COFE

Mechanized Harvesting Systems

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REPORT FROM THE SOUTH[1]

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The South is in a period of relatively good business activity in wood products manufacturing. Lumber and plywood business is brisk, and pulp and paper is very strong in both the domestic and export markets. Loggers in the South are heavily mechanized and highly productive. The bobtail truck/manual system producing of 15-20 cords of wood per week is basically a historical phenomenon. Southern loggers are professional businessmen, with harvesting systems capable of producing 500 cords or more of wood per week being commonplace.

Based on a recent American Pulpwood Association survey, pulpwood usage in the South in 1987 was 67.4 million cords, or 71.2 percent of the total U.S. pulpwood production. Of the total southern production 24.9 percent was transported by rail, 72.9 percent by truck, and 2.2 percent by water. Of significance was the fact that 46 percent of the wood transported by truck was delivered directly from the woods to the mill. This is an indication of the current level of mechanization in the South, and possibly points to the reduced dependence of pulpmills on the dealer system for the supply of pulpwood to the mill. Large company crews have been greatly reduced, with independent, contract loggers being responsible for most the production in the South.

SOUTH'S FOURTH FOREST

An evaluation of the South's Fourth Forest was released by the USDA Forest Service in June, 1988. This report is an encompassing study of the evolving forest in the South, and is a description of recent and prospective trends for the timber resource. There were several positive points noted in the report:

1) timber is the most important agricultural crop in the South,

2) employment and income in the forest industries exceeds other manufacturing industries, and

3) the regeneration and growth of the second and third forests were a great achievement.

But, a number of projections were made that should concern southern foresters:

1) net annual timber growth has begun to decline,

2) removals of softwood timber inventory are exceeding annual growth, and softwood net annual growth will not increase until the year 2000, and

3) the South is entering a period of rising stumpage and roundwood prices with potential declines in employment, wages, and salaries in the forest industry.

This gloomy picture can only be rationalized by stating that there are great opportunities to increase forest productivity in the South. Achieving a productive fourth forest will require large increases in technical and financial assistance, research, education, and management programs.

RAW MATERIAL MARKET IMPACT ON TIMBER HARVESTING

A key factor in the wood products market has been international competition, with an emphasis on raw material quality. This emphasis on quality has resulted in numerous changes in the raw material market. The most significant of these changes has been the timber species composition for both solid wood and pulpwood products. In particular, pulpmills are producing higher quality products, which require a larger percentage of hardwood and a higher quality of wood furnish.

Hardwood Resources

Hardwood usage currently accounts for approximately 32 percent of the wood furnish in the South. This high percentage has caused some companies to re-evaluate their timber management plans, and has produced some local shortages of hardwood pulpwood. The shift towards greater usage of hardwood pulpwood has not produced any novel approaches in timber harvesting, but a couple of techniques that failed in the past are being tested once again.

An Alabama pulp company started a "bank wood" program within the past year. Independent cutting contractors are paid to fell and deliver pulpwood in shortwood lengths to the roadside. The wood produced is scaled and payments for production are made weekly. Another contractor specializing only in loading and hauling, transports the banked wood to the mill. This type of system is widely used in the Scandinavian countries, but has not been used in the South in recent times. Several problems that plague small loggers in the South are addressed. Many contractors find it difficult to economically operate on small areas and low-volume tracts; low volume harvesters are usually under-capitalized, and are unable to economically maintain a legal highway truck in their operation. In addition, much of the hardwood pulpwood vollume in the southern U.S. is owned by non-industrial landowners, whose small tracks are difficult to economically harvest with highly mechanized systems. The "banked wood" program has been primarily a success of management. Approximately 15 percent of this pulpmill's requirements are delivered by a producer force averaging only 80 cords per contractor per week. Efforts are being concentrated on clearcuts of low volume, marginally profitable tracts of hardwood timber that are unattractive to high-volume, heavily mechanized harvesting operations.

Scott Natural Resources has developed innovative practices for cultivating harvesting, and transporting the hardwood resource in a large, river bottom swamp. A 40-50 acre patch clearcut system with coppice regeneration is used in conjunction with helicopter logging and barging of treelength hardwood. Felling, limbing and topping is by chainsaw, with a small helicopter used to forward pulpwood stems to the riverbank. This helicopter has a 4,000 lb. lift, and produces approximately 35 cords per hour. All wood produced is barged down the Mobile River by company tugboats. This

[1]Presented at the 11th Annual Council on Forest Engineering Meeting, Saint Foy, Quebec, Sept. 13-14, 1988.

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intensive harvesting system has a low environmental impact on the wetland sites, achieves excellent species regeneration, and produces wood at a cost of $3 to $5 per cord less than conventional logging. For this effort, Scott has received the Forest Conservationist of the Year award from the Alabama Wildlife Federation. There are some real opportunities in both growing and harvesting the hardwood resource in the South.

Chip Quality

Higher chip quality requirements have generated less interest in whole-tree and sawmill residue chips, but have conversely spawned a resurgence in the construction of satellite chip mills by both pulp companies and independent producers. Methods of producing cleaner whole-tree chips are also being explored.

One area currently being evaluated by Mississippi State University and the USDA Forest Service Harvesting Research Unit in Auburn, Alabama is the use of chain flail debarkers in conjunction with whole tree chippers. They have found that the chips produced are of reasonably good quality, with bark contents of less than 2 percent. This system produced no apparent cost advantages to the pulpmill, but there is the potential to revitalize whole-tree chipping with an additional capital investment.

Work on whole-tree chip quality is also being conducted at Virginia Tech. Air separation and deflection systems to remove dirt and bark from whole-tree chips are being evaluated.

Quality in Solid Wood Products

A relatively recent occurrence in the South is the reluctance of sawmills and plywood mills to purchase logs that have been felled by a hydraulic shear. During the past 25 years, hydraulic shears have been replacing chainsaws in the woods, and have produced safer, more productive logging operations. But, shears produce varying amounts of splitting damage or shatter in the butt log. During the past year several major companies have decided to reject sheared logs at their mills because of the economic loss. This is causing independent contractors to evaluate saw-heads for felling, which is boon to sawhead manufacturers, but an additional expense to the logger. Some companies are compensating loggers for this additional expense, and some are not. A study completed in July, 1988 by the University of Georgia has found saw-heads to be generally more productive than shear-heads but more costly to operate. Sawheads also produce a higher stump than shear-heads.

TRUCKING

Efforts towards making trucking safer and more efficient are ongoing at several locations. The American Pulpwood Association in cooperation with forest industry, state cooperative extension organizations, and state forestry associations is conducting a Truck Driver's Workshop. It is a 1-day course aimed at the professional log truck driver. Principles of safe vehicle operation and vehicle inspection are stressed. Several hundred drivers have been through the course.

Trucking efficiency is being studied by Union Camp Corporation in Georgia. They are interested in maximizing log payloads, and have tested loader mounted scales, truck mounted scales, and air bag suspension systems. The air bags operate on driver evaluation of air pressure on the bags as the truck is loaded. Also, air suspension may offer some potential wear savings to both tractor and log trailer.

Many states are experiencing a deteriorating system of roads and bridges, which has an unquantified impact on the performance of truck transportation. The modeling of truck performance as influenced by route, road quality, and driver skills is being studied at Virginia Tech.

SITE PREPARATION

Herbicide application continues to increase as a means of site preparation for regeneration. But, mechanical means are still widely used in many locations for a variety of reasons. Current work is being conducted at Auburn University, University of Georgia, USDA Forest Service Harvesting Research Unit, and Union Camp Corporation. Much of this work is centered around predicting production in terms of site conditions. One of the studies was an evaluation of the rotary rake. This system is more productive than conventional raking operations and produces a very clean windrow. However, some structural problems were experienced with the earlier models. Other new site preparation equipment on the market include a relief bedding plow to reduce maintenance cost and improve effectiveness in areas of rough terrain and high stumps, and a blade plow to reduce competing vegetation and alleviate compaction.

There is a lot of activity in timber harvesting and forest mechanization ongoing in the South. This report has been a cursory review of some of the prominent activities, but should by no means be considered as being all-inclusive.

Western Regional Update[1]

Stephen P. Aulerich, P.E.[2]

HARVESTING

Falling and Bucking

Computers are being used to make bucking decisions in the woods. Buckers in Oregon are experimenting with a hand-held computer to tell them how to buck the most value from a tree (Pacific Logging Congress 1988). In British Columbia, fallers on a helicopter show wear radio headsets and communicate tree measurements directly to a "central controller" operating a desk-top computer in the field (Coulson 1988)[3]. The "controller" analyzes the tree and relays how it should be bucked for value as well as optimum weight considerations for the helicopter. One "controller" can analyze and relay information to approximately 6 fallers.

Yarding

There have been several organizational changes for some Northwest logging equipment manufacturers. Berger and Washington moved into the Skagit Manufacturing facilities in Sedro-Woolley, WA (Skagit Manufacturing Co. 1988). Howard-Cooper will be the exclusive dealer for all three yarder brands. S.Madill has started to sell their yarders factory direct. Danebo, Ductr Manufacturing, and Ross Equipment have moved under one roof and are now Ross Corporation.

There are new interlock swing yarders that can operate under various system configurations rather than just a running skyline mode. Each drum is equipped with an interlock clutch, a pulling clutch, and a band brake allowing control of all drums individually or automatically in the interlock mode. S.Madill and Ross Corporation have recently introduced interlock yarders with this capability. Several 5-drum, medium-sized tower yarders have recently appeared on the market. They range in height from 15 to 21 meters (50-70 feet) and can operate at either height.

Skycars are on the comeback, primarily due to environmental restrictions. Full suspension to protect buffer strips along riparian zones, as well as wildlife tree requirements, mandate the use of carriages which can fly logs above and snake logs around these obstacles. Even the smaller, 20-millimeter (3/4-inch) skyline carriages are becoming more sophisticated. These small, radio-controlled clamping carriages with accumulators are replacing the older style clamping carriages, which utilized a stop on the skyline.

Multispan rigging is becoming common, with several North American carriage manufacturers offering multispan carriages or attachments. One manufacturer has on the drawing board a multispan carriage which will go around a 30-degree corner (Maki 1988)[4]. An Oregon logger is already using a shop-built multispan carriage that can log around a 25-degree corner under certain conditions (Van Norman 1988)[5].

There are now approximately 20 sets of radio-controlled chokers being used (Johnson 1988)[6]. Originally designed for 16 or 20-millimeter (5/8 or 3/4-inch) wire rope, the new radio-controlled bells can be used on 26-millimeter (1-inch) line.

Interest in the mono-cable system is continuing. The Alaska Region State and Private Forestry has purchased a yarder and is demonstrating the concept in Alaska (Wheeler 1988)[7].

