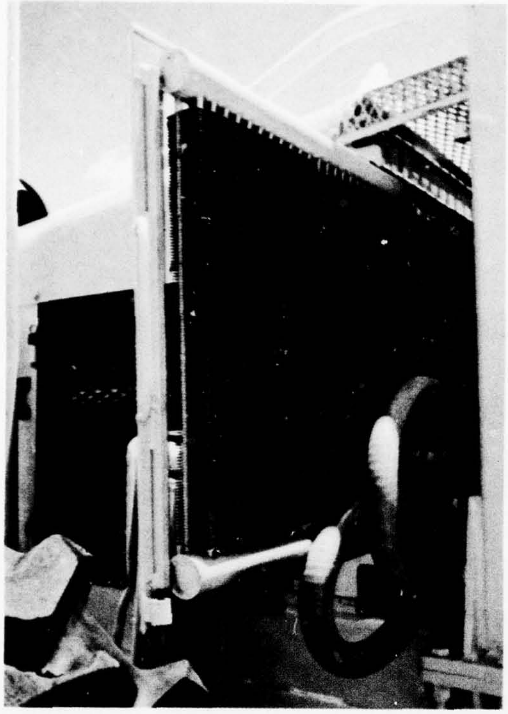
RELIABILITY AND VERSATILITY MEAN PROFIT AND EFFICIENCY

Pettibone's Hydro Mower is powered by a G.M. 6V53 diesel engine with these money-saving advantages. A pull-out type oil cooler allows easy access for cleaning and maintenance. The protective steel belly pan eliminates possible damage to the engine and drive line components. Power loss on hilly terrain is kept to a minimum by the rugged 4-speed hydrostatic transmission. As a result, production is maintained at peak efficiency.

CAB HIGHLIGHTS *(Top Photo):*
In the rigidly built cab all OSHA requirements are met, adding to the operator's protection and safety. The fully-instrumented dash board combined with our new simplified control panel increases productivity and creates less operator fatigue.



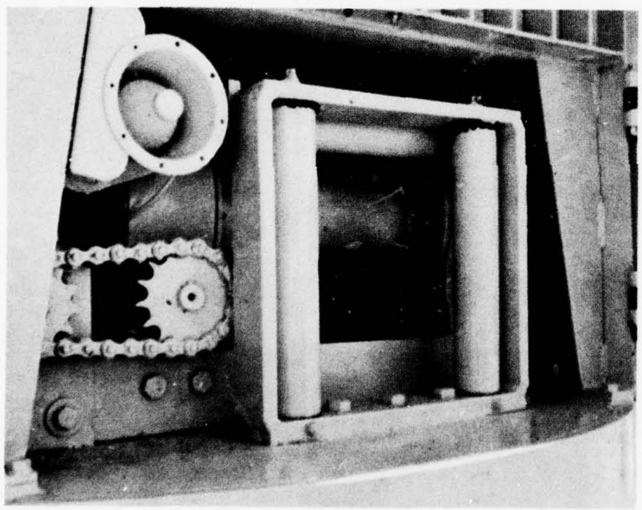
ARTICULATION AND OSCILLATION
(Lower Photos):
The fully-articulated frame, four-wheel drive and reduced turning radius give the 800 greater maneuverability in difficult cutting areas. Oscillation of the body maintains balanced weight distribution, keeping the cab in a safer vertical position.



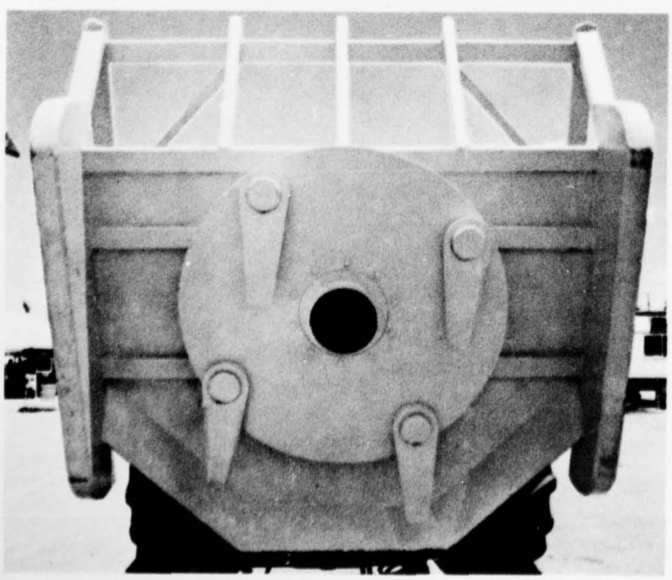
MAINTENANCE AND UPKEEP *(Top Photo):*
The pull-out type hydraulic oil cooler allows easy access to the engine radiator and oil cooler. This saves time and reduces cleaning problems. Inspection and lubrication are made easier by the removal of strategically located access plates.

PULLING POWER PLUS *(Center Photo):*
The 15,000 lb. hydraulic winch system with self-retrieval capabilities enables you to break free from unseen hazardous terrain. The winch is equipped with a hefty 250 foot, 5/8" thick cable.

MORE CUTTING EFFICIENCY *(Bottom Photo):*
The four 3/4" thick T-1 steel free swinging blades increase mulching effectiveness to produce a finer biodegradable chip. Time is greatly reduced on site preparation and pre-commercial thinning, resulting in a reduction of costs.



Pettibone's PM-800 handles the terrain with ease and agility. It gets into the hard to reach areas because of its full-frame articulation. The small turning radius provides maxium productivity in all phases of land clearing.

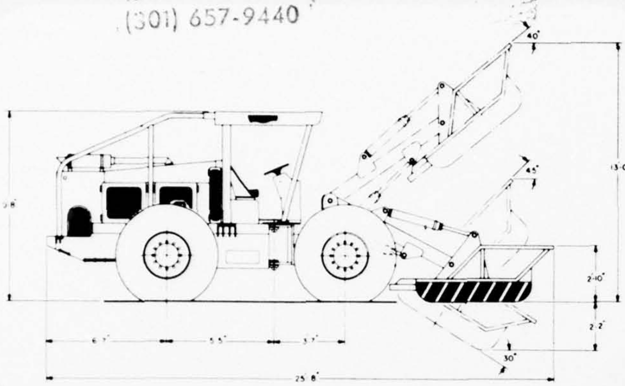


Outstanding features and construction combine to make the PM-800 the leader in its field. By bringing together ease of maintenance, durability and power, Pettibone makes the forestry equipment of tomorrow for your needs of today.

SALES AND SERVICE:

PETTIBONE CORPORATION
Government Defense Products Division
7 0 Montgomery Lane
Washington, D.C. 20014

R. T. TIEBOUT
(301) 657-9440



SPECIFICATIONS:

Pettibone Corporation reserves the right to change specifications without notice to follow its policy of constantly striving to manufacture a better product.

OVERALL DIMENSIONS:

Height	9'-10"	Width	9'- 0"
Length	25'- 4"	Ground clearance	1'- 7"
Wheel base			9'- 0"

WEIGHT (Approx.):

Total Weight	24,350 lbs.
Front axle	12,780 lbs.
Rear axle	11,570 lbs.

ENGINE:

Make	GMC	Model	6V53 Diesel
Horsepower	180	R.P.M.	2400
Bore & Stroke			3⅞" X 4½"
Number of cylinders			6
Electrical system			12 V.
Fuel tank capacity			55 gal.

CUTTER:

Shaft, rotor	6C Mechanics Universal
Bearings	Timken roller bearings
Blades	Four ¾" T-1 steel free swinging
Overall Width	8'-0"
Drive motor	Sundstrand Hydrostatic
RPM	Variable, control in cab

POWER TRAIN:

Transmission	Hydrostatic
Transfer case	4 speed

BRAKES AND AXLES:

Brakes	Disc., hydraulic with brake lock
Axles, front & rear	Planetary with no spin

TRAVEL SPEEDS:

1st	1.4 MPH	2nd	3.3 MPH
3rd	6.2 MPH	4th	15.0 MPH

WHEELS AND TIRES:

Wheels (interchangeable)	20 X 26w /reinforced flanges
Tires (interchangeable)	23.1 X 26-10 ply logger special

TURNING RADIUS:

Articulated steering	17'6" Outside wheel
Hydraulic oil reservoir	64 Gal.

HYDRAULIC PUMP:

Main	39 GPM at 2400 RPM & 1500 PSI
Strg.	21 GPM at 2400 RPM & 1250 PSI

HYDRAULIC CYLINDERS:

Lift	4½" bore 23¾" stroke
Tilt	4½" bore 24¾" stroke
Steering	4" bore 13" stroke
Level	3½" bore 12" stroke

WINCH:

Model	HJ15A Ramsey
F.P.M.	20
Line pull	15,000# bare drum
Cable capacity	⅝" X 258' Max.

STANDARD EQUIPMENT:

Articulated steering, Cradle, Adjustable upholstered seat, Hand friction throttle, Alternator, Starter, Voltage regulator, Battery, Ammeter, Oil pressure gauge, Air cleaner, Engine oil filter, Hydraulic oil filters, Chrome cylinder shafts, Exhaust muffler, Water temp. gauge, Heavy duty canopy with roof, Spindle wrench, No spin axles.

OPTIONAL EQUIPMENT:

Cab, Heater, Air conditioning, Wipers, Defroster, Lights, Winch and fairlead, Hourmeter, Tachometer (Engine), Hydraulic leveling (Rear section), 67 X 3400 X 25 swamp type tire, 250' of ⅝" Cable.

PRINTED IN U.S.A.

PETTIBONE

PETTIBONE CORPORATION

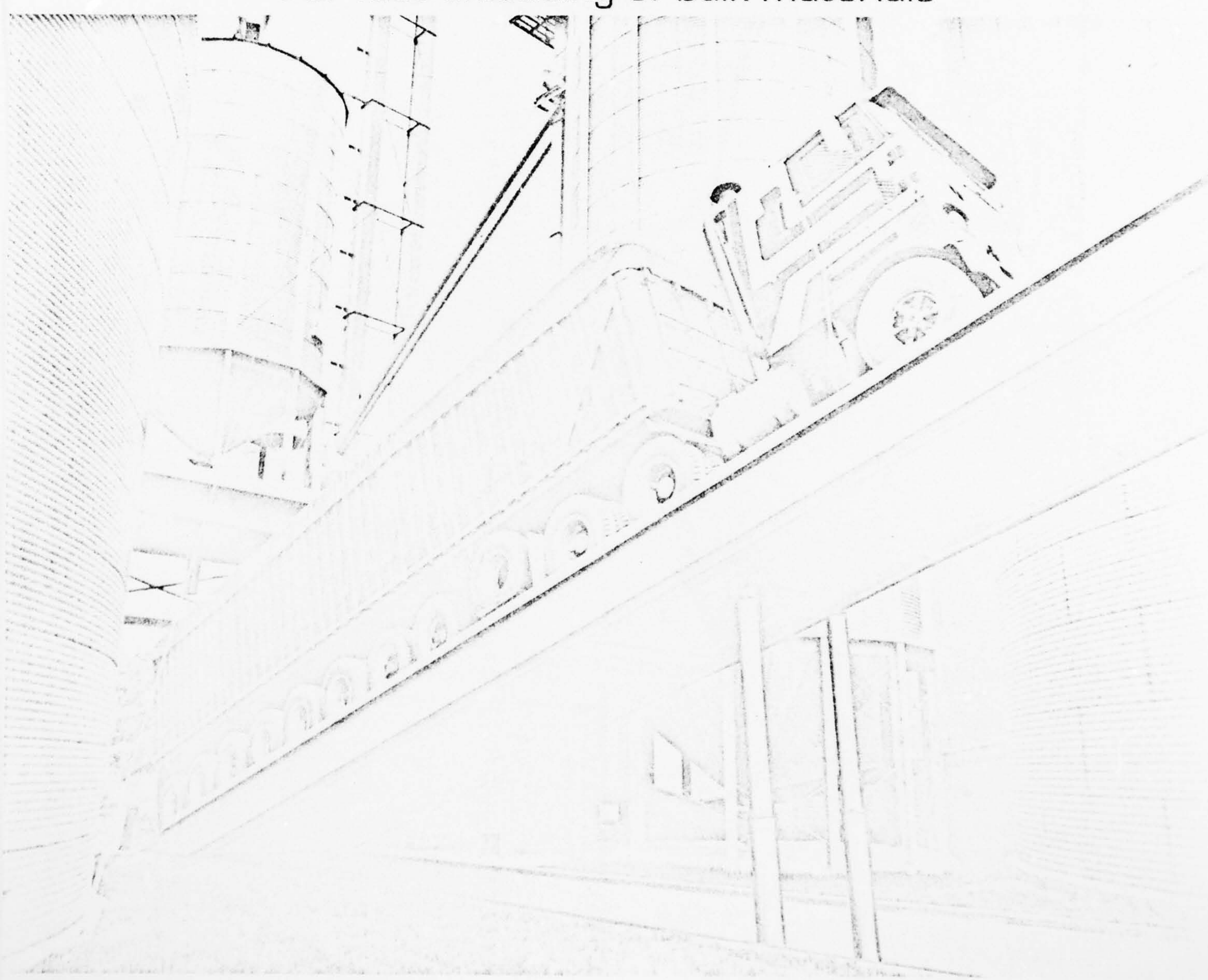
4700 WEST DIVISION ST. CHICAGO, ILLINOIS 60651 312-772-9300

CATALOG NO. 877

Screw Conveyor Corporation

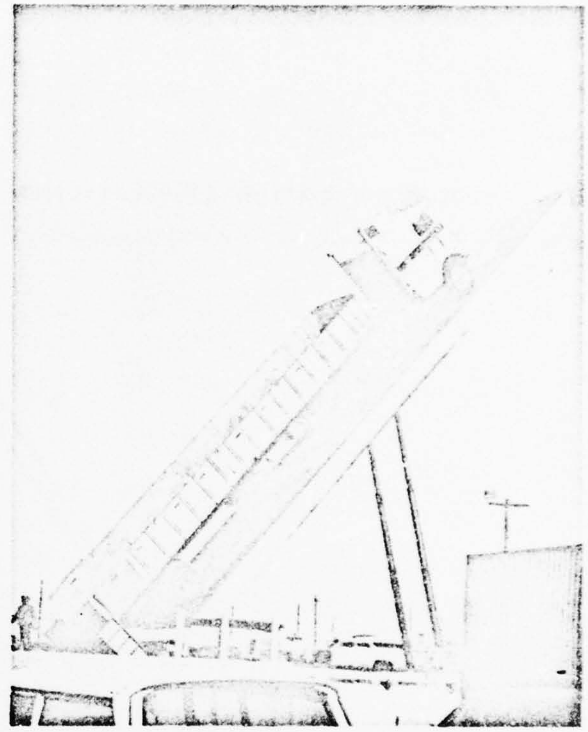
Kewanee Hydraulic Truck Dumpers

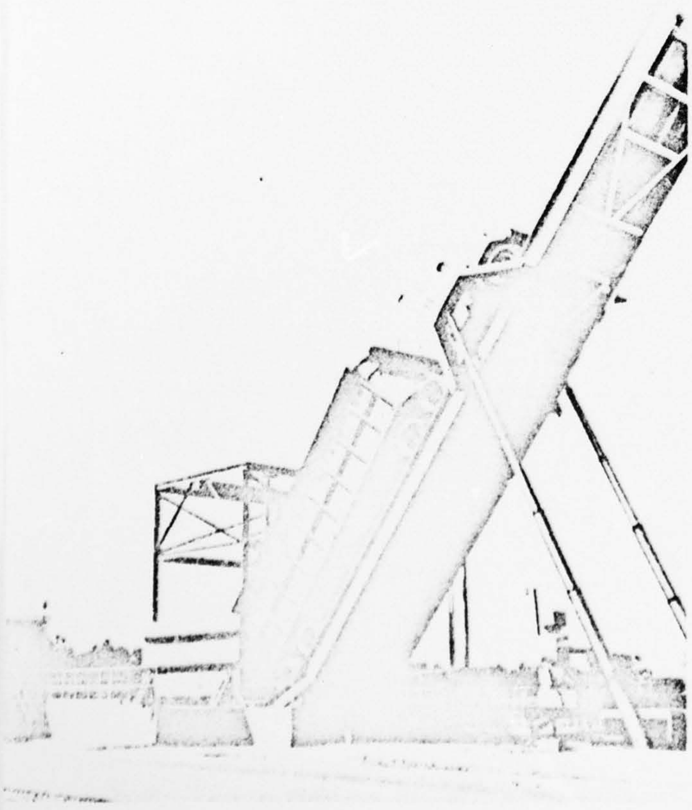
For fast unloading of bulk materials



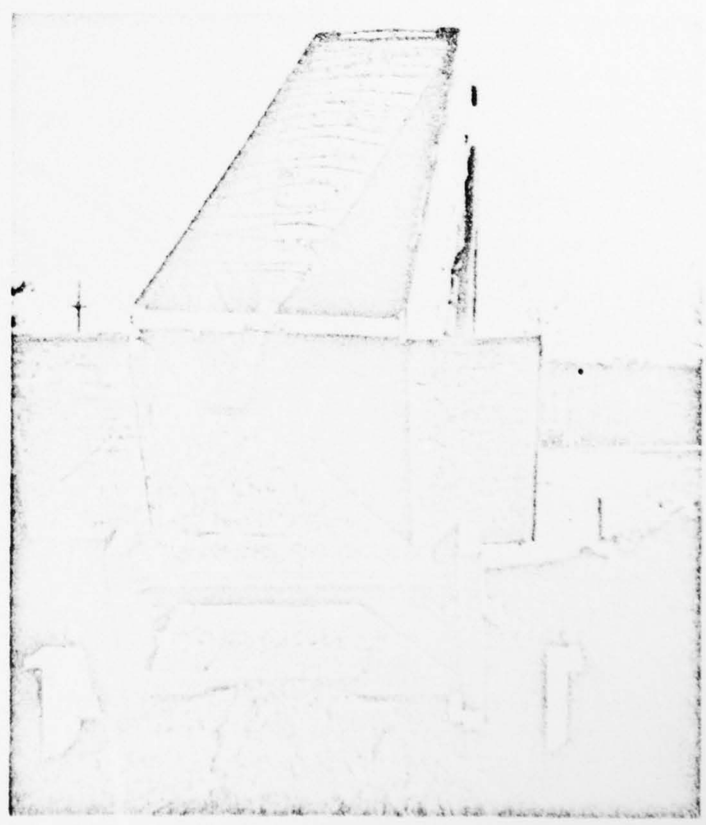
Kewanee 60-ft. grade level dumper unloading grain.

Scrap batteries are dumped by this installation in Texas.





This installation handles up to 60 ton loads at 60° angle of tilt.



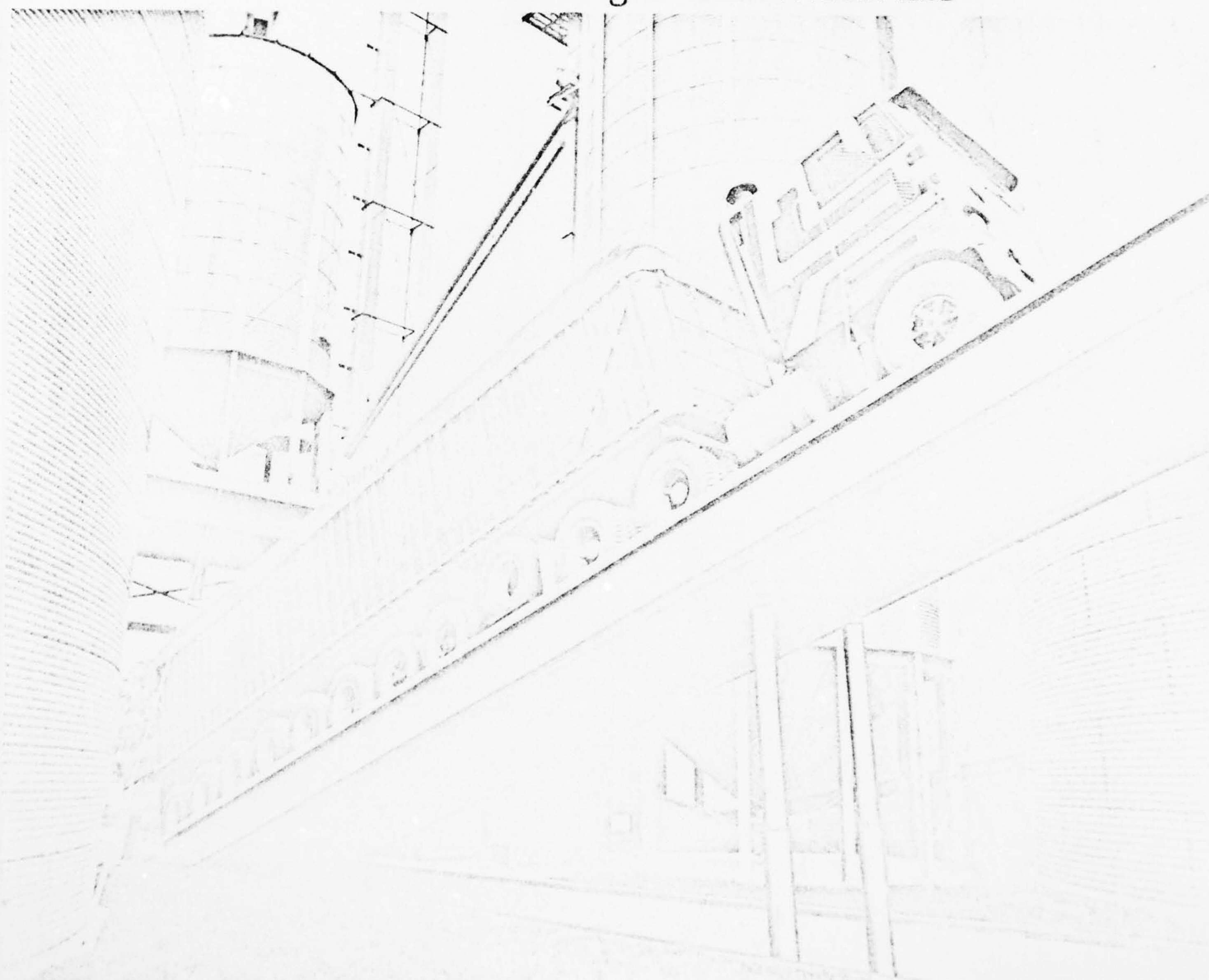
Typical trailer backstop as used on high angle of tilt Kewanee Dumpers.

CATALOG NO. 877

Screw Conveyor Corporation

Kewanee Hydraulic Truck Dumpers

For fast unloading of bulk materials



AD-A071 791 ARMY FACILITIES ENGINEERING SUPPORT AGENCY FORT BELV--ETC F/G 11/12
CONSIDERATIONS IN SELECTING WOOD AS AN IMMEDIATE SOURCE OF RELI--ETC(U)
DEC 78 S A HELMS
UNCLASSIFIED USAFESA-TS-2061 NL