Aerial Systems

A logging outfit in British Columbia is perfecting the use of a hydraulic grapple on the end of the tag line of a Sikorsky S61 helicopter (Coulson 1988)[3]. Two pilots with no ground personnel are producing 90 to 100 cubic meters (16-18 mbf) per flying hour in a clearcut situation. The trees are bucked and marked with different colored tags to indicate weight. One or two-piece turns, weighing approximately 3,600 kilograms (8,000 pounds), can be picked up by the 150-centimeter (60-inch) grapple and flown to a landing for processing.

Labor

Strikes are in effect at several Western mills in Oregon and Washington. Unions want to restore the concessions they made in 1986 because of the recession. Some mills have already consented to raise wages to pre-recession levels.

TIMBER SUPPLY

Preservationists

Tree sitters were arrested in August after trying to block the construction of logging roads into some of the Oregon timber which burned during last summer's fires.

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[1]Presented at the 11th Annual Council On Forest Engineering Meeting, Sainte-Foy, Quebec, September 13-17, 1988.

[2]Vice-President, Forest Engineering Incorporated, Corvallis, OR.

[3]Personal communication from Wayne Coulson, Coulson Forest Products, Port Alberni, B.C., August 15, 1988.

[4]Personal communication from Bill Maki, Maki Manufacturing Inc., Pierce, ID, April 8, 1988.

[5]Personal communication from Bud Van Norman, Mt. Reuben Logging Inc., Glendale, OR, September 3, 1988.

[6]Personal communication from Norm Johnson, Johnson Industries Ltd., Richmond, B.C., August 12, 1988.

[7]Personal communication from Eugene Wheeler, State and Private Forestry, USDA Forest Service, Anchorage, AK, July 20, 1988.

A convoy of approximately 1,000 log, chip, and lumber trucks rolled into Grants Pass, OR the end of August to show support for harvesting timber damaged by the 38,850-hectare (96,000-acre) Silver Fire. Preservation groups have stated that little or none of the timber should be harvested.

Preservationists have used the appeal process to delay timber sales and continue to do so. One Forest Service employee on the Siuslaw National Forest estimated that three out of four of their sales are appealed. On the average, it has taken 225 days to decide an appeal at the first level (USDA Forest Service 1988a). The Forest Service is reviewing its current process and has determined that it needs to streamline, simplify, and expedite the process.

Owls

The Forest Service preferred alternative for the spotted owl in Oregon and Washington will prevent logging on 140,700 hectares (347,700 acres) of old-growth and mature forest land considered suitable for timber production (USDA Forest Service 1988b). This equates to a loss of 905,556 cubic meters (163 mbf) per year.

WESTERN REGIONAL COUNCIL ON FOREST ENGINEERING

Third Subdivision of COFE Formed

On December 6, 1987 an organizational meeting of the Western Regional Council on Forest Engineering (WRCOFE) was held in Portland, OR. General guidelines for the organization and potential activities were discussed. It was decided that initial boundaries would be "states west of the Rockies" in order to determine the area of those interested in becoming active members of the subdivision. A voluntary steering committee was formed to plan the organization's activities.

First Meeting

The first event of WRCOFE was a meeting and field trip examining riparian zone management from several perspectives in Oregon and Washington. A total of 81 people attended. The meeting was held in Astoria, OR on June 23-25, 1988.

On the first day, the afternoon session consisted of talks on the Oregon and Washington approaches to riparian zone management, fisheries and wildlife considerations, and the industry viewpoint of riparian issues.

The second day, a field trip to both sides of the Columbia River allowed discussions to continue as well as a chance to view riparian zone management techniques being implemented.

On the third day, the morning session dealt with the forester's or forest engineer's view of riparian zones, what works and what does not work. Audience participation was encouraged, and there was a good discussion on problems and solutions.

The meetings and field trip were open to anyone interested. Industry and government participation were equal, with each accounting for 44 percent. University and student participants accounted for the remaining 12 percent. Only 26 percent of the participants were COFE members. An additional 4 percent became members within one month after the meeting.

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Forest Engineering Research 1988 A Northeast Prospectus[1]

Thomas J. Corcoran, Ph.D.[2]

INTRODUCTION

Three institutions in the northeast sector of North America currently have been accredited by Accreditation Board for Engineering and Technology (ABET) or its Canadian counterpart as forest engineering degree-granting universities. All three have had prominent research programs active during 1988. These universities include: The University of New Brunswick at Fredericton, State University of New York at Syracuse, and The University of Maine at Orono. The following synopses highlight some of their research activities.

NEW BRUNSWICK

OP-PLAN is a decision support system (DSS) for forest operational planning. It is currently being installed at a major Canadian forest-products firm. Modifications are under development to tie short-term planning to long-term strategic planning needs. Linkage of a DSS system like OP-PLAN to harvest scheduling models (like FORPLAN) via geographic information systems (GIS) is contemplated after the installation of a PC based ARC/INFO GIS system.

New tree forms for harvesting and delivery to centralized processing and marketing facilities are under evaluation. A systems engineering approach is being used to analyze compromises between tree-length forms and full-tree forms that can meet long-term priorities for high net market values and optimum forest yields.

Investigations continue into the testing and evaluation of small-scale wood chip-fueled central heating appliances. Technical focus is on improving the reliability and performance of handling systems for particulate biomass fuels. Specifically, the study will address use of a new UKAF Non-Consolidating bin feeder to improve the flow of material in and from hoppers in a cost effective and quiet manner suitable for residential and similar installations.

Operational experiments are underway to compare the effect of site preparation strategies on spruce survival and growth and to assess the effect of soil tillage on soil moisture and temperature as well as on nutrient mineralization. Efforts focus on the questions: "what is the effect of a silvicultural treatment on a site" and "what is the commensurate effect on tree growth". Additionally, the question of timing for precommercial thinnings for maximum growth benefits in black spruce is being explored with time defined in terms of pre-treatment density-size relationships.

Projects into the measurement of labor productivity in non-manufacturing areas such as maintenance and also the productivity of capital are in progress as are studies into the suitability of geotextiles for forest roads, techniques for truck performance simulation and the haul route location by computerized roadbeds. A new initiative looks into terramechanics.

NEW YORK

Remote sensing activities include a project entitled "Assessment of Landsat Thematic Mapper Imagery for Forest Classification." This project has three principal objectives: 1) to investigate the information content of Landsat Thematic Mapper (TM) imagery for forest cover types; 2) to assess the capability of digital TM imagery for computer classification of forest types; and 3) to compare TM and Multispectral Scanner (MSS) imagery for their success in forest classification and analyze the reasons for any differences between the classifications. This work is being done on a commercially available PC based image processing system with additional programming to improve accuracy assessment.

Development of a digital photogrammetric system has progressed with the purchase of an IBM RT PC engineering workstation which provides high speed advanced processing capabilities. This system automatically extracts information about the topography of the ground from a digitized aerial photograph.

Geographic Information Systems (GIS) activity has increased rapidly with the acquisition of ARC/INFO on both a DEC Micro Vax workstation and several IBM PC based systems. Background research and testing is underway to provide an ARC/INFO database for a large experimental forest and eventually for all of the College's forest properties. GRASS (Geographical Resources Analysis Support System), a public domain GIS software package, is being adapted and implemented on an IBM RT PC. Several other GIS packages, grid based, are also available on campus and transfer of data between some of the systems has been achieved.

MAINE

Simulations with computer animation developments include the use of GPSSPC and of SIMSCRIPTS II.5's SIMFACTORY and both as they relate to differing views of the operation and management of woodyard facilities. The woodyard is comprised of the mechanized functions of scaling, unloading, slashing and debarking with multiple-station possibilities for any or all functions. While these animated models are reasonably functional, the detail level can be described as level II. The projected descriptive levels are three in number:

1) FIRST LEVEL - Low recognition, recognizable only to modeler.

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[1]Presented at the Council on Forest Engineering Annual Meeting, September 13-15, 1988, Auberge des Gouveneurs, Ste. Foy, Quebec. Maine Agricultural Experiment Station EPR# 1302.

[2]Executive Chairman, New England Regional Council on Forest Engineering and Professor of Forest Engineering, University of Maine, Orono, Maine 04469.

2) SECOND LEVEL - Moderate recognition, recognizable to those familiar with the system and explainable to others.

3) THIRD LEVEL - High recognition, recognizable to most without explanation beyond the setting of the scenario.

A study has been initiated to analyze factors influencing operability on industrial forest lands. It attempts to aggregate those factors that tend to make industrial forest lands inoperable for timber removals and to devise a logical computer-assisted decision system that incorporates and evaluates the impact of these factors. Among the factors to be examined are the attributes of the forest resource, inplace physical land and terrain features, prevailing economic/market conditions and environmental or regulatory impediment. The study will initially concentrate on landholdings of greater than 10,000 hectares.

An investigation into the use of satellite image processing techniques to inventory the location and distribution of boreal forest communities in north central Maine nears completion. The current thrust is on appropriate techniques to identify broad species composition and stand structure classes. Although conifer dominant and hardwood dominant stands can be identified with acceptable accuracy, the mixed stands with their inherent diversity pose greater challenges for development of innovative computer analysis strategies.

The Resource Information Management and Spatial Analysis Laboratory (RIMSAL) has been actively developing a Geographic Information System (GIS) since 1978 and is associated with the National Center for Geographic Information Analyses. It has developed a line-intersection, polygon-based geographic information system for large-scale mainframe and mini-computers. It is linked to the Informix relational data base for tabular information. Research activities have concentrated on the identification and elimination of errors propagated during data entry and data set overlay. Sources of errors are statistically identified and quantified, allowing the user to modify his analysis procedures to minimize error propagation. The Maine Geographic Information System (MeGIS) also produces national mapping output mapped products that conform to National Mapping Standards. MeGIS also contains an extensive library of resource inventory packages to assist in the updating of mapped products. MeGIS was officially adopted by the Ministry of Forestry of the People's Republic of China in July 1988 as the GIS for national forest resource inventory and planning.

A Regional Report of Forest Industrial Activity in the Lake States[1]

John A. Sturos[2]

Abstract: The U.S. forest industry is investing its record profits in the Lake States by continuing to expand existing plants or by erecting new ones. The forest products industry has recently invested $2.2 billion in Michigan, Minnesota, and Wisconsin.

Keywords: industrial expansion, economics, utilization, forest products, employment, capital investment

These are boom times for the $85 billion U.S. forest products industry. It earned a record $4.6 billion on its paper operations in 1987, and profits may grow another 25 percent in 1988 (Levine 1988). The forest industry in the Lake States shares a part of these record profits and continues to expand (Thompson and Sturos [1988], Sturos [1987]). More than $2.2 billion has been invested in 1987 and 1988 to expand and/or build new plants in the three Lake States.