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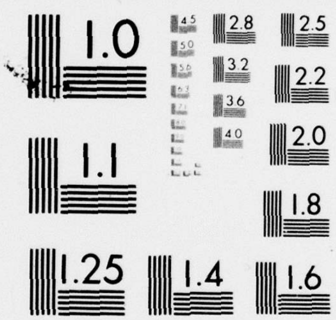
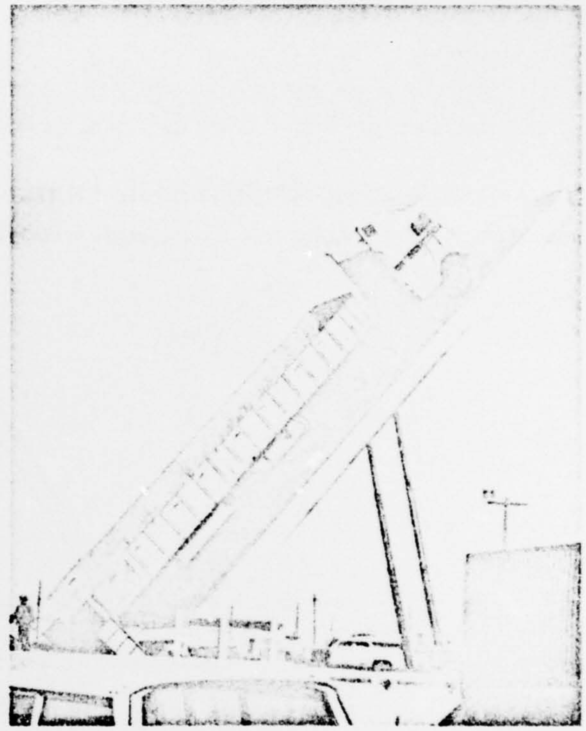
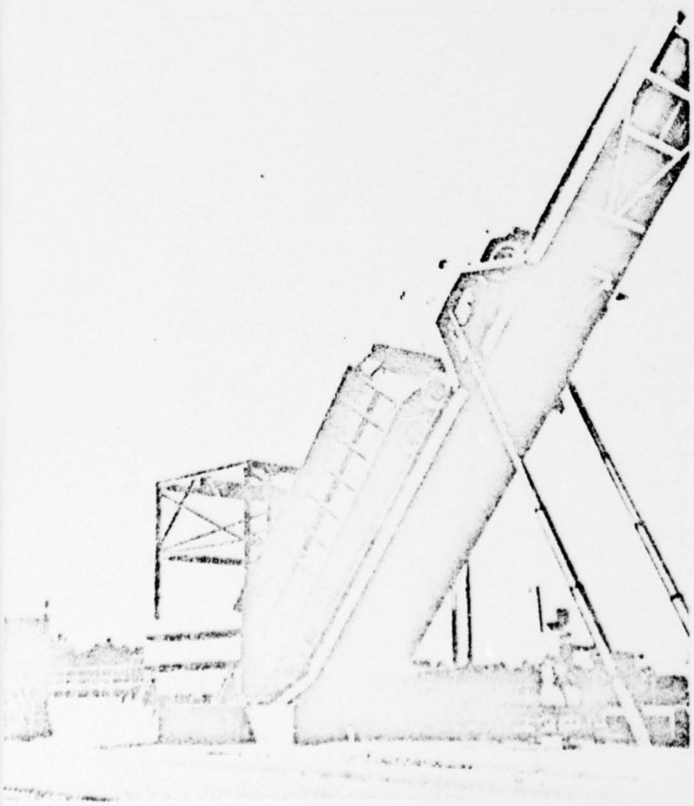


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Kewanee 60-ft. grade level dumper unloading grain.

Scrap batteries are dumped by this installation in Texas.





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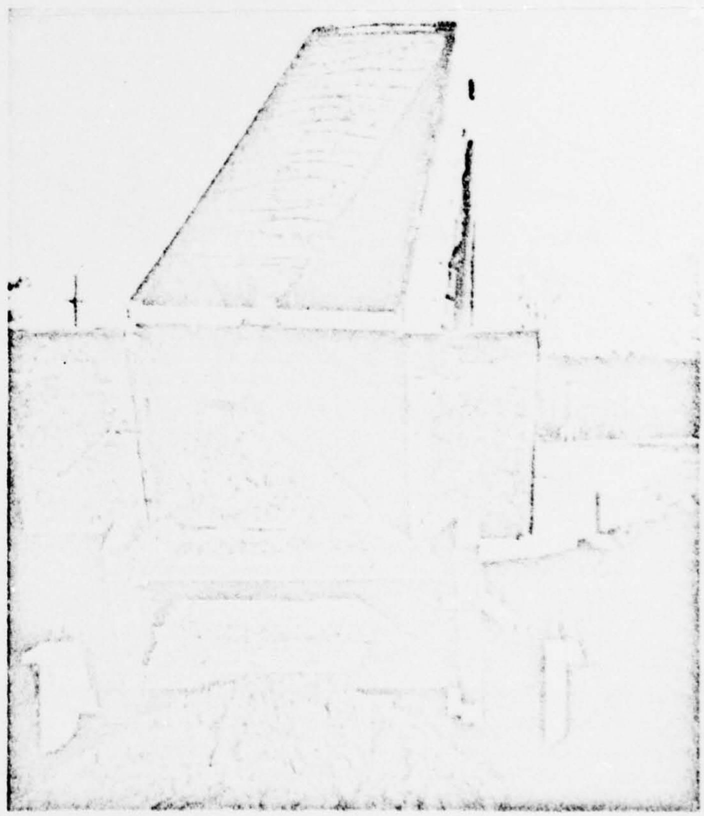


Typical trailer backstop as used on high angle of tilt Kewanee Dumpers.

BARKO 80

LIFT CAPACITY 8,000 LBS.

BACK OF CAB / TAIL MOUNT

STANDARD SPECIFICATIONS & FEATURES

AVERAGE LIFT CAPACITY (LESS ATTACHMENT)

- 10′ Radius 8,000 lbs.
- 15′ Radius 5,300 lbs.
- Full Reach 3,500 lbs.

BOOM REACH

- Horizontal—20′-0″
- Vertical—32′-0″ based on 40″ high truck frame.

BOOM DATA

- Main boom length—11′-0″.
- Secondary boom length—9′-4″.
- High tensile 50,000 PSI yield fabricated tube structure 6″ wide x 8″ high.
- Tapered roller bearings at boom pivot points.

SWING SYSTEM

- 400° gear and rack rotation with 5″ cylinders.
- Swing speed 10 RPM.
- Mast 130,000 PSI yield high-tensile cast steel.
- Timken tapered roller bearing.

CYLINDERS

- Barko-built - double acting with extra heavy chromed rods - aircraft aluminum pistons and glands - micro-uniform honed to exacting tolerances.
- Main boom—6″ x 36″ with 2½″ rod.
- Secondary boom—6″ x 24″ with 2½″ rod.

The LoaderMakers

BARKO HYDRAULICS P.O. BOX 6227 / DULUTH, MINNESOTA 55806

HYDRAULIC SYSTEM

- 35 gallon multi-baffled reservoir with submerged suction and external return line filters.
- Control vaives - stack-type Gresen 25P with port reliefs and anti-cavitation checks.
- Pump - 21/14 GPM tandem Vickers.
- Heavy walled tubing and 2-wire braided hose with reuseable fittings throughout system.
- Operating pressure - 1750 PSI.

CONTROL DECK

- Rotating platform.
- Front mount valve control station with foot control swing pedals.
- Cushion seat.

STABILIZERS/SUBFRAME

- Telescopic stabilizers spread to 10', 3½" x 43" cylinders enclosed in A-frame assembly. Unique frame design is excellent for close quarters operation.

MOUNTING DATA

- Loader requires 24" of mounting space. Mounting bolts and pads are supplied.

POWER SOURCE

- Power take-off.

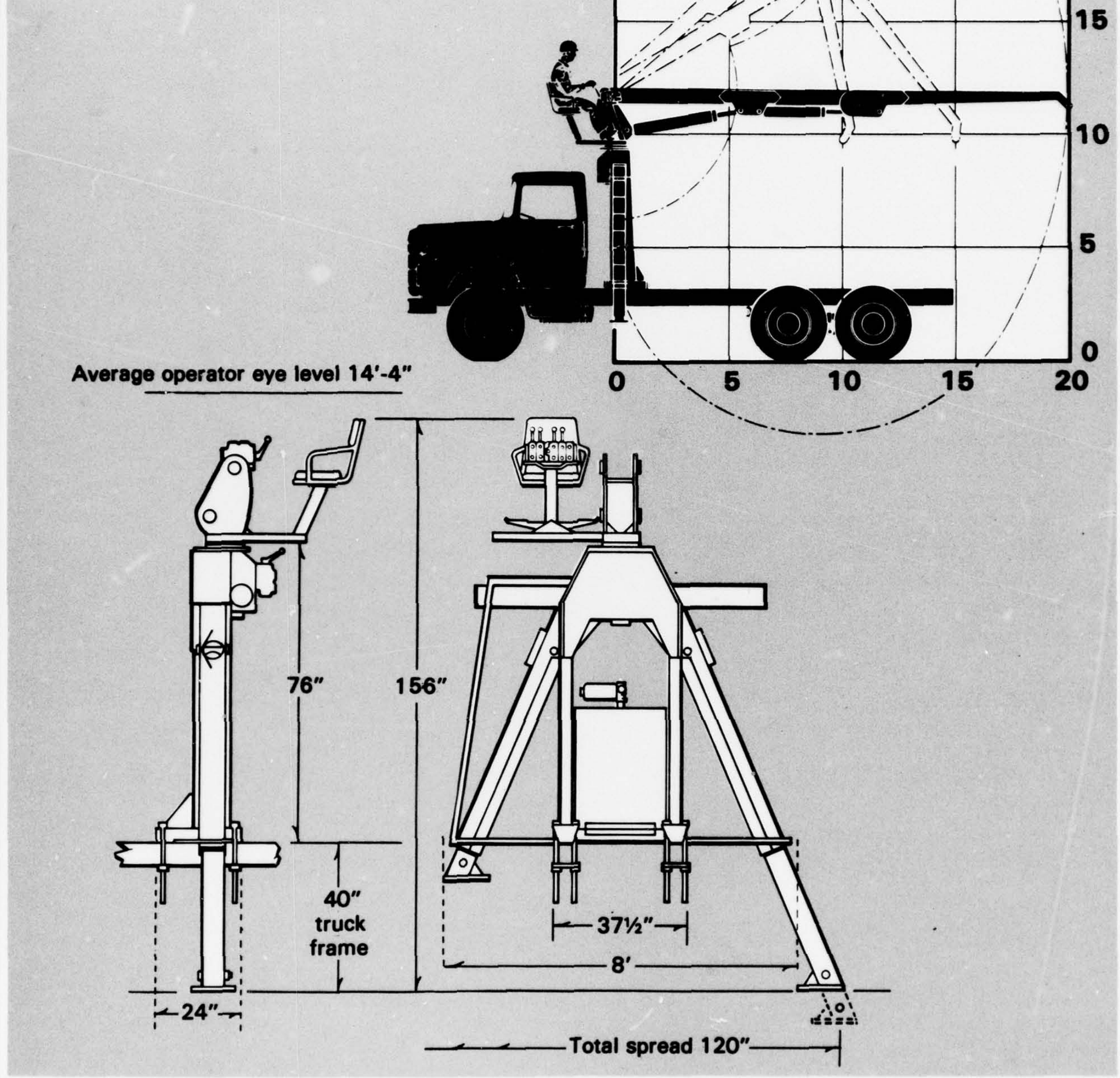
MISCELLANEOUS

- Weight 4,600 lbs. with standard equipment (less attachment and oil).
- Trailer mount versions available.

OPTIONS/ACCESSORIES

- 20/20 GPM tandem Commercial pump.
- Governor kit for tandem pump.
- Boom extension to 22'.
- Log and pulp grapples.

80 BACK OF CAB/TAIL MOUNT



ALL SPECIFICATIONS SHOWN HEREIN ARE SUBJECT TO CHANGE WITHOUT NOTICE

8004/8-77/10 PRINTED IN U.S.A.

FOR HAULING SAWDUST, WOOD CHIPS, BARK, ETC.

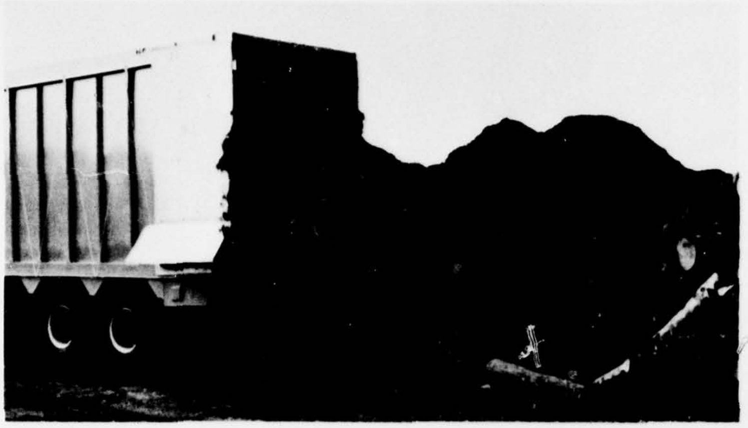
BOCATS - a pioneer in engineering and design of a self-unloading trailer to provide an easy, fast, and profitable way of transportation.

BOCATS live bottom trailers, all have high standard of quality materials, components, and workmanship - Insuring greater reliability while hauling a maximum payload.

BOCATS - Efficient unloading with trouble free heavy duty conveyor chains and slats, built INTO floor structure.

CHOOSE A BOCATS LIVE BOTTOM TRAILER

YOUR TRANSPORTATION PROGRAM WILL BE COMPLETE



CHECK THESE FEATURES

Unload a full capacity payload in 8 to 10 minutes.

Full open doors allow complete unloading.

Uneven ground and side winds have no effect on this unit.