MINNESOTA INDUSTRIAL ACTIVITY

In Minnesota, $1.42 billion of capital investment has been committed to new or expanded forest product plants in 1987 and 1988. This compares to $911 million invested in the forest products industry from 1977 to 1986.

Most of the investment in Minnesota has been made by the following companies (Minnesota Forest Industries, Inc. 1988):

- Lake Superior Paper Company, Duluth - $440 million (pulp)
- Blandin Paper Company, Grand Rapids - $350 million (pulp)
- Boise Cascade Corporation, International Falls - $525 million (pulp)
- Potlatch Corporation, Bemidji - $45 million (waferboard)
- Potlatch Corporation, Cloquet - $100 million (pulp)
- MacMillan Bloedel, Inc., Deerwood - (waferboard).

The $525 million project by Boise Cascade Corporation is the largest of its kind ever in Minnesota. It includes modernization and expansion of the pulp and uncoated white paper mill at International Falls (The Timber Producer 1988d), construction of a new bleach plant, and a new 345-inch trim paper machine. The increase in paper production will be 300,000 tons per year, bringing the total production to 510,000 tons per year. The new paper machine is expected to start up late in 1990.

MICHIGAN INDUSTRIAL ACTIVITY

In Michigan, the forest products industry continues to expand. Six major investments are as follows (The Timber Producer 1988a, 1988e):

- Champion International, Inc., Quinnesec - $300 million (pulp)
- Louisiana-Pacific Corporation, Sagola - $35 million (waferboard)
- Scott Paper Company, Muskegon - $120 million (pulp and paper)
- K.I. Sawyer Air Force Base, Gwinn - $16 million (power plant)
- Viking Energy, Inc., McBain - $27 million (power plant)
- Viking Energy, Inc., Lincoln - $27 million (power plant).

The $300 million project by Champion International at Quinnesec involves a new paper machine to be built adjacent to the recently completed $500 million pulp mill. It will provide 100 new jobs, bringing the total employment at the pulp and paper complex to 400. Construction is scheduled to begin in the fall of 1988 with startup expected to be in the fall of 1990.

The use of wood as fuel for electrical generating plants has become big business. After installing its first 16.5 megawatt power plant in Pennsylvania several years ago, Viking Energy, Inc. has two identical plants coming on line in Michigan in early 1989 at McBain and Lincoln.[3] The company is already accepting wood at both locations where 180,000 green tons per year of chips, sawdust, and/or hog fuel will be burned. Viking Energy plans four more power plants of the same 16.5 megawatt size at Onaway, Roscommon, Newaygo, and Ionia for a total capital investment in Michigan of $162 million.

In addition, Mead Corporation is conducting a feasibility study on the installation of another new paper machine at its pulp and paper mill at Escanaba. Several large pulp and paper companies are also considering a new pulp mill at a site near Baraga. Several smaller investments have been made in the solid wood products category and secondary manufacturing of furniture, flooring, fencing, lumber, etc. One example is the $1 million sawmill by Connor Forest Industries at Wakefield. Direct and indirect employment in Michigan's forest products industry has increased by 10,000 since 1980 to a total of 154,000 (BeVier 1988).

There has been corresponding growth in employment for woods workers in Michigan. Membership in the Michigan Association of Timbermen (MAT) has almost doubled in the last 5 years from 400 to 720.[4] MAT represents primarily small logging and sawmill companies.

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[1]Presented at the 11th Annual Council on Forest Engineering Meeting, Ste. Foy, Quebec, Canada, September 13-15, 1988.

[2]Principal Mechanical Engineer, Forestry Sciences Laboratory, North Central Forest Experiment Station, Houghton, MI.

[3]Personal communication from Larry Hiebel, Viking Energy, Inc., Midland, MI, December 5, 1988.

[4]Personal communication from Peter Grieves, Michigan Association of Timbermen, Newberry, MI, December 5, 1988.

WISCONSIN INDUSTRIAL ACTIVITY

Wisconsin still leads the country in paper production as it has since 1953, amounting to 4.2 million tons per year (The Timber Producer 1987). Activities in Wisconsin include the following (The Timber Producer 1988c):

- Chesapeake Corporation, Menasha - $148 million (pulp and paper)
- Wausau Paper Mills Company, Rhinelander - $40 million (paper)
- Wausau Paper Mills Company, Brokaw - $20 million (pulp)
- Consolidated Papers, Inc., Wisconsin Rapids - $96.7 million (pulp and paper)
- Biewer Lumber Company, Prentice - $15 million (sawmill)
- Kimberly-Clark Corporation, Whiting - $25 million (pulp and paper)
- Weyerhaeuser Company, Rothschild - $18 million (paper)
- Pride Manufacturing Company, Florence - $2.5 million (miscellaneous wood products).

In addition, a feasibility study is underway by Pentair-Niagara of Wisconsin for a $300 million modernization and expansion at its pulp and paper mill at Niagara. It will increase production of its coated publication paper by 40 percent, to a total of 320,000 tons per year. Pulpwood consumption is expected to increase by 30 to 50 percent.

LOGGING EQUIPMENT UPDATE

A new development in the logging equipment area is the recent purchase of Gafner Machine, Inc., of Gladstone, Michigan, by Valmet Corporation of Finland. The new company, Valmet-Gafner, Inc., will become Valmet's logging division headquarters in the U.S.--its first U.S. venture. It will also develop an export market for Gafner products. Valmet is expected to conduct research and development in Gladstone, modifying its equipment for North American markets. Gafner Machine, Inc. has annual sales of $6 million and has 62 employees. Valmet, Inc. has 17,000 employees and sales in excess of $1.8 billion.

There have been several other developments. Barko Hydraulics of Duluth, Minnesota, has purchased the Melroe Bobcat feller/buncher line. In the past year, D&D Manufacturing, Inc., of Escanaba, Michigan, introduced its new Silver Streak tree harvesting/processing head that uses chain saw felling before the tree is delimbed and bucked in a horizontal position. D-C Equipment, Inc., Menominee, Michigan, has introduced a medium-size, tracked DC490D feller/buncher (The Timber Producer 1988b). Gafner Machine, Inc. (now Valmet-Gafner, Inc.), Gladstone, Michigan, has begun marketing their new Tri-Trac feller/buncher (Andrews 1988).

SUMMARY

Some of the major forest products companies are experiencing their best performance since 1974 with record earnings and 16 percent return on equity (Levine 1988). They continue to recognize the Lake States as a viable region in which to make major new capital investments.

Besides the abundant timber resources and proximity to major markets, another reason for the industry's interest in the Lake States is the support it obtains from state and local governments. All three state governments cooperated in sponsoring the "Upper Great Lakes Governor's Conference in Forestry" in 1987. An outgrowth of that conference is the Lake States Forestry Alliance, which promotes further cooperative work among the three Lake States to encourage additional forest industry development. The Alliance also serves as a liaison with Congress on forestry issues.

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FOREST MECHANIZATION TRENDS IN EASTERN CANADA[1]

J.-F. Gingras[2]

ABSTRACT

Forestry machines are undergoing rapid changes in response to a changing physical, social and economic environment. This text examines the trends in logging equipment population over the last decade. As well, concurrent progress in system productivity is discussed and forecasts on future machine evolution are presented.

KEYWORDS: Logging, mechanization, productivity, forestry equipment.

With the introduction and the evolution of mechanized harvesting equipment, man-day productivity in the forest has increased seven-fold since the early days of logging. Despite this progress, forest machines are still undergoing rapid changes in response to a changing physical, social and economic environment. For example, large fleets of company-owned machines have been largely replaced by smaller scale, privately-owned machines on many operations. As well, growing concern for environmental protection, multiple use of the resource and forest renewal has altered the logging practices of the past.

This text will examine trends in logging equipment population by comparing the fleet of machines of 39 company divisions at work in the mid-seventies to that of the mid-eighties. As well, it will look at the evolution of productivity of generic harvesting systems over the same period. Finally, based on current economic, social and legislative conditions, predictions will be made as to which machines are expected to be preferred and how these will need to change to face the new challenges of the Canadian forestry environment.

TRENDS IN HARVESTING SYSTEMS

Changes in the proportion of wood brought to roadside, in the form of shortwood bolts versus tree-length (delimbed at the stump) or as full trees, provide an excellent background to understand the increasing or decreasing popularity of particular machines and systems. Figure 1 compares the proportion of wood cut under the three systems in 1977 and 1986.

In less than a decade, the popularity of the tree-length system has dropped almost by half with a corresponding shift towards full-tree to roadside operations. As a result, many cut-and-skid operations were converted to fell-and-skid operations where delimbing is performed at roadside instead of in the stump area. This shift is also reflected by the significant population increase of feller-bunchers and feller-forwarders. The shortwood system now only represents about 12 percent of the harvest and this results mainly from the progressive retirement of Koehring shortwood harvesters.

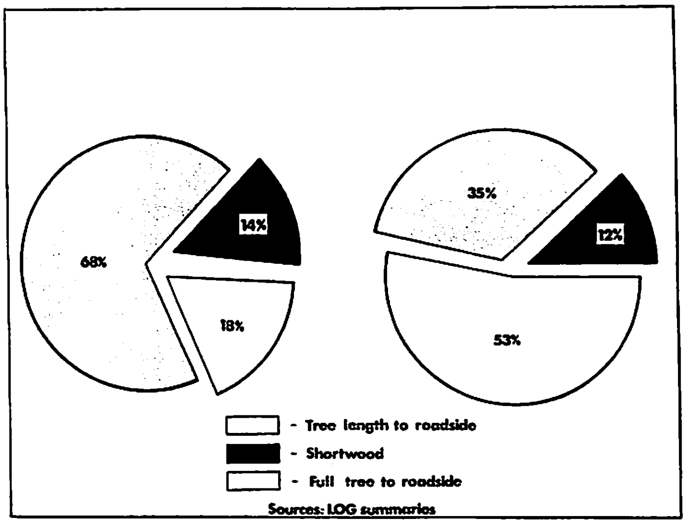

Figure 1. Evolution in harvesting systems, 1977-1986 (Eastern Canada).

Based on a sample covering a yearly harvest of about 14 million cubic meters (39 companies), the following sections compare the type and the number of machines at work today compared to those of a decade ago.

TRENDS IN FELLING/HARVESTING EQUIPMENT

Figure 2 illustrates the population variation of felling/harvesting machines since 1977. Feller-bunchers have achieved the most spectacular progress since the mid-seventies with numbers increasing by 240 percent. During this period, felling head designs and machine controls have improved to the point where productions of 200 trees per hour are not uncommon. Most are equipped with accumulator arms which provide multiple-stem cutting capabilities facilitating proper bunch size to maximize system productivity. Circular saw felling heads, both high-speed/low torque and low-speed/high torque designs, are now dominating shear felling heads in new machinery purchases because of mill requirements for damage-free stems at competitive costs.