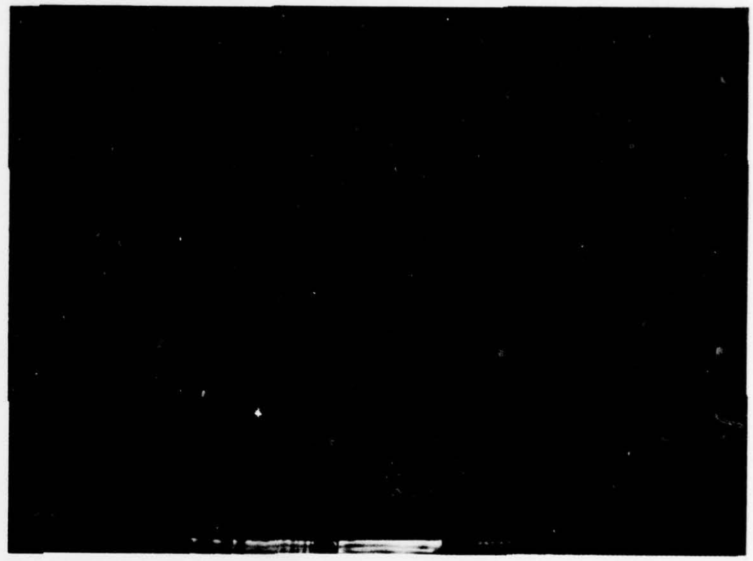
Lengths from 30′ to 50′ let you choose the trailer that fits your operation.

Full open top with roll away tarp makes easy loading.

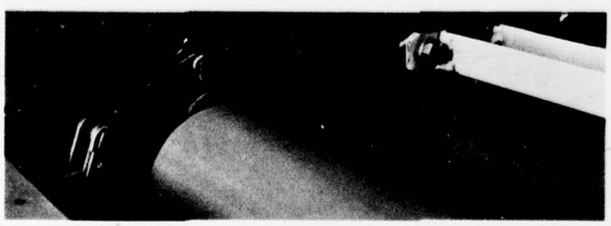
A valuable piece of equipment to any portable chipping operation. Blow chips directly into trailer, transport and unload at any destination.

Hydraulic PTO powered direct from tractor truck makes unloading a simple one man operation. (Self-contained power units OPTIONAL.)

Hydraulically driven conveyor bed with 48,000 lb. tensile strength chain and 3″ channel slats extending the full width of the trailer.



THERE'S NEVER BEEN A BETTER TIME TO FIND OUT THE VALUE OF YOUR WOOD RESIDUE



SPECIFICATIONS

CAPACITY	**Up to 3,000 Cu. Ft.**
Height	**13′6″ (Optional)**
Inside Width	**7′6″ rear**
	7′4″ front
Load Capacity	**Legal payload**
Tires	**10:00 x 20**
Axles	**5 spoke cast (standard)**
	10 hole Budd (Option)
Kingpin Location	**48″**
Suspension Location	**102″ or 90″**
Inside Height	**96″ Approximately (front)**
	104″ Approximately (rear)
Exterior Panels	**Aluminum**
Rear Doors	**¾″ Plymetal**
Floor	**14 GA. Steel**
Weight	**40′ 15,650 lbs.**

ICC REGULATION LIGHTS-MUD FLAPS-LANDING GEAR

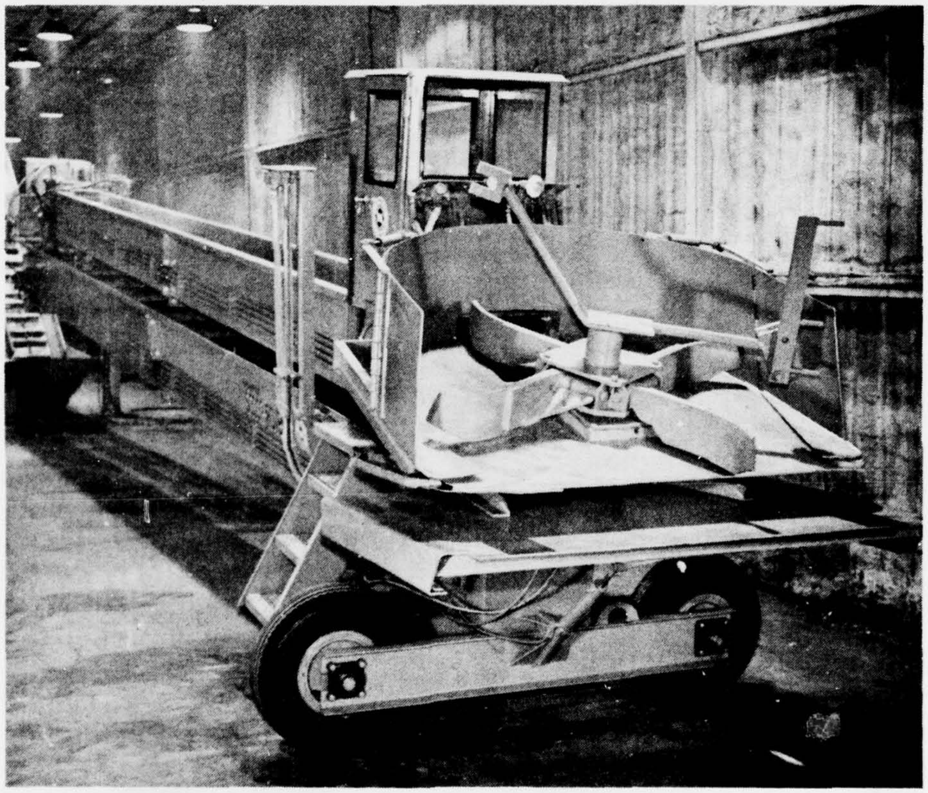
BOCATS INC
GARDEN CITY, KS.
MARTIN, N.D.

Garden City Div. Box 1021, Garden City, Kansas 67846 316-275-7167
Martin Div. Box 326, Martin, North Dakota 58758 / 701-693-6776

HIGH PLAINS PUBLISHERS, INC., DODGE CITY

MORBARK'S

MODEL 45 SCOOP-ROVEYOR



SPECIAL FEATURES OF THE NEW MODEL 45:

- Extended unloading capability. Can unload vans up to 45 feet long.
- Operator's cab, with optional electric heat and electric lights.

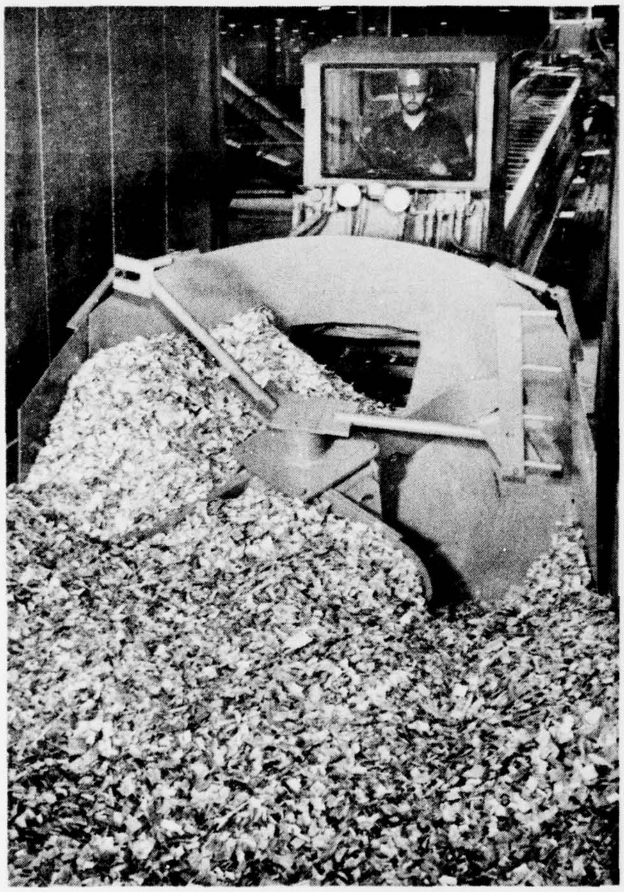
(over)

MORBARK INDUSTRIES, INC.

WINN, MICHIGAN 48896 • 517-866-2381 • TELEX 227 443 (MORBARK WINN)

45SR778

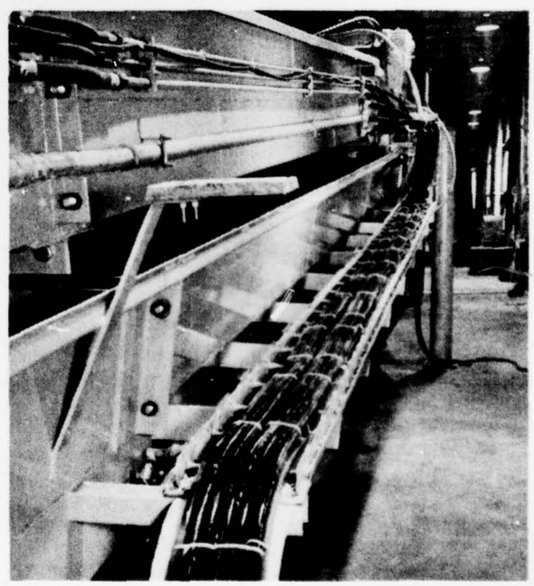
MORBARK'S
MODEL 45 SCOOP-ROVEYOR



THE MORBARK MODEL 45 SCOOP-ROVEYOR

- Unloads a 45-foot van in approximately 15 minutes.
- Will handle wood chips, hogged bark, sawmill shavings and numerous other materials, such as corn cobs.
- Not only unloads, but also transports chips.
- Eliminates long unloading lines.
- Can be installed quickly and easily.

A curling retractable hose carrier neatly carries the hydraulic hoses which supply power to the Scoop-Roveyor.



SPECIFICATIONS

Length (retracted) – 61'6"
Length (extended) – 107'
Length of ramp movement – 10"
Overall width – 9'6"
Minimum van width inside – 91"
Weight of top conveyor and scoop – 10,000 lbs.
Weight of bottom conveyor and pivot – 10,500 lbs.
Conveyor rotary head speed – 19 R.P.M.
Hydraulic fluid pressure – 1,500 to 2,000 PSI
Maximum hydraulic pump capacity – 60 gals.

(over)

MORBARK INDUSTRIES, INC.

45SR778

WINN, MICHIGAN 48896 • 517-866-2381 • TELEX 227 443 (MORBARK WINN)

Model 22 RXL Total Chiparvestor®

GENERAL FEATURES & SPECIFICATIONS

Air Brakes & Lights to ICC Regulations
Air Compressor & Tank (from Main Engine)
Chicago Pneumatic Wrench
Knife Babbitting Tools
Optional Parts Kits
Length . . . . 34' 6"
Width . . . . 10' 0" (max.)
Height . . . . 13' 6"
Weight . . . . 65,000 lbs.
(Specifications with Morbark SS-300 Loader & Cummins 380 Engine.)
Fuel Tank Capacity . . . . 150 gal.
Suspension . . . . Dual Tandem Axles

FEED SYSTEM

Hydraulic Power. . .(2) 2620V (21-14) Pumps
(5) 10,000 – 57 Motors
Side Wheels. . . . . .16" dia. x 23" long
Top Wheel . . . . 20" dia. x 47" long
Conveyor & Chain . . Morbark 30" Cat-Type
Bed Length . . . . 12' 6"

CHIPPER

Model . . . . L.H. Rotation, Horizontal Feed, End Discharge
Disc . . . . .75" dia. - round
Type . . Optional – Separator or Nonseparator
Pockets . . . . Optional 2 or 3 Knife (conventional)
Chip Size . . . . . Optional – 5/8",3/4" & 7/8" 1" Chip
Discharge Spout . . . . . . Hydraulically-Powered
Swivel Optional—Electric Quick Flip

STANDARD MORBARK MODEL SS - 300 LOADER

Boom Reach . . . . 30 feet
Swing . . . . 90 degrees
Power Supply . . . . . .2620V Hydraulic Pump on Main Engine
Standard . . . . Air Conditioner, Heater, Hydraulic Tilt, Removable Insulated Cab