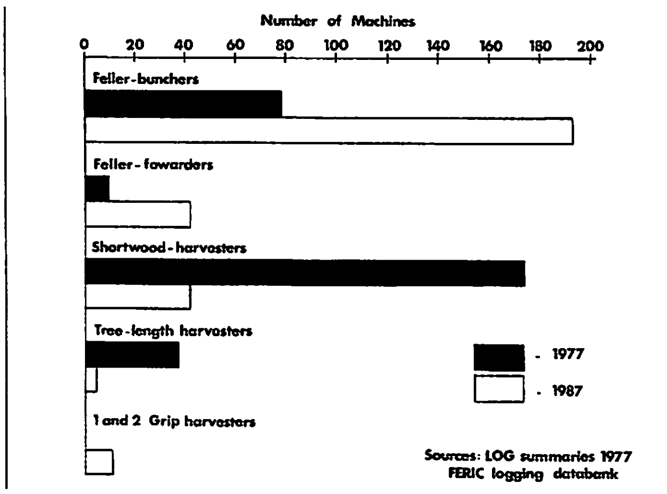

Figure 2. Trends in felling/harvesting equipment, 1977-1987.

[1]Presented at the 12th Annual Council on Forest Engineering Meeting, Quebec, Que., September 12-13, 1988.

[2]Supervisor, Wood Harvesting Group, Forest Engineering Research Institute of Canada, Pte Claire, Que.

Feller-forwarders have also increased in popularity because of their high productivity and low manpower requirements. However, their number is expected to stabilize because of their high capital and operating cost and the limited amount of terrain where they can be operated to their full potential.

Mechanized tree-length harvesting systems have become nearly extinct with the discontinued use of tree-length harvesters. However, the introduction to Canada of Scandinavian 1 and 2-grip harvesters may signify a comeback for the mechanized tree-length and shortwood system as these machines fell and delimb at the stump. If required, they may also top and buck stems to specified lengths. Further, the need to do away with roadside piles of delimbing residues and the desire to protect advance regeneration are fueling the development of domestically-designed feller-delimbers. These machines are conventional stroke delimber configurations equiped with a light, chain-saw felling head and are currently undergoing field tests.

Finally, since money-tight owner/operators are increasingly involved with forest harvesting, low-cost feller-director heads which can be fitted on light-duty excavator bases are being introduced. These systems represent an intermediate step between the manual fell & skid and the full-scale feller-buncher/skidder system of larger operations.

TRENDS IN SKIDDING/FORWARDING EQUIPMENT

Skidders and forwarders are now required to move farther, faster, haul bigger loads and cross rougher ground then ever before. Because of this, the larger and more powerful skidders are being favored by many owner/operators. In our sample (Figure 3), it can be seen that few skidders of less than 75 kW (100 hp) are still being operated. Most of these are now being used in small-scale and woodlot applications, or have been converted as service-type vehicles. Concurrent to the increase in the quantity of trees felled mechanically, cable skidders have often been adapted to sling bunches with longer chokers of 3 to 5 meters, (10 to 16 feet) building loads containing anywhere up to 5 bunches. Loads of 3 to 5 cubic meters (1.2 to 2.1 cords) are not uncommon with these configurations.

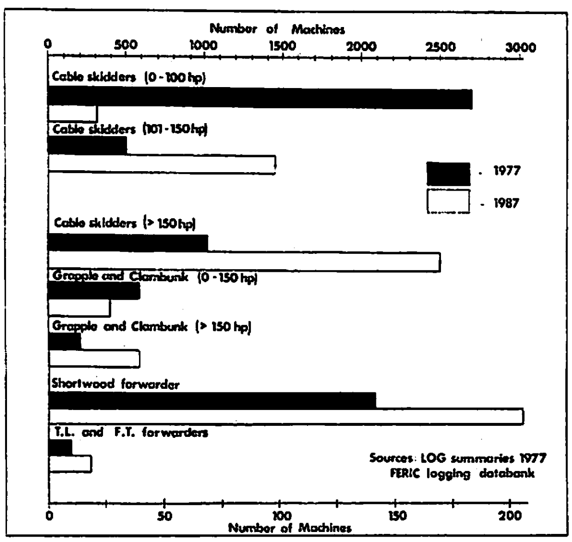

Figure 3. Trends in skidding and forwarding equipment, 1977-1987.

The total number of grapple and clambunk skidders has remained fairly constant although a shift to larger machines has been noted.

Although grapple skidders are, in theory, better adapted to handle bunches, the rough or wet ground conditions frequently encountered in eastern Canada limit their utilization. However, skidder manufacturers have indicated that grapple skidder currently represent their most active market. Some recent developments such as inexpensive grapple retrofits for cable skidders and swing-boom grapples may prove popular and increase the quantity of wood skidded with grapple-type skidders. Increasing concern for operator safety and comfort also favor the adoption of grapple or clambunk skidders.

Clambunk skidders have gained limited acceptance in areas of high road building costs because their large payload of 10 to 15 cubic meters (4 to 6 cords) allow for a long skid distance, and, as a result, increased spacing between roads.

Large tree-length and full-tree forwarders are not used to any great extent because of their cost and the fact that there is seldom a necessity to provide clean raw material to downstream processing except for a few full-tree chipping operations. There are however, a large number of pulpjack-type shortwood carriers. These machines are flexible and affordable to the small contractor and have proven popular in the Atlantic provinces.

TRENDS IN PROCESSING EQUIPMENT

Along with the shift towards full-tree logging to roadside, a significant amount of processing (delimbing, bucking, chipping) is being done at roadside. As can be seen in Figure 4, the number of stroke delimbers has increased by 500 percent in the past 10 years and their numbers are expected to continue expanding as more cut-and-skid operations are converted to fell-and-skid. Many stroke delimbers are now equipped with length measuring devices along with butt and top saws which give them interesting processing capabilities.

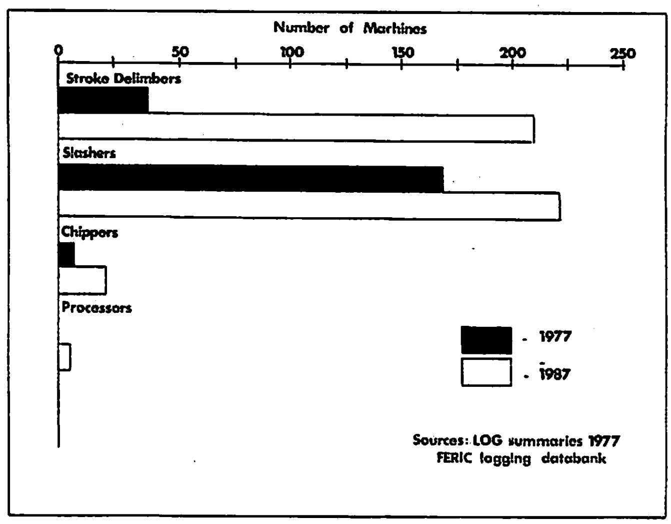

Figure 4. Trends in processing equipment, 1977-1987.

The number of roadside slashers has increased slightly in recent years, showing a 23 percent rise over the 1977 population in our sample. While less and less wood is harvested under the shortwood system, either mechanical or motor-manual percent the load configuration on haul trucks has not shifted proportionally to tree-length loading. Since about half of the wood is still trucked in cross-wise loaded shortwood form, there is still a high demand for roadside slashing.

As the forest resource gets further away from the mills and deteriorates in quantity and quality, there is growing interest to convert trees directly into chips to maximize fiber recovery from a given area. For this reason, both roadside and off-road chippers are an expanding market. As well, since many pulp and paper mills now use sawmill chips as their primary fiber source, obtaining chips from the woodlands operation would allow these mills to phase out costly wood handling facilities in their yard. There is growing interest to produce bark-free chips directly in the forest and a few delimber-debarker-chipper installations are being looked at in various locations.

Finally, as mentionned previously, a few Scandinavian processors which delimb and buck at the stump are being examined in certain areas, especially those with small wood conditions and where full-scale mechanized operations are unsuitable.

TRENDS IN SECONDARY TRANSPORTATION EQUIPMENT

Because of their complex infrastructure, transportation systems have not undergone changes to the same degree as harvesting operations. Figure 5 illustrates the changes in the methods for transporting the wood fibre to its final utilization point.

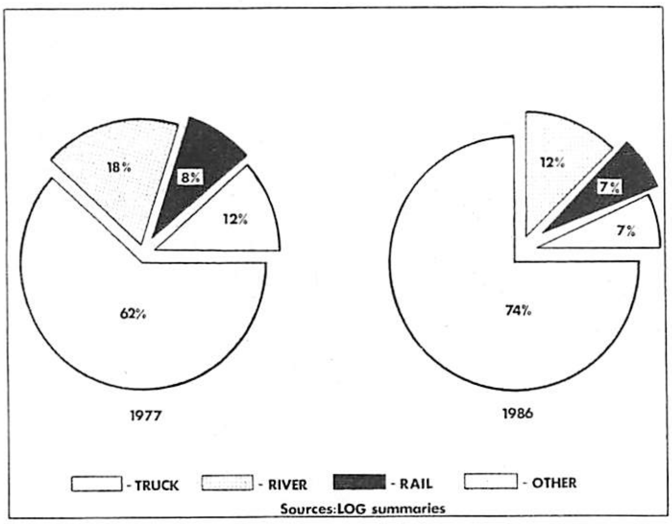

Figure 5. Trends in transportation systems, 1977-1986.

By far, trucking is the most common way to transport the wood. In fact, it should be noted that 100 percent of the wood is trucked for a part of its journey to the mill. All other systems, including rail, barge, flume or river drive, have been declining in popularity. This trend is expected to continue because of the flexibility of trucking and its lower infrastructure costs over other modes of transportation. There is also growing environmental pressure to stop water-based wood transportation. Scheduling problems, uncertainty over rates and accessibility to rail networks is reducing the interest towards rail transportation. Finally, an increasing amount of fiber is expected to reach the mills in the form of chips for pulp mills and tree-length for wood processing mills.

EVOLUTION OF SYSTEMS AND MACHINES PRODUCTIVITY

To this point, trends in the degree of utilization of the various machines and systems over the past decade have been examined. During the same period, the productivity of these machines and systems has also increased. Figure 6 provides the current picture of how the forest is harvested in eastern Canada. The evolution of productivity of the various systems is given in Table 1.

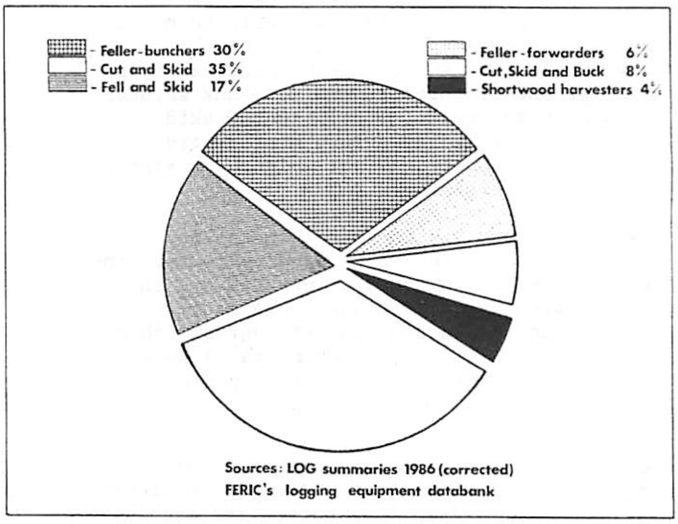

Figure 6. Wood harvesting systems in eastern Canada, 1987.

Table 1. Evolution of productivity of harvesting systems[1] (1975-1985)

System		Productivity (m^3/man-hour) 1975	1985
Shortwood	• manual	1.0	1.2
	• mechanical	4.2	4.9
Tree-length	• cut & skid	2.0	2.9
	• mechanical	3.1	few in use
Full-tree	• fell & skid	1.9	3.3
	• feller-buncher/skidder	3.0	9.1
	• feller-forwarder	9.3	15.1

[1] source: FERIC

Improvements in design, hydraulic circuitry, maintenance techniques and operational planning have generally increased the man-hour productivity of most harvesting systems. The adoption of bigger, more powerful skidders has increased productivity of cut-and-skid and fell-and-skid operations. Mechanical availability of harvesting machines has increased because of technological improvements, design simplifications, but also because the majority of the equipment are now run by owner/operators. Mechanical felling productivity has generally increased with the introduction of machines designed specifically for harvesting rather than modifications to existing construction or mining equipment.

CHALLENGES OF THE CANADIAN LOGGING INDUSTRY

Changes in the socio-economic and legislative environment related to forestry operations have implications as to how harvesting may be conducted, which machines will be preferred and how these should be modified to adapt to changing conditions.

For example, in most provinces, forest companies now have the responsibility of putting harvested areas back into production. This entails closer integration of the harvesting and silvicultural operations, as well as modifications to current logging techniques and machines. Thus, we can expect to see machinery designed to minimize site disturbance and protect advance regeneration (Heidersdorf, 1987). For example, the use of feller-forwarders minimizes the number of machine passes required to harvest a given area. Feller-bunchers with longer, possibly telescopic booms to increase swath width may be introduced on the market. Wide tires on skidding equipment can help to minimize ground disturbance and clambunk skidders can be used with systems of widely-spaced skid trails. General weight reductions of forestry machines through the use of light-weight yet strong alloys can also be expexted.

Owners of forestry machines feel increasing responsibility towards the safety and comfort of the operators. Therefore, ergonomic improvements in cabs and controls should continue to be made, possibly catching up to Scandinavian standards within a few years. In parallel, an improving marriage of electronic and hydraulic circuitry is expected (Sauder, 1987).

Because of the shift to owner/operator machines over company-owned equipment, the overall complexity and maintenance requirements of harvesting machines should decrease. Standardization of components would also be improvement in this respect.

Finally, the industry must face the challenge of a resource diminishing in quality, accessibility and quantity. The equipment will need to compensate lower raw material specifications by higher productivity. In this context, increasing emphasis is expected for example in the areas of multiple-stem delimbing with flails, production of bark-free chips in the woods, and further down the road automation, computer controls and robotics.

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THIS IS DOMTAR[1]

I. Scott[2]

Abstract: This presentation is a review of the major business activities of Domtar, a predominately forest products oriented company. This Canadian Company maintains most of its manufacturing facilities within Canada, but with some in the United States. Sales are concentrated in the North American market with a limited volume overseas.

When you read a newspaper, shake salt on your food, open up a shipping container, or add a room to your house, chances are good you're coming into contact with Domtar. That's because this widely diversified corporation produces pulp & paper, packaging, chemicals and construction materials, products which are part and parcel of our daily lives.

Domtar is present in some 80 locations throughout North America reaching from the forests of northern Quebec to the California coast. It markets hundreds of products in Canada, the United States and around the world. With over $2.6 billion in annual sales, 16,000 employees, 18,000 shareholders, it ranks among the top 40 most important manufacturing companies in Canada.

HISTORY

The corporation saw the light of day in Sydney, Nova Scotia in 1903 with the establishment of a coal tar plant, and which was called the Dominion Tar and Chemical Company Limited. Over the next two decades, it diversified into wood preserving and construction materials. Changing hands in 1929, it moved into new fields, particularly industrial and consumer salt and gave major focus to the expansion of its construction materials side. In the 1960s, it became a leading Canadian pulp and paper producer through the acquisition of Howard Smith Paper Mills Limited, and St. Lawrence Corporation Limited. In 1964, a brand new kraft-pulp mill was built at Lebel-sur-Quevillon in Northern Quebec.

In 1965, the name was changed to Domtar Limited. In 1978, shareholders adopted the name Domtar Inc. by which we are known today. The organization has continued to grow and develop through strategic expansion and acquisitions. While sales and operations are predominantly Canadian, with domestic markets accounting for 67 percent of our total sales of almost $2.6 billion, Domtar functions as a truly North American corporation.

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[1]Presented at the 12th Annual Council on Forest Engineering Meeting, Quebec City, Canada, Septembre 14, 1988.

[2]Superintendent of Services, Domtar Forest Products, Montreal, Canada.

OPERATING GROUPS

The company is composed of five operating groups, and these include:

1. PULP & PAPER GROUP

Sales (1987)	$1,070 million
Percent of total sales	42 pct

This is the biggest operating group and makes Domtar one of Canada's most successful pulp and paper producers. There are three subdivisions within the group:

a) Fine papers
b) Newsprint & kraft
c) Forest Products

a) <u>Fine papers</u>

Domtar is Canada's leading manufacturer and marketer in this field and supplies more than 500 grades in a wide variety of finishes, colors, weightsand sizes.

The following breakdown shows the range and scope of the different products:

1) Business papers
2) Printing papers
3) Forms, bond papers
4) White and kraft envelopes
5) Exercice tablets
6) Cover and text report papers
7) Computer printout paper

The divisions manufacturing base consists of two high output integrated mills in Cornwall, Ontario and the newly rehabilitated mill in Windsor, Quebec. There are three other smaller mills located in Quebec and Ontario, producing specialized grades.

b) <u>Newsprint & Kraft Pulp</u>

1) <u>Newsprint and Groundwood Specialty Papers</u>
Domtar supplies newsprint to large and small newspapers, principally in the United States and Canada. Its higher value-added groundwood specialty papers, available in a range of grades, are used mainly in paperback books, newspaper inserts, brochures and magazines. The groundwood and newsprint grades are produced in two integrated mills in Quebec and one in Ontario.

2) <u>Kraft pulp</u>

Domtar's market pulp mill in Quebec produces bleached and semi-bleached kraft pulp from high-density softwoods. This facility supplies other Domtar mills with an integrated source of softwood pulp, with almost 40% of output used for that purpose. Approximately 60% of the Domtar market pulp sold to other paper producers is exported to the United States and offshore markets; the balance is sold in Canada.

c) Forest Products

Domtar has four modern sawmill complexes making it one of the largest manufacturers of lumber east of the Rockies. These sawmills have the capacity to produce, on an annual basis, 470 million board feet of studs and random-length lumber. More than 70 pct of this production is exported to the United States.

The Forest Products Division is also responsible for the supply of the wood fibre requirements of Domtar's seven pulp and paper mills.

2. CONSTRUCTION MATERIALS

Annual Sales (1987)	$787 million
Percent of total sales	30 pct

Domtar is a leading North American manufacturer and marketer of a diversified range of construction materials including Gyproc gypsum board, high and low pressure laminates known as "Arborite" and "Cladboard" as well as insulation and roofing products to name just a few.

3. PACKAGING GROUP

Annual Sales (1987)	$456 million
Percent of total sales	18 pct

The manufacture and marketing of corrugated containers, composite cans and containerboard comprise the principal business of this Group. Domtar Packaging is highly integrated, producing its own linerboard and corrugatingmedium from virgin and recycled fibers at three paper mills.

a) Corrugated Containers

Domtar holds a substantial share of this market from coast to coast. From its diversified products base, the Packaging Group sells to thousands of customers with some 50% of sales directed towards the food industry and related product areas.

b) Containerboard

Domtar is the largest Canadian supplier of linerboard and corrugating medium used in the manufacture of corrugated containers.

c) Recycling

Waste paper salvage operations are a viable source of a cost effective alternative to virgin wood fibre in containerboard manufacture.

4. THE CHEMICALS GROUP

Sales (1987)	$248 million
Percent of total sales	10 pct

The business base of this Group is derived from an extensive line of salt products, pressure-treated wood, specialty chemicals and coal tar products.

5. THE ENERGY GROUP

Sales (1987)	$7 million
Percent of total sales	less than 1 pct

Domtar is engaged in programs to explore and develop oil and natural gas reserves in southern Alberta. The supply of some of its own energy needs from these sources is being planned.

Fiber Supply

The Corporations pulp and paper mills annually require 3.1 million bone dry tons of raw material (approximately equivalent to 3.1 million cords). This volume is made up of 87 pct softwood fibre and 13 pct hardwood. Domtar harvests half of this on its own timber limits or through supply contracts with provincial governments. The remainder is purchased from marketing cooperatives, local farmers and jobbers in the form of logs, and from independent sawmills as chips sawdust and shavings.

Domtar owns approximately 1,570 square miles (406,800 hectares) of forested land, chiefly in the provinces of Ontario and Quebec. Some areas are also owned in Maine and New York state.

It holds forest management agreements (FMA's) and licenses from the Province of Ontario covering approximately 1.6 million hectares or 6175 square miles.

The corporation also harvests timber in the Province of Quebec where cutting rights are now subject to annual renewal under the terms of new legislation. The latter also includes the provision for timber allocations and management agreements, commonly known as CAAFS, but which still remain to be negotiated.

Forest Management

The corporation acknowledges that its forest resources are essential to the continued pursuit of its business activities. Forest management is based on the fundamental principle of sustained yield, thus providing for a steady supply of raw material to the mills.

The maximum volume harvested must not exceed the annual growth, less an allowance for losses from insects, diseases, fire, etc. Domtar has developed an intensive management program for all of its privately owned Ontario and Quebec woodlands as well as the publicly owned Ontario holdings. In Quebec, new plans will be developed following negotiations of the CAAF agreements.

In recent years Domtar has increased its silvicultural activities to speed regeneration on cutover forest lands. When natural regeneration does not take place after a major disturbance such as logging or fire, artificial reforestation is undertaken.