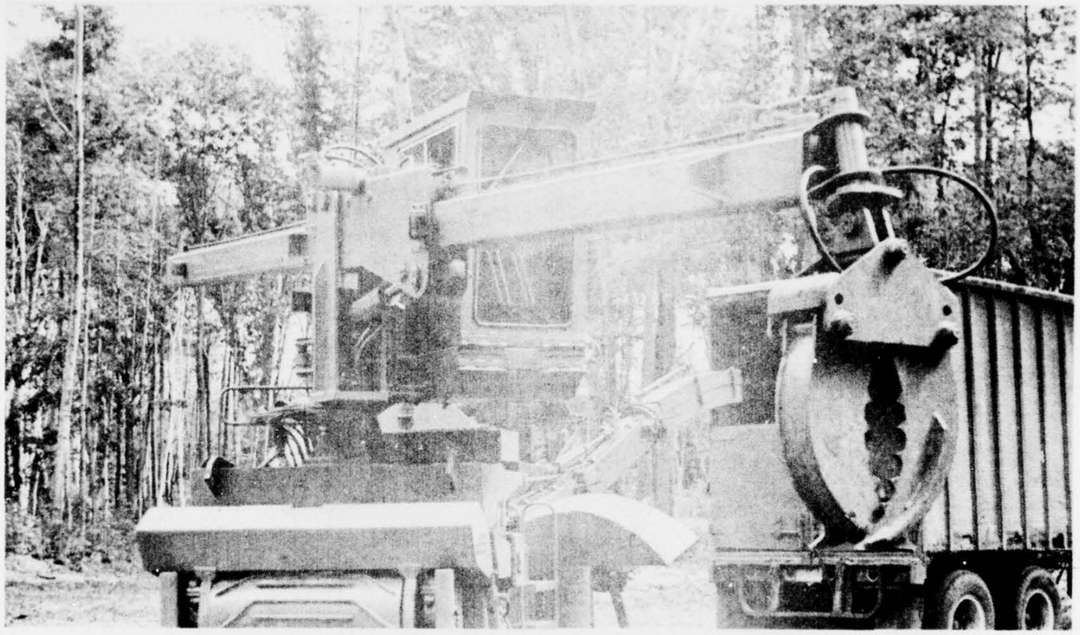
OPTIONAL POWER SUPPLY (DIESEL)

Cummins 380 . . . . 380 HP
Cummins 450 K . . . . 450 HP
Cummins 600 K . . . . 600 HP
GMC 12V71 . . . . 425 HP

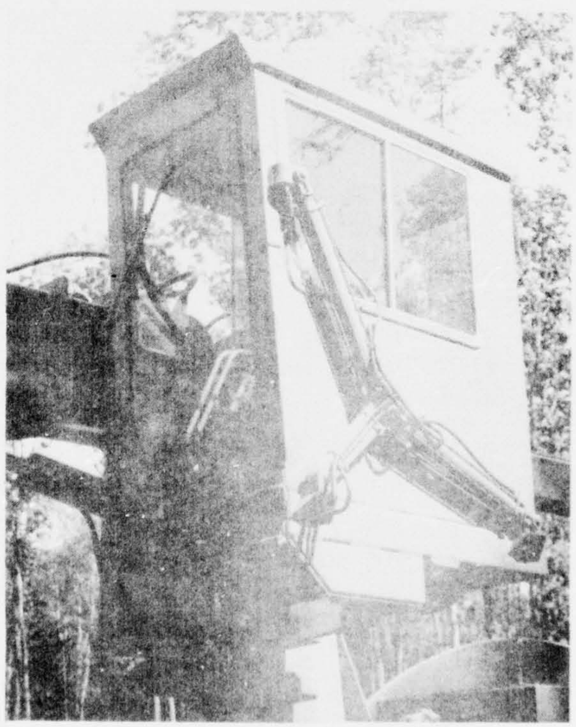
MORBARK INDUSTRIES, INC.

22RXL0878

BOX 1000 • WINN, MICHIGAN 48896 • 517-866-2381 • TELEX 227 443 (MORBARK WINN)

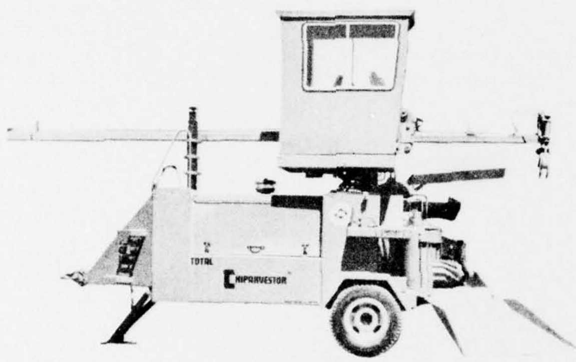


The Morbark Model SS-300 slide boom loader operates quickly and is designed for efficiency.



Morbarks Model 22 RXL has a air-conditioned, fully equipped cab that allows the operator to perform in all types of weather.

Model 12
Total Chiparvestor®
Specifications



FEED SYSTEM
Hydraulic Power Compression Feed Rolls
Side Rolls .... Dia. 8″
Length .... 21″
Bottom & Top Feed Rolls .... Dia. 8″
Length .... 24″

FEED RATE
5/8″ Chip .... 84 ft. per minute
3/4″ Chip .... 101 ft. per minute
7/8″ Chip .... 118 ft. per minute
1″ Chip .... 135 ft. per minute
Note: at 2300 Engine R.P.M.

POWER UNITS
John Deere 6466A
Engine Type .... In Line 6 Cylinder Diesel
Horsepower .... 230 H.P. at 2300 R.P.M.
Fuel Tank .... 45 Gal.

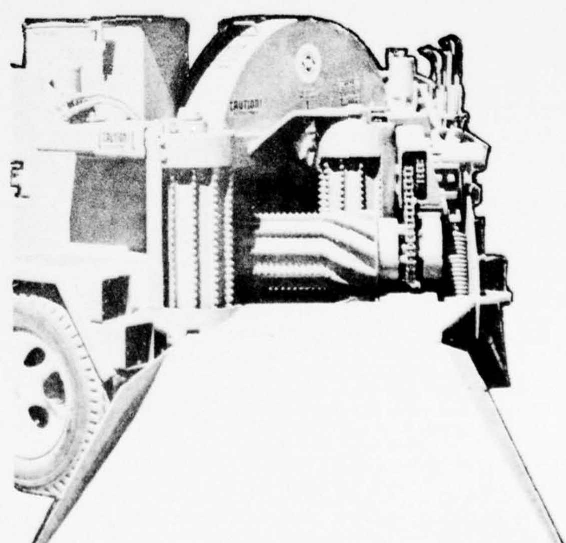
POWER UNITS
Cummins VT 903
Engine Type .... V8 Diesel
Horsepower .... 310 H.P. at 2300 R.P.M.
Fuel Tank Capacity .... 45 Gal.

CHIPPER
Number of knives 2
Max. Opening .... 12″
Available with Optional Dirt Separator

LOADER
Make-Morbark SS25
Boom Reach from Centerline of Feed Wheels . . 13′
Swing .... 90°
Available with the choice of either the Brush & Round Wood Grapple or the Stem Wood Grapple.

STANDARD EQUIPMENT
- 4 Hydraulically Powered Compression Wheel Infeed System with top and bottom rolls adjustable up and down.
- Hydraulically operated Leveling Jack
- 40″ 2-Knife Chipper — will handle up to 12″ diameter material.
- Trailer Hitch — 3″ Lanet
- Single Axle Suspension — dual wheel 8.75-16.5 10 ply rating
- Manual Swivel Discharge Spout
- Totally Enclosed All-weather Operator's Cab

GENERAL
Length .... 16′ 6″
Width .... 8″
Height .... 9′ 9″ wo/cab
Height .... 12′ w/cab
Weight .... 14350 w/cab
(Approximately 12,700 over rear axles)
Approximate Tongue Weight 1650



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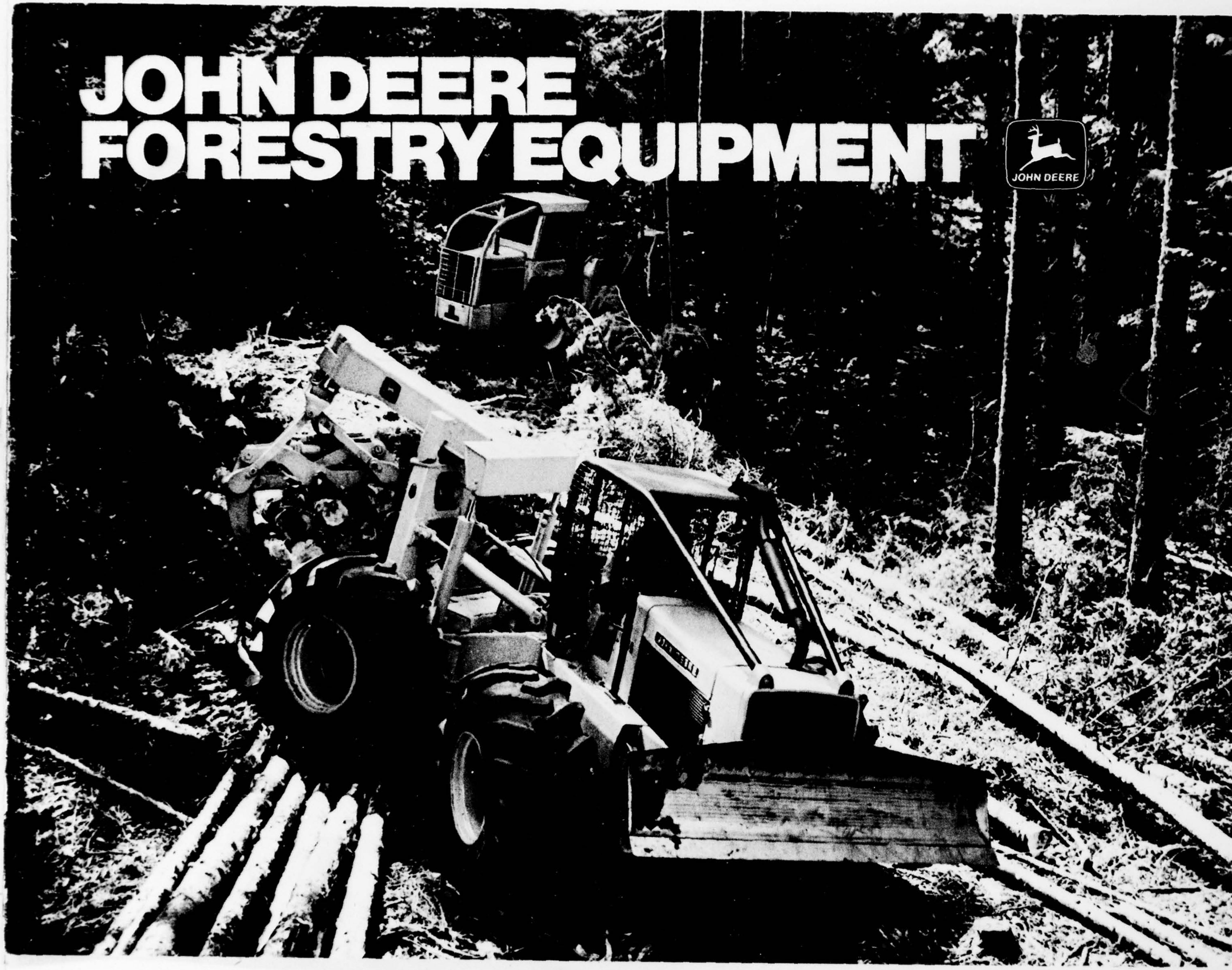
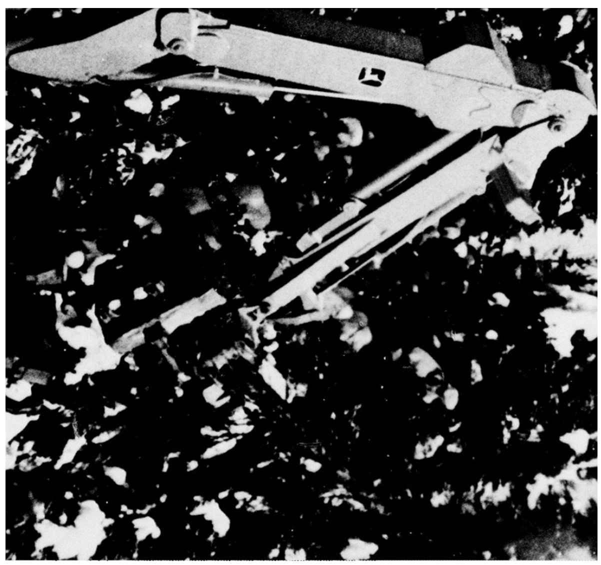

JOHN DEERE
FORESTRY EQUIPMENT
JOHN DEERE



Depend on John Deere for your tree-harvesting needs

If you've been searching for new and better ways to increase production on your mechanized operations, John Deere has some ideas worth looking at...for felling, skidding, loading, and reforestation.

John Deere equipment is basic, versatile, and dependable, and can be adapted to do a variety of jobs. Under the allied equipment program, attachments made by other manufacturers are tested by John Deere engineers, approved for John Deere financing, and sold and serviced by John Deere dealers. They add special capability to the basic machine you buy, giving you more machine for your money.

With a John Deere system, you're way ahead on maintenance, too, because many parts are common throughout the line. That can save you downtime and reduce inventory expenses.

Your John Deere dealer also has a number of finance plans for purchase, rental or lease. You can buy outright with a choice of down-payment options and repayment plans. You can also rent the unit you need for up to six months, with the option to buy at any time during, or at the end of the period. Lease plans are also available, to help you conserve on tying up money in equipment.

Take a few minutes now to look over the forestry systems available from John Deere. When you consider parts, equipment, service, and finance, you'll find that John Deere is the only name you have to know to make your operation more productive and economical.

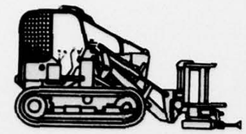
Here are five easy ways to mechanize your felling operations

If your timber and terrain are suited for mechanized felling, consider the selection of shearing units that John Deere has to offer.

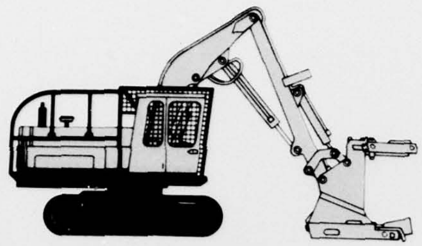
Choose the JD450-C for felling trees up to 16-inch butt diameter. It can cut and carry trees vertically to the bunching point, and its small size and easy maneuverability makes it ideal for selective-cut and row-thinning operations.

If you need more production at the stump, John Deere offers the 4-wheel-drive JD544-B and the crawler-type JD693-B Feller-Bunchers. The JD544-B with top accumulator clamp can cut and bunch a number of trees for convenient skidder pickup. The JD693-B reaches over 25 feet to cut and bunch trees over a wide radius.

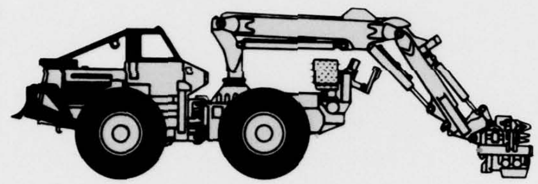
For highly mechanized stands the JD743 Tree Harvester can simultaneously cut and delimb, handling up to two 18-inch trees every minute. With more than a 17-foot reach to either side, the JD743 is engineered for top production in both selective-cut and clearcut operations. Delimbing can be controlled manually or automatically. The highly mobile JD743 Feller-Buncher (without delimber) also cuts up to 18-inch-diameter trees and can be used for high-production felling.



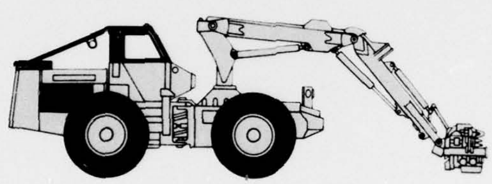
JD450-C Feller-Buncher cuts and carries 16-inch-diameter trees vertically to the bunching point. It's compact and maneuverable for selective cutting and thinning operations.



JD693-B Feller-Buncher has a 131-SAE-net-horsepower engine, and can cut trees up to 18 inches in diameter. At its longest reach of 25 feet 4 inches, the boom lifts 3000 pounds.

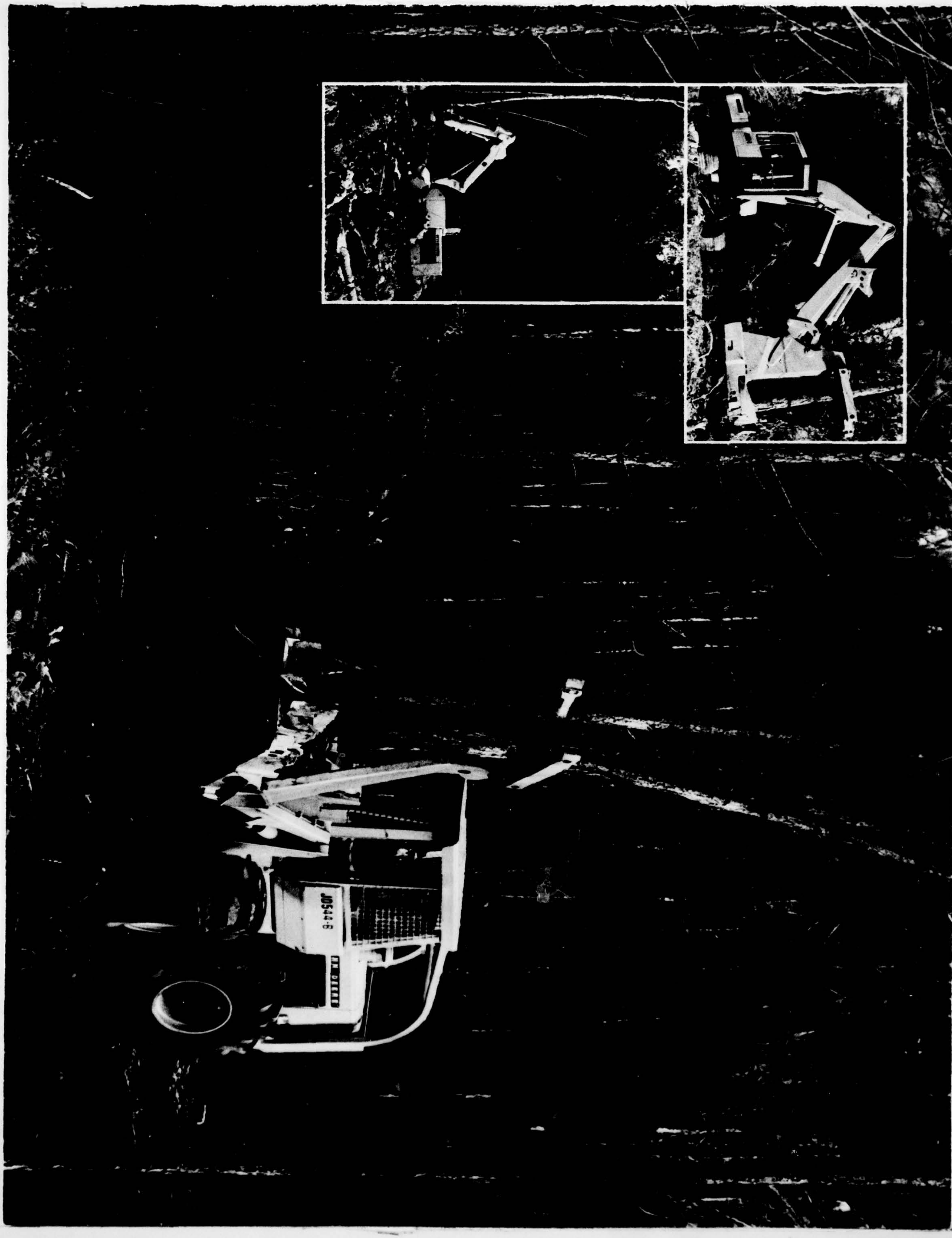


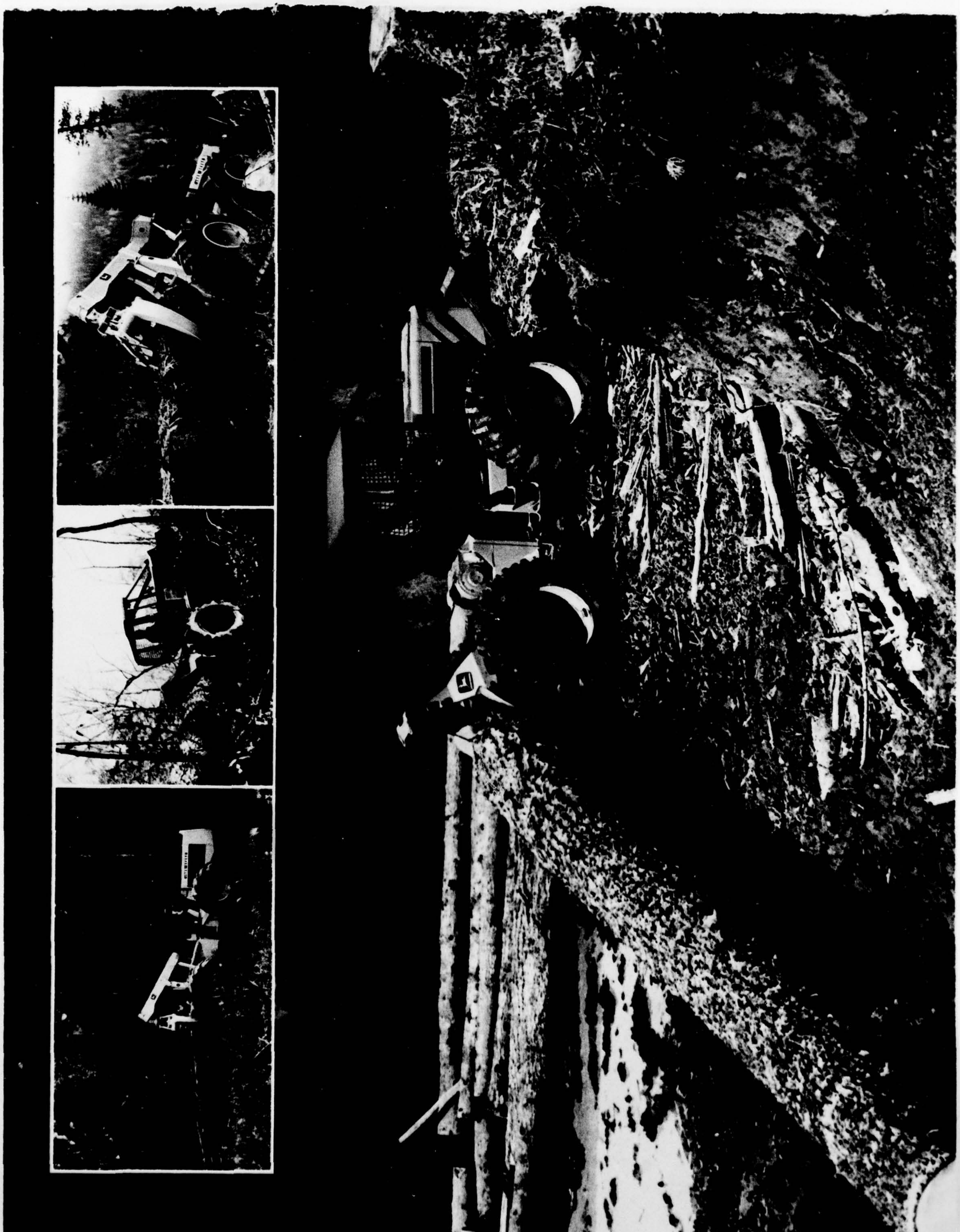
JD743 Tree Harvester cuts and delimbs up to 18-inch-diameter trees. Delimber knives also top automatically. Power from a 152-SAE-net-horsepower engine is channeled through an 8-speed Power Shift transmission.



JD743 Feller-Buncher shears up to 18-inch-diameter trees with curved blades that cut low, driving shatter forces into the stump. Isolated cab and climate control make operation more comfortable.

JD544-B Feller-Buncher cuts up to 20-inch-diameter trees. With top accumulator clamp, it can cut and carry small trees to the bunching point.





Cable or grapple skidding? John Deere has the answer

Big or small, cable or grapple, John Deere has the skidder for your operation: You can choose between cable or grapple skidders in four classes: 70, 90, 110, and 145 SAE net horsepower.

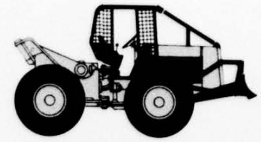
At 70 SAE net horsepower, JD440-C skidders deliver 22,200 pounds bare-drum linepull in the cable model and 17,600 pounds of lift in the grapple. Also JD540-B models give 29,800 pounds of bare-drum linepull in the cable model and 20,700 pounds of lift in the grapple. Both JD440-C and JD540-B grapples are of welded box construction and open to 75 inches.

The JD640s and JD740s come in two different designs, for cable and grapple skidding. The cable skidders have a low winch and power train mounting for added stability with big loads. And to take the extra grapple weight, the JD640 and JD740 Grapple Skidders have longer wheelbases.