In Ontario, through the implementation of Forest Management Agreements (FMA) with the Provincial government, Domtar is moving ahead rapidly with its program for reforestation of cutover lands. All cutover is now subject to treatment of some kind, if it is necessary to ensure adequate regeneration. Exceptions are made for untreatable areas such as very wet sites or unusually shallow soils where natural regeneration must be relied upon. Depending upon the geographical location, the percentage of the cutover requiring treatment can vary between 20 and 75 pct. To achieve our overall goal of forest renewal, 8,000,000 trees are being planted this year in Ontario and Quebec by Domtar.

With the introduction of Bill 150 and CAAF's in Quebec, a surge is foreseen in reforestation practices to achieve adequate stocking of recent cutovers.

Both Provinces have programs to treat the backlog areas of non-sufficient regeneration (NSR) in former cutovers. Again exceptions can be made for untreatable areas such as very wet ground or unusually rough mountainous or inaccessible terrain.

On its own or in conjunction with industry or government organizations, Domtar has become involved in a range of silvicultural research programs, including the development of fast-growing superior tree species, improved planting techniques and tree farming.

The primary function of Domtar's woodlands is to produce wood fibre. However, provisions are built into the management plans for multiple use of the forest.

As an example, cutting practices have been modified to protect deer yards in South-East Quebec and cutting patterns have been planned to allow for moose corridors in the more northerly regions of the Corporation's holdings. Specific logging methods, such as strip, gap or checkerboard cutting are applied to protect environmentally fragile sites.

From a multiple use point of view, Domtar woodlands operations permit access to many non-profit sports and other organizations. In some instances, private lands are leased to appropriately structured groups and used by them for such activities as fishing, hunting and cross-country skiing.

Windsor Project - Quebec

Domtar first acquired an interest in the Windsor paper mill in 1963. It was the oldest of its kind, and had been making paper since 1859. Because of its age and the obsolete condition of its equipment, the mill could no longer comply with the latest government environmental standards. Studies showed that the investment needed to bring the existing mill up to date, while keeping it at the same site, would be so great that it never would be economically viable. The alternative was a major rehabilitation program, involving a fine papers complex on a new site covering 75 hectares (183 acres) at a projected cost of $1.2 billion and to be developed in two stages. This was the option chosen by Domtar.

Start-up of Stage I was completed in late 1987 with full commercial production from the first machine in mid 1988. Stage II includes a second machine with production planned for Spring 1989. Total annual production from the complex is planned at 350,000 short tons. This will allow Domtar to consolidate its leadership in the domestic and international markets and to meet the growing demand for fine papers used in the office, such as letterhead stock, computer printout sheets, reproduction paper, and a wide variety of other grades.

For the Windsor complex, where the existing infrastructures were inadequate, new facilities were provided with the construction of access roads, railroad spur lines, and connections for the energy needs of the new facility.

Domtar is investing more than $20 million to develop and implement a training program for some 625 mill employees, so as to prepare them to carry out their functions in a new work environment based on state-of-the art technology.

Harvesting Techniques

In recent years, most of Domtar's logging operations have become mechanized to a high degree. The feller buncher and the roadside delimber have replaced most of the men with powersaws on the ground. The use of the cable skidder is still widespread although more use is now being made of grapple skidders and forwarders. Three of our six operating locations now deliver the wood in tree length form to the mills.

Where restricted by public highway regulations, loads must conform to permitted weights and truck dimensions, but when transporting on company roads, advantage is taken of the heaviest equipment available. Gross vehicle weights vary from 125,000 lbs - 700,000 lbs, with payloads ranging from 20 - 100 cords. To unload these large volumes of tree length being delivered to our mills, heavier equipment such as portal cranes are utilized which can unload a truck in two passes.

Road construction is a major expenditure in the production of wood products. To harvest the 55 percent of its annual requirements obtained from its own operations, Domtar must construct several hundred miles of road each year as well as maintain a very extensive network of existing roads. In the actual construction, widespread use has been made of more effective and cost efficient equipment such as the backhoe and off-highway articulated trucks.

Conclusion

In concluding my talk today, I hope that you now have a better understanding of your host company for Demo 88 and that this will help to make your stay in Quebec both more informative and interesting.

Modeling the Obstacle Performance of Cable-Towed Vehicles[1]

Bruce R. Hartsough, Chengxian Gao, John A. Miles and Andrew A. Frank[2]

Abstract: We studied the forces required to pull wheeled vehicles over idealized terrain obstacles. Scale models and computer simulations were used to evaluate the peak forces for single-axle vehicles equipped with a) rigid wheels, b) pneumatic tires and c) rimless spoked wheels. The results from the scale model and simulation differed for the pneumatic tires, due probably to differences in assumptions. These assumptions need to be verified. The scale model showed that spoked rimless wheels required relatively high towing forces. The computer results indicated that towing forces could be reduced by 90 percent in some situations by using low pressure tires instead of rigid wheels. Even with low pressure tires, it is probably not economically feasible to pull vehicles over obstacles larger than approximately 1/4 the wheel diameter.

Keywords: tethered vehicles, simulation, timber harvesting, yarding

Vehicles towed or tethered by cables have been suggested for various forest operations on steep slopes (Gonsier, 1980; McKenzie and Richardson, 1978; Schenck, 1968). Tethered rollers were employed for site preparation in New Zealand (Larson and Hallman, 1980) and one cable-towed device was tested for yarding timber (Biller and Gibson, 1978).

We are investigating towed vehicles, represented by the concept shown in figure 1, for transporting prebunched small timber on steep terrain. Earlier modeling work indicated that, when compared with conventional running skyline systems, cable-towed vehicles might reduce yarding costs by approximately 1/4, with greater reductions on less steep terrain and in areas with low deflection (Gao and Hartsough, 1988).

Obstacles, including stumps, slash, rocks and abrupt breaks in slope, would impede the travel of a towed vehicle. Loggers can reduce the size of or completely remove some obstacles, and others can be avoided by steering around them, but vehicles will have to traverse some obstacles. To properly design a vehicle for logging, we must know how various vehicle configurations perform when traversing obstacles.

[1]Presented at the 12th Annual Council on Forest Engineering Meeting, Sainte-Foy, PQ, September 13-17, 1988.

[2]Assistant Professor, Postgraduate Researcher and Professor, Agricultural Engineering Department, and Professor, Mechanical Engineering Department, University of California, Davis, CA 95616.

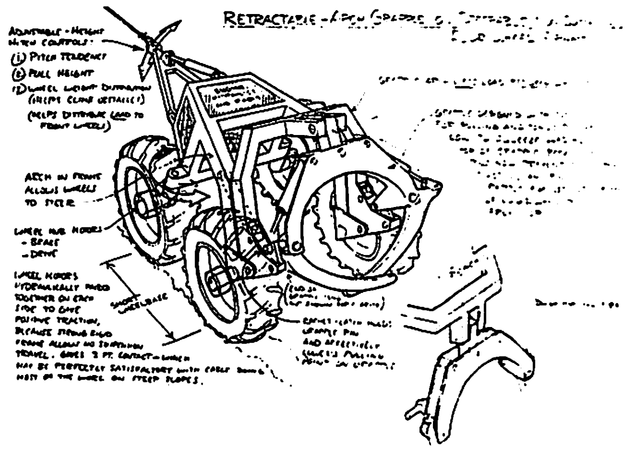

Figure 1--Cable-towed vehicle concept.

Previous research evaluated the obstacle performance of self-powered tractive vehicles. Bekker (1956) theoretically investigated the abilities of two-axle vehicles to traverse obstacles, based on the assumption of rigid wheels and rigid suspensions. He included obstacle height, wheel diameter and coefficient of adhesion as independent variables. His results indicated the largest obstacles that could be traversed by a given vehicle, assuming that torque was not limiting. Jindra (1966) extended Bekker's study to permit the analysis of towed trailer effects on the obstacle performance of four-wheel drive vehicles, again using the assumption of rigid wheels. Janosi and Eilers (1968) looked at the problem of hangups, where the vehicle frame bottoms out on the terrain. They only considered the geometry of the vehicle and the ground surface. None of these studies determined the forces required for towed vehicles, nor did they evaluate the effects of using low pressure pneumatic tires in place of rigid wheels. As low-pressure tires are becoming more widely used in forestry applications, and have apparent advantages when traversing obstacles, we need to extend the previous work to tires and other promising concepts.

APPROACH

We used computer simulation and scale models to study the towing forces required to pull both wheels of a single-axled vehicle over an idealized obstacle consisting of a right-angle step (fig. 2). We considered three types of wheels: a) pneumatic-tired, b) a rimless, 6-spoked device which might "walk" over obstacles (fig. 3) and c) a rigid circular wheel as a standard for comparison.

Scale models were used for all three types. Rigid and rimless spoked wheels of 6" diameter were fabricated from plexiglass, as were the step obstacles of various heights. Pneumatic inner tubes of 8" diameter were used as models for the pneumatic tires (fig. 4). The vehicles were towed by a variable-speed electric winch. Tension in the towing cable was monitored by an Interface SM-100 strain gage load cell placed between the cable and vehicle, while a string potentiometer measured the distance moved by the vehicle as it traversed the step. The data was recorded by a Campbell Scientific CR10 datalogger and downloaded to a microcomputer for analysis. The test stand and data collection setup is displayed in figure 5.

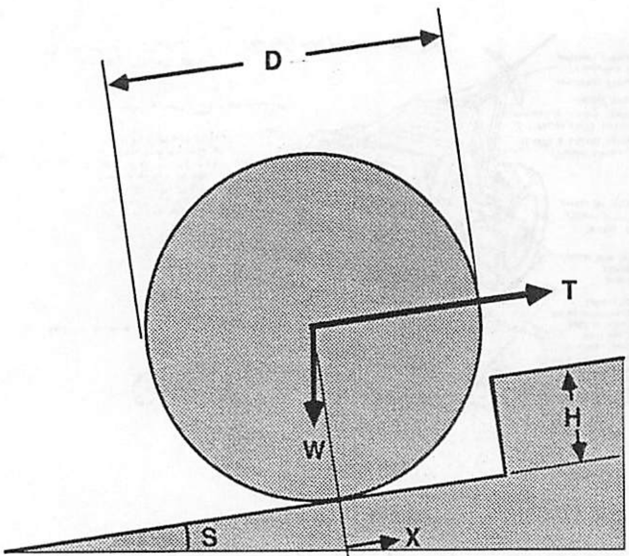

Figure 2--Obstacle and wheel geometry and forces.