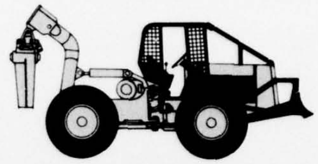
Features common to all John Deere Skidders include self-adjusting wet-disk power brakes, automotive-type power steering, and inboard mounted planetary final drives. A ROPS canopy with limb risers, brush screens, seat belt, and two fire extinguishers come standard.

Matching machine size to your logging operations—that's the benefit of the John Deere Skidder line.

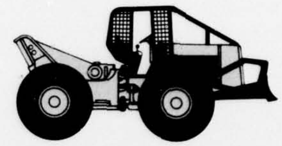
JD440-C Skidder has a 70-SAE-net-horsepower engine and 6-speed Syncro-Range transmission. Bare-drum linepull is over 22,000 pounds.



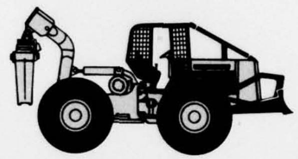
JD440-C Grapple Skidder features 17,600-pound lift capacity with grapple that opens to 75 inches, closes to 5 inches. Front differential lock gives maximum traction in slick conditions.



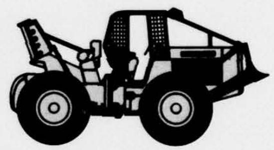
JD540-B Skidder has a 90-SAE-net-horsepower engine, 8-speed Power Shift transmission, and power steering and brakes. Bare-drum linepull is 29,800 pounds.



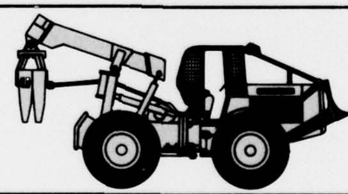
JD540-B Grapple Skidder delivers 20,700 pounds of lift. Continuous grapple rotation of 360 degrees helps simplify pickups, and 6300 pounds of continuous hydraulic clamping force helps keep logs in tow even if the load shifts.



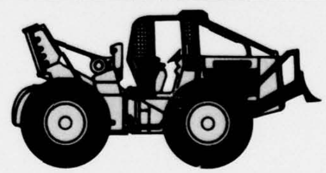
JD640 Skidder has a 110-SAE-net-horsepower engine, front and rear differential locks, and winch with 30,200-pound bare-drum linepull. A John Deere built engine with altitude-compensating turbocharger is standard.



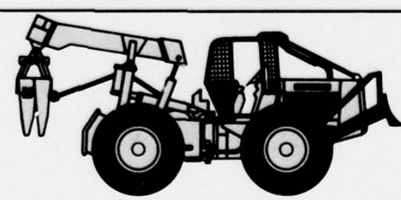
JD640 Grapple Skidder features pushbutton grapple control, 10-foot grapple opening, and 5-foot fore-and-aft range. Lift capacity is 25,000 pounds, and the grapple has 360 degree continuous rotation.



JD740 Skidder has 145 SAE net horsepower, front and rear differential locks, and winch with 45,000 pound bare-drum linepull. An auxiliary winch is available.



JD740 Grapple Skidder answers the demands of highly mechanized systems. The grapple opens 10 feet and has 5-foot range fore-and-aft. Lift capacity is 30,750 pounds.



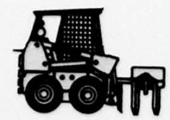
Choose the right loader for your timber and terrain

Whether you need a skid-steer at the mill or a 4-wheel-drive loader at the landing, John Deere has a loader for you.

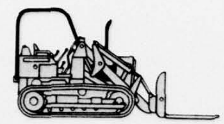
The JD24-A takes over the innumerable small jobs that come up at the mill. The patented "Quik-Tatch" system lets you change from loader to forks in minutes, and the small size makes it ideal for tight conditions.

Where the terrain calls for tracks, you can choose from three crawler loaders, ranging from 42 to 72 SAE net horse-power. All have the durability of oil-cooled steering and brakes, and feature hydraulic track adjustment, one-stop daily maintenance, and ROPS canopy as standard.

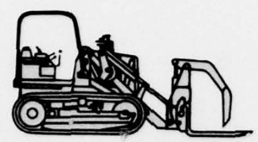
Two rough-terrain forklifts can help solve your material-handling problems, especially in slippery footing. For your larger log-loading jobs, choose one of the three articulated-frame, 4-wheel-drive log loaders. They all feature No-Spin front axle (optional on JD444), power steering, wet-disk power brakes, inboard planetaries, and ROPS cab as standard.



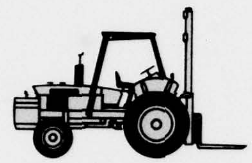
JD24-A Skid-Steer Loader comes with a 37-net-horsepower engine, hydrostatic drive, and a variety of loader and fork options. The 25-SAE-net-horsepower JD14 is also available for work in tighter quarters.



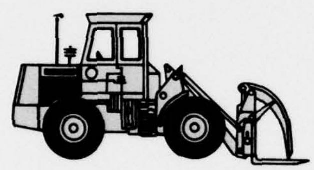
JD350-C and JD450-C Loaders are excellent where ground conditions call for tracks. They have oil-cooled steering clutches and brakes for durability, and offer many options.



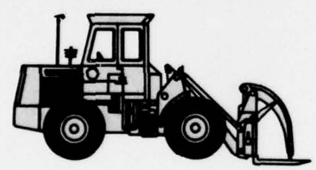
JD555 Loader has the added toughness of a single-stage torque converter with 3-speed Power Shift transmission to complement oil-cooled steering and brakes and sealed tracks. Turbocharged diesel provides 72 SAE net horsepower.



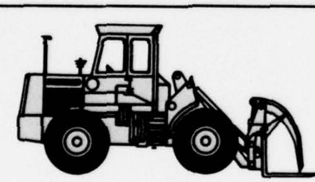
JD380 and JD480-B Forklifts have the high clearance and wide stance you need in potholed mill yards. Five masts to 28 feet are available. Lift capacities range to 6000 pounds.



JD444 Log Loader with 85-SAE-net-horsepower engine can lift more than 5500 pounds. Excellent maneuverability and responsive hydraulics make it a natural at the mill or landing.

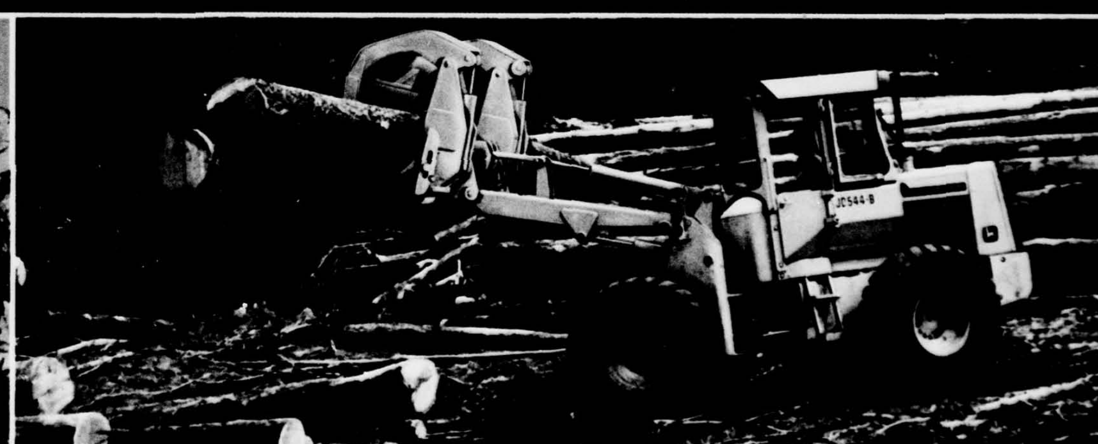


JD544-B Log Loader lifts more than 7650 pounds to 10 feet 7 inches. With 4-wheel drive and No-Spin front axle, it serves both yard and landing requirements.



JD644-B Log Loader lifts more than 9000 pounds over 11 feet. Articulated frame, power steering, and power brakes make this one an easy-handling, high-production loader.


JOHN DEERE
JD644-B

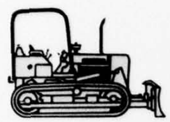

JD544-B

Cleanup and reforestation are also John Deere jobs

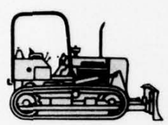
Plan for tomorrow's trees with a John Deere machine today. After harvesting, the big JD740 makes fast work of preparing for your next generation. Its pressure-lubricated, direct-drive transmission delivers 93 percent of the 145 SAE net horsepower to the inboard planetary final drives. There's no power loss or heat buildup through a torque converter. You can move right out with plows, choppers, or chains.

If you don't need all the pulling power that goes with the JD740, John Deere has three forestry bulldozers that can handle most of the dirt work of logging. With 42, 65, and 72 SAE net horsepower, they're sized right for planters, fire plows, and other reforestation equipment.

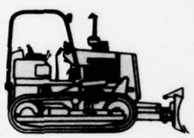
Preserving today's growing forests for harvest or preparing land for tomorrow's trees, you can figure on John Deere in your plans for future success.



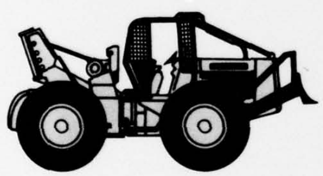
JD350-C Bulldozer offers three blade options and up to 10,850 pounds of drawbar pull. An easy choice for pulling planters and other reforestation equipment.



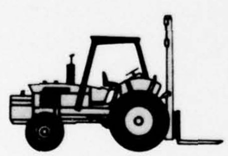
JD450-C Bulldozer has both inside- and outside-mounted blades for building ramps and other dirt work. For rear-mounted reforestation equipment, maximum drawbar pull is more than 18,000 pounds.



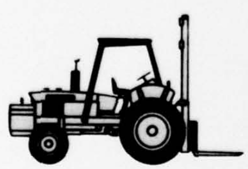
JD550 Bulldozer gives you the durability of torque-converter Power Shift transmission, oil-cooled steering and brakes, and fully sealed tracks. Transmission offers three forward and three reverse speeds to 6 mph.



JD740 Skidder has 23,000 pounds of usable rimpull, plenty for pulling plows, choppers, or chains. Front mounted bulldozer blade piles slash and logs, and maintains roads.



JD380 Forklift can handle a variety of lifting jobs economically. It has 8 forward and reverse speeds, a 43-SAE-net-horsepower engine, and lift capacities to 4000 pounds.



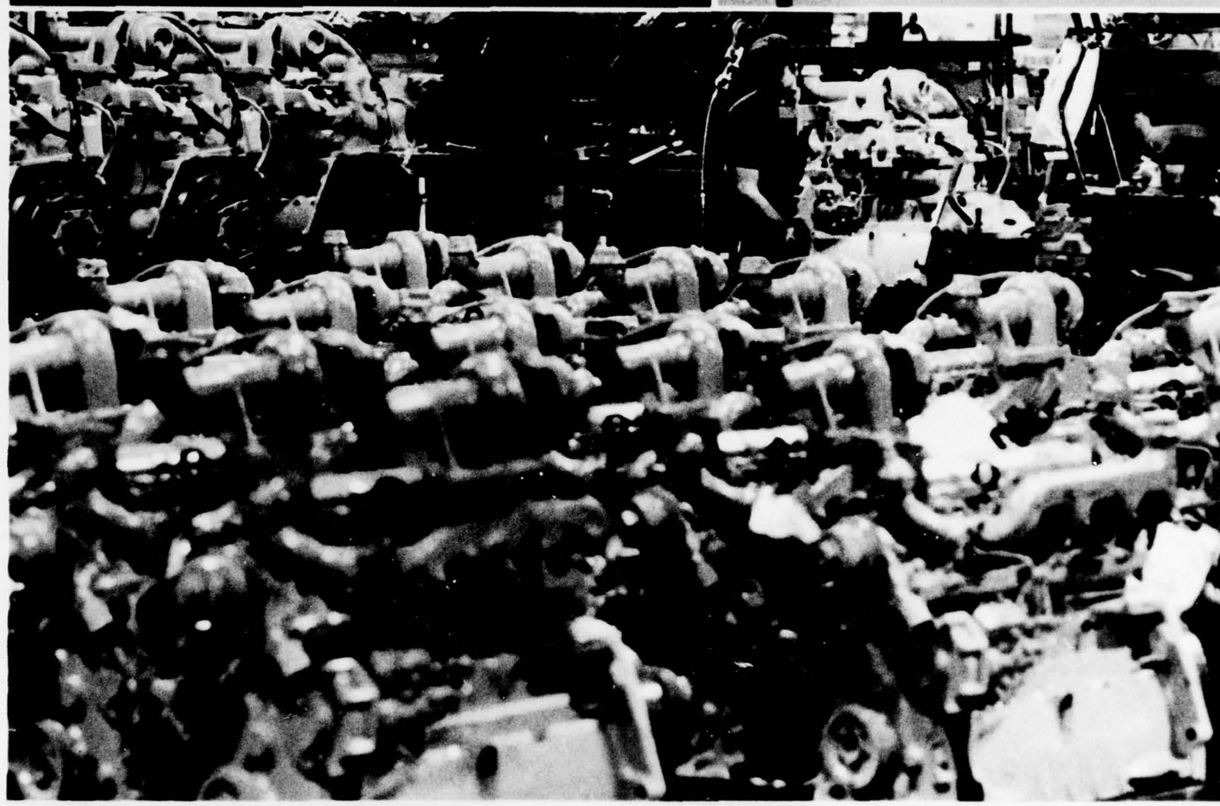
JD480-B Forklift hustles palletized seedlings on or off the truck and to the point of planting. It features a 62-SAE-net-horsepower engine, 8-speed transmission, and lift capacities to 6000 pounds.