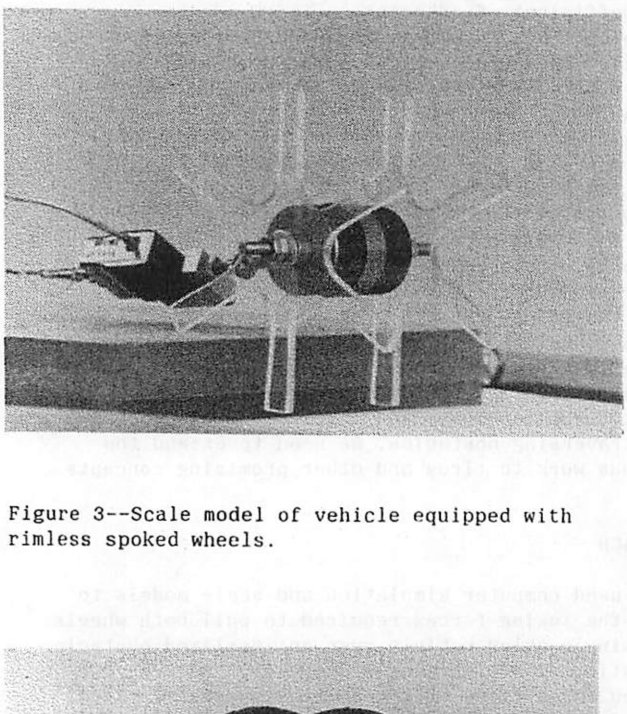

Figure 3--Scale model of vehicle equipped with rimless spoked wheels.

Figure 4--Scale Model of vehicle equipped with pneumatic tires.

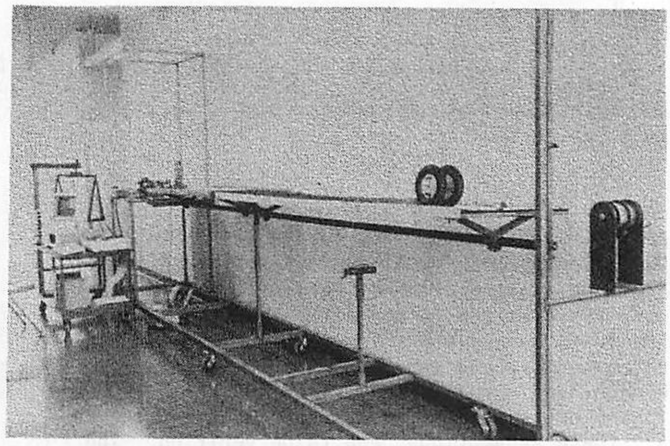

Figure 5--Test stand and data collection equipment.

Computer simulations, based on static theoretical analysis, modeled vehicles with rigid and pneumatic tires. The analysis for rigid wheels was straightforward, resulting in a single relationship to estimate the peak towing force. That for pneumatic tires was more complex. We assumed that the tire had a rectangular cross section of constant width, even when deflected, which resulted in a contact area with the ground that was also rectangular. The ground pressure was assumed to be the same as the tire air pressure. Governing equations were derived using the principle of virtual work, and required an iterative solution approach.

The analysis included several variables. Those for the terrain were:

H height of the step obstacle
S ground slope

and for the wheels:

D diameter
w width
X displacement of the axle, along the slope, from an initial position D/2 from the edge of the obstacle
p inflation pressure
W total weight on each wheel
T towing force required per wheel

These were combined into four dimensionless ratios. The three independent ratios were:

H/D obstacle height:wheel diameter ratio
W/pwD tire flexure index (zero for rigid wheels)
X/D travel distance:wheel diameter ratio

and the dependent variables were:

T/W towing force:weight ratio
MAX T/W the peak value of T/W as the wheel traverses the obstacle

RESULTS

For rigid wheels the scale model gave results which closely approximated those from theory (fig. 6). This indicated that bearing friction and rolling resistance for the scale model were negligible.

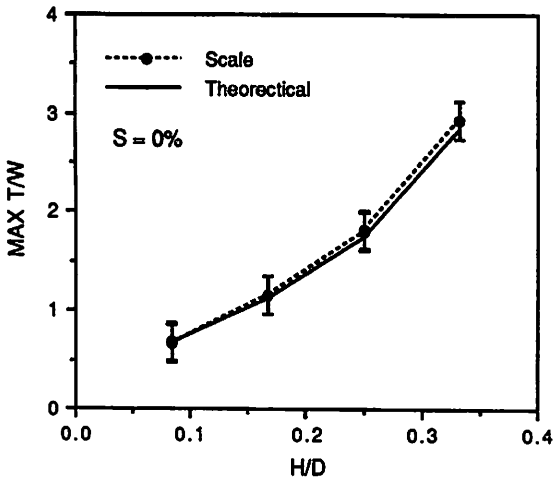

Figure 6--Comparison of maximum towing forces for vehicle with rigid wheels, theoretical versus scale model.

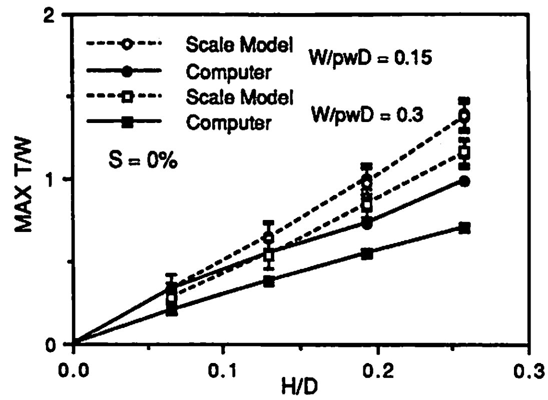

Figure 8--Comparison of maximum towing force results for a vehicle with pneumatic tires, computer simulation versus scale model.

For pneumatic tires, the computer and scale models did not agree as closely (figs. 7 and 8). In most situations, the scale model indicated a higher towing force for a given set of conditions. This may be partly due to rolling resistance, but we expect that another factor accounted for most of the differences. The cross section of the scale model tire was round, while the assumption for the computer simulation was a rectangular section. The two behave somewhat differently when crossing obstacles, and we expect that a real tire is an intermediate case between the scale model and computer simulation.

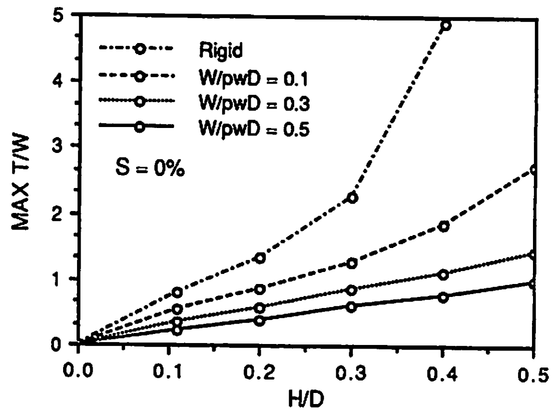

Figure 9 -Maximum towing force results from computer simulation for a vehicle with pneumatic tires, with slope = 0 percent.

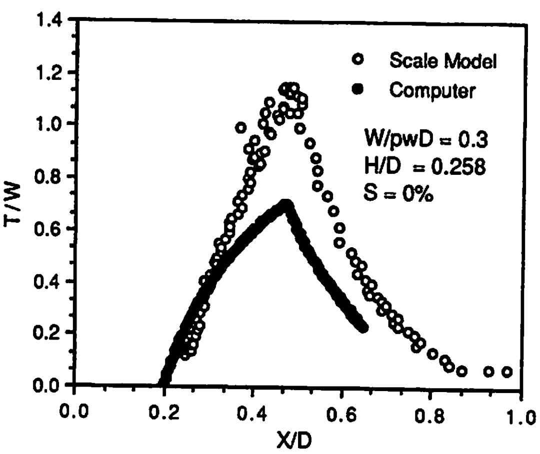

Figure 7--Comparison of towing force traces for a vehicle with pneumatic tires, computer simulation versus scale model.

We compared rigid wheels and pneumatic tires over a wide range of conditions (figs. 9 and 10). The computer model predicted that use of a relatively soft tire (W/pwD = 0.5) would reduce towing force requirements drastically (e.g. by 90 percent for H/D = 0.4 and S = 0 percent) when compared to those for a rigid wheel of equal diameter.

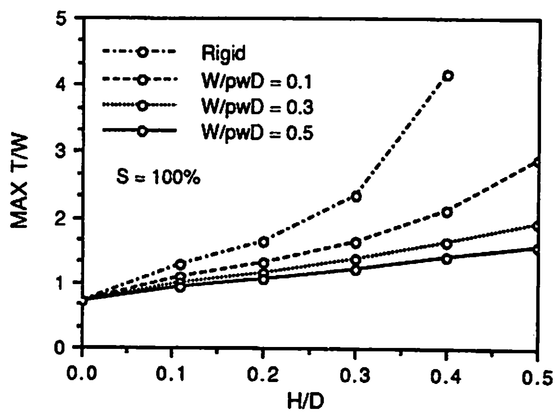

Figure 10--Maximum towing force results from computer simulation for a vehicle with pneumatic tires, with slope = 100 percent.

The model rimless spoked wheel was able to traverse obstacles that were theoretically not possible to climb with a rigid wheel, but towing force requirements were relatively high for small obstacles and even on flat ground (fig. 11). This was due to the climbing motion of the vehicle after each spoke contacted the ground.

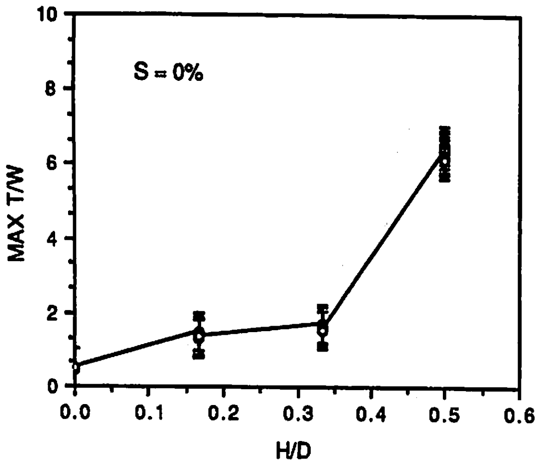

Figure 11--Maximum towing force results from scale modeling for a vehicle with rimless spoked wheels, with slope = 0 percent.

CONCLUSIONS

The work by Gao and Hartsough (1988) showed that, for a cable-towed vehicle to be economically practical, the towed force:weight ratio should not exceed approximately 1. (The maximum feasible value depends on the specific conditions and how they affect the economics of the alternative cable systems.) For a vehicle with rigid wheels operating on a 50 percent slope, this indicates that the largest obstacle be no larger than 1/10 of the wheel diameter. The ratio of H/D can be no larger than 1/10 for a rimless spoked wheel, even on flat ground. A low pressure tire can operate on a 50 percent slope with an H/D of up to 1/4, so pneumatic tires are clearly advantageous for cable-towed vehicles. Avoiding large obstacles, either by removing them or by steering around them, appears to be critical for practical operation. Supplying torque to the wheels would reduce the pull requirements, but overuse of tractive power could result in excessive soil disturbance.