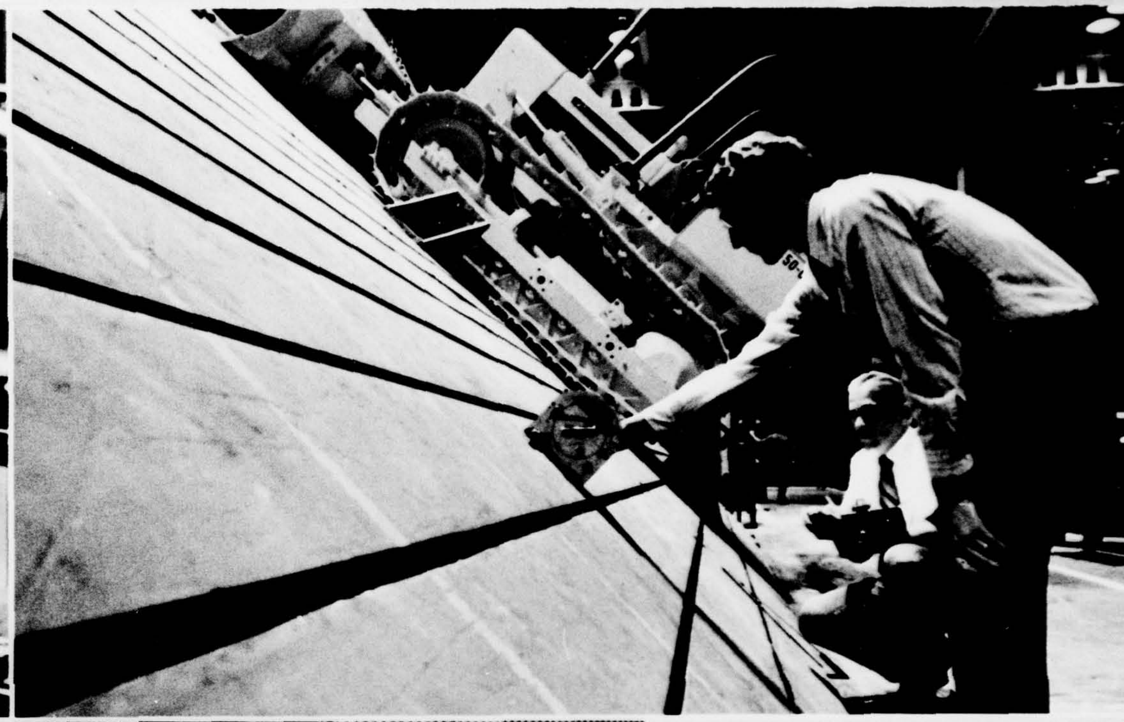
John Deere's professional team backs up your decision

Through the combined efforts of more than 7000 workers at John Deere factories in Dubuque and Davenport, Iowa, thousands of hours of designing, engineering testing, and manufacturing have been spent to make your John Deere machine one of the best money can buy.

Other professionals have designed John Deere finance plans to make your ownership easier. Whether you prefer to buy outright, rent, or lease, you can select the right plan to meet your budget requirements.

Once you get the equipment you need, you can depend on your John Deere dealer to help keep it working for you day after day. He has a large inventory of parts on hand. And if he should happen to be out of a part when your machine goes down, he can rely on the John Deere F.L.A.S.H.™ computer network to locate the closest part and rush it to you. More important, he has factory-trained service personnel who know what to do when parts arrive. For equipment, finance, parts, and service, you can count on the John Deere team.



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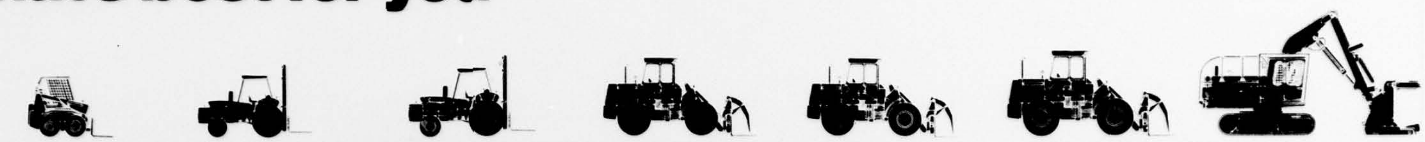
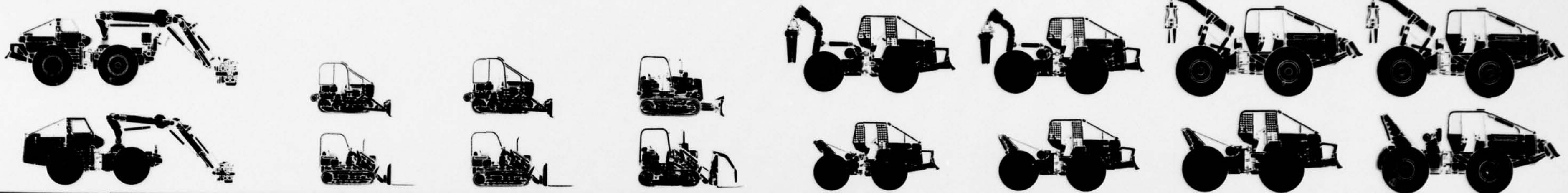
Compare the specifications, then decide what's best for you



	JD24-A	JD380	JD480-B	JD444	JD544-B	JD644-B	JD693-B
Engine	Isuzu C-190 (diesel) Continental Y-112 (gas)	JD3-135 (gas) JD3-152 (diesel)	JD4-219 (gas) JD4-219 (diesel)	JD6-329	JD6-414	JD6-531	JD6-404
SAE net hp @ rpm	37 @ 2800	43 @ 2500	62 @ 2500	85 @ 2400	105 @ 2200	145 @ 2200	131 @ 2400
Transmission type	Hydrostatic	Sliding gear with hydraulic direction reverser	Sliding gear with hydraulic direction reverser	Torque-converter Power Shift	Torque-converter Power Shift	Torque-converter Power Shift	Hydrostatic 2-speed propel
Transmission speeds	Infinite F-R	8F-8R	8F-8R	4F-2R	4F-2R	4F-2R	2F-2R
Hydraulics gpm @ rpm	Gear 15 @ 2900	Gear 23 @ 2500	Gear 23 @ 2500	Vane 39.5 @ 2400	Vane 44 @ 2200	Vane 62 @ 2200	Piston 84 @ 2400
Steering	T-bar	Power hydrostatic	Power hydrostatic	Power articulated-frame	Power articulated-frame	Power articulated-frame	Hydraulic
Brakes	Parking	Wet-disk	Wet-disk	Power wet-disk	Power wet-disk	Power wet-disk	Automatically applied
Overall length (in.) with standard equipment	115.5	146 less forks	151 less forks	260	260	269.5	440 (extended)
Overall width (in.) with standard equipment	59.5	79	79	85.5	87.5	100.5	113.5
Maximum SAE operating weight (lb.)	5483	11,290	11,690	18,870	21,516	26,720	49,000
Attachments	1 pallet fork 4 Quik-Tatch buckets	Log clamps Dozer blade Sideshift	Log clamps Dozer blade Sideshift	Top clamp Lumber forks Log inserts	Lumber forks Log inserts Top clamp Feller-Buncher	Lumber forks Log inserts Top clamp	



JD743 Tree Harvester JD743 Feller Buncher	JD350-C	JD450-C	JD550, JD555	JD440-C Cable/Grapple	JD540-B Cable/Grapple	JD640 Cable/Grapple	JD740 Cable/Grapple
JD6-466	JD3-152	JD4-219	JD4-276	JD4-276	JD4-276	JD6-414	JD6-404
152 @ 2200	42 @ 2500	65 @ 2500	72 @ 2200	70 @ 2200	90 @ 2200	110 @ 2200	145 @ 2200
Direct drive Power Shift	Sliding gear with hydraulic direction reverser	Range Power Shift	Torque Converter Power Shift	Syncro-Range	Direct drive Power Shift	Direct drive Power Shift	Direct drive Power Shift
8F-4R	4F-4R	8F-4R	3F-3R	6F-3R	8F-4R	8F-4R	8F-4R
Piston 72 @ 2200	Gear 23 @ 2500	Gear 28 @ 2500	Gear 28 @ 2200	Piston 25 @ 2200	Piston 25 @ 2200 (cable) 33.4 @ 2200 (grapple)	Piston 36 @ 2200 (cable) 54 @ 2200 (grapple)	Piston 36 @ 2200 (cable) 54 @ 2200 (grapple)
Power articulated- frame	Self-adjusting wet multidisk clutches	Self-adjusting wet multidisk clutches	Self-adjusting wet multidisk clutches	Power articulated- frame	Power articulated- frame	Power articulated- frame	Power articulated- frame
Power wet-disk	Self-adjusting wet band	Self-adjusting wet band	Self-adjusting wet band	Power wet-disk	Power wet-disk	Power wet-disk	Power wet-disk
406.5 (FB) 427 (TH)	162.6 (loader) 132 to 135 (dozer)	185.5 (loader) 137 to 148 (dozer)	185.5 (loader) 137 to 148 (dozer)	205 (cable) 238 (grapple in transport)	224 (cable) 242.5 (grapple in transport)	248.5 (cable) 266 (grapple in transport)	259 (cable) 269 (grapple in transport)
127.5 (FB) 129.5 (TH)	60 (loader) 72 to 93 (dozer)	66 (loader) 90 to 106 (dozer)	66 (loader) 90 to 106 (dozer)	92.4	103.9	109.4 (cable) 111.5 (grapple)	118.5
36,900 (FB) 41,400 (TH)	12,900 (loader) 10,600 (dozer)	19,650 (loader) 14,650 (dozer)	20,545 (loader) 15,750 (dozer)	14,175 (cable) 16,525 (grapple)	16,675 (cable) 18,675 (grapple)	19,900 (cable) 26,250 (grapple)	26,700 (cable) 31,500 (grapple)
	3 bulldozer blades 3 fork options Winch Integral log arch Fairlead and drawbar	3 bulldozer blades 2 fork options Winch Integral log arch Fairlead and drawbar Shears	3 bulldozer blades 2 fork options Winch Integral log arch Fairlead and drawbar			Reforestation equipment	Auxiliary winch Reforestation equipment

Look to the future with John Deere

Before you buy tree-harvesting equipment you need today, think about tomorrow. You need machines that will grow with your operation; equipment that fits in well with your present show, and the system you envision five or ten years from now.

You have difficult questions to answer. For example, what's the most efficient and economical way to thin plantations? Are you going to shears? What's the best way to get your wood to the landing? Does your terrain call for cable skidding or can it handle the more mechanized grapple? Is natural regeneration falling by the wayside? What machines can you use for high-yield regeneration? All these things can affect your future production . . . and profits.

It's much the same at John Deere. For a number of years, we've been putting a larger-than-average percentage of income into research and development on equipment systems that will help solve your tree-harvesting problems. The results of that commitment are shown not only in the current John Deere line, but also in prototypes of machines that may be a few years down the road. Visit your John Deere dealer today and see what he can do for you.

JOHN DEERE

JOHN DEERE on the move