The relative validity of the computer simulation and the scale model for pneumatic ties should be determined by comparing the results with those from tests of a full-size model.

Acknowledgement: This material is based upon work supported by the U.S. Department of Agriculture Competitive Grants Research Office under Agreement No. 86-FSTY-9-0198. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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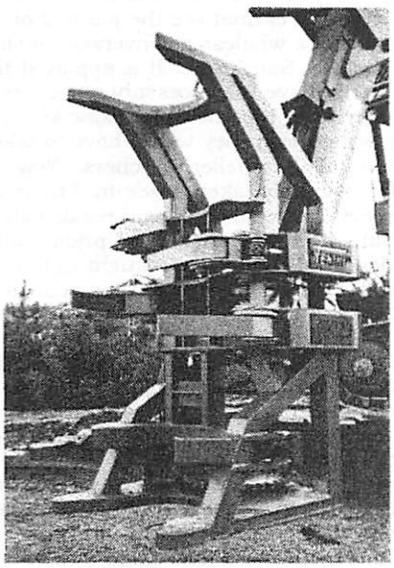
Title[1] High Torque Disk Saws

Author[2] Chuck MacLennan

Thank you Mr. Bellemore. Good afternoon, Ladies and Gentlemen. Welcome to Quebec City and the beautiful outlying area. You will have an opportunity over the next few days of seeing probably the single largest collection of forestry-related equipment in North America, live and in living colour.

Turning to address my paper's subject of High Torque Disk Saws, I am of the opinion we should expand the heading to reference the characteristics of high rim speeds and the intermittent rotation of the disk on demand. Therefore, the principle difference between the two disk saw concepts is that of **on/off** versus **constant** revolutions or rotation.



Tenco TC 223 Intermittent Disk Saw

That might be the principle difference technically, but from an operational point of view, the only thing the two principles have in common is they cut or saw trees. Each concept has its features, advantages and benefits. As well, each has its shortcomings or limitations. It therefore follows that we should be able, after analysis, to determine the disk saw principle most suited for a particular harvesting environment and circumstances.

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1 Presented at the Council on Forest Engineering Meeting, Quebec City, Canada, September 14, 1988.

2 President, Tenco-Cives, Inc., Division of Cives Manufacturing Corporation, Roswell, GA

My colleague, Daniel, bestowed upon you the benefits of the high speed inertia disk, so I will not attempt to repeat or rehash them at this time. Now, I know most of you who think you know me believe I am just "champing at the bit" to let'm have it, but you are going to be disappointed. You will see, I believe, that each principle has its distinct characteristics, and that they should determine the application.

High Torque Disk Saws– *RotoSaw* from Grand-Prairie, Alberta; and *Tenco* from Gouverneur, New York and Montreal, Canada. Both companies manufacture several models to adapt to both boom and front mount applications. From the small trees of the Boreal Forest, to the large, tall timber of the West Coast, there is a model of saw engineered within that framework and for those specific purposes.

Characteristics

The characteristics of the High Torque Disk Saw are the following:

1. The disk only rotates during the cutting mode.

2. These felling heads in general, in line with the size of timber they are designed to handle, are lighter in weight than comparable inertia disk saws. You will note I left out the reference to high speed. We make both principles and the disk saws rotate within 200 to 250 R.P.M. of each other. Therefore it's not reasonable to say one is high speed, as it implies the other is slow. Today's high torque disk saws are definitely not slow.

3. Consumption of energy or the generation of heat is substantially lower with the on/off High Torque Disk Saw---as much as 50 horsepower or 1-1/2 to 2 gallons of diesel an hour. They negate the requirement of special radiators to cool the oil that would be constantly circulating under pressure. Now, some high inertia hydraulic systems are more efficient than others and those using variable displacement motors do not generate nearly as much heat, as they do not take the hydraulic system over system relief every time they cut a tree and drop some of their R.P.M.'s.

4. Capital costs of the tractor or felling machine normally are substantially lower (anywhere from $10,000 to a maximum of $30-$50,000) because they do not require special pump drives, coolers and the need for the machines to be of a larger class to hold onto the weight and torque of the inertia disks.

5. Operating Costs– Certainly not the least consideration for anyone wishing to remain profitable in today's competitive marketplace. The debate over which principle is cheaper to operate has raged for years. In my view, the principles are at opposite ends of the spectrum. A disk that only rotates during the cutting mode obviously is less exposed to rocks, abrasion and wear-out (gyroscopic effect) than a disk that turns continuously. It therefore follows that if the ground is rocky and difficult or if the tractor requires

the use of the felling head to negotiate the terrain, then the risk of impacts and consequent costs would be less with the intermittent disk. Remove the terrain considerations, and I believe the operating **costs per hour** would be very similar, one principle versus the other.

If you have ever worked directly on one of these felling saws, you would appreciate what a time saving convenience it is to be able to manhandle or carry the repair components. All of the large manufacturers offer mechanically replaceable and, in some cases, rebuildable cutting teeth. This in itself covers most of the need for in-shift repairs. Without a doubt, the single largest cost per hour is the maintenance of the cutting edge. If the edge deteriorates, quality cuts suffer, energy consumption rises, heat rises and productivity falls off. No matter what saw principle, simple, inexpensive cutting teeth are a must, in my book.

If I didn't emphasize it before clearly, I was talking **cost per hour** and not necessarily **cost per volume,** or cost per cord. Introducing the volume question really heats up the debates. I have some personal beliefs but they are feelings, impressions, not really substantiated by concrete facts. There is an intermittent saw at Donahue St. Felicien in the Lake St. John sector about 300 miles north of here that produced the most wood per feller on their limits last year. I might add, it was on a relatively small carrier. In Quebec, normally we are of a mind that big is better.

I am deviating. Volume. If there is one other single differentiation between the two principles, it's in the **locating time** it takes for the high torque principle. By locating time I am referring to the time it takes to position the head up to the tree, close the grappling arms around the tree without clamping it (because if the tree is clamped, the saw will bind during cutting, requiring the grapples to be released and the saw sequence to be repeated. This is all very time-consuming!). Complete the actual cutting of the tree, and then secure the tree with the grapple arms prior to maneuvering to dump or repeat the cycle. Whether it takes one second, let's say, for the inertia disk to sever a tree or if it takes 3 seconds for the intermittent disk, this only amounts to approximately 6 percent at the end of a 10-hour shift and 1200 trees.

Therefore, to be as productive as a high speed inertia saw, what is required of an intermittent saw is a reduction in the locating time tree to tree! We believe we have accomplished this with our exclusive **trap arm!** The trap arm ensures the tree is contained within the frame of the felling head without actually touching the tree. It **traps** the tree until such time as the two grappling arms of the accumulator are activated to firmly hold the tree or trees to the frame. We use a trap arm on the new generation Tenco saws with the back to front cutting action and on our high speed inertia disk model as well. The trap arm concept is a substantial step forward in safety as well.

I don't mean to be sidetracked and go into a long-winded sales speech, but safety, liability and the general operation of any saw is inherently very dangerous. They are taking down trees of great and awkwardly-distributed weight, on a wide variety of terrains, and are attached to and powered by a wide variety of carriers. The greater the energy stored in the disk, the greater the potential hazard. Safe operating procedures must be worked out—preferably with the carrier manufacturers—and every reasonable means used to ensure their safe use.

Back to **Cost per Volume.** You can see there is no one standard, pat answer for everyone's conditions. Under the best conditions and with a balanced feller and felling head, the inertia disk is a very productive tool indeed. Alter the terrain and/or apply some volume constraints on the contractor and one has to question the economic rationale.

6. Convertability/Adaptability—I guess because of my education and banker's background, I tend to be dollar-orientated. Maybe it's because of my Scottish heritage. In any event, I cannot see the parking or wastage of capital that a wholesale conversion to saws would entail in the U.S. Southeast. It is apparent that a lot of loggers do not have the necessary resources to finance these larger feller bunchers, let alone stand the depreciation write-down they would have to take on trading in their old shear feller bunchers. New equipment dealers will only take a trade-in if there are reasonable prospects for resale and said resale can be effected at a profit. Otherwise distressed pricing will prevail and the logger is going to get caught in the middle. Doomed if he doesn't trade but too poor to do anything about it.

Enter the high torque disk. In one form or another both *RotoSaw* and *Tenco* operate similar to a man with a chain saw in his hands. If we lean on our disks or push/feed them too hard, our disks bind and stall. We meter the feed speed to the density of the tree being cut. Larger trees take more time to sever than smaller ones. It is also true that the more hydraulic power or torque available, the faster the cut. Inversely, small front mount or boom tractors can be used as carriers provided all-out production of 4000 trees per shift, etc. is not the goal. Carriers such as the Hydro Ax 411/511, Franklin 105, Cat 518, etc., make quite acceptable saw feller bunchers with no—I repeat, no—modifications to their carrier hydraulics. The cutting cycle, instead of 3 seconds, might be 6 seconds. Still half the time it used to take a 20" shear blade to sever an equivalent tree. And for less than one-third the capital cost of a new tractor.

7. Risk Return-Revenue Potential—I would like more money for what I do. Heaven knows I am worth every penny. So, too, would every logger or forest products company involved in this business. Disk saws maximize the product yields, allowing better hygrading of timber and producing higher value end products. Board feet instead of chips.

Unfortunately, disk saws cost more money to buy and, what's worse, more money to operate. Either the logger has to get more revenue per volume or he has to be able to deliver the increased volume these disks produce. An increase in total revenue, to support his added costs of operation.

Efficiency dictates a reduction in the number of loggers, with these remaining producing more volume to the point of maximized economy of scale. Capital requirements and maintenance practice will weed out the inferior operator over time.

Today's capital intensive logging jobs require year-round work and steady cash flows to support the obligations of capital. Proper scheduling by forest products companies is mandatory if they wish to retain competitive costs and efficient logging crews. I don't need to tell you the single largest variable in the manufacturing cost of product is the cost of fiber to mills. One sure way to stabilize this cost is to work with and understand your contractor's situation.

To summarize— High Torque or High Inertia? There is no single right answer. We produce both We make felling attachments. I believe generally that the High Torque On/Off Disk Saw is advantaged in bad ground or steep slopes. The high speed inertia disk is advantaged on the plains of the U.S. Southeast where there is very little rock and reduced opportunity for impacts. A balance-harvesting unit producing the required volume is another factor. Both principles have survived for over 5 years, meaning— they are here to stay.

In the future we may well be felling trees with lasers. Change is the only constant. Productivity will demand optimized solutions.

I compare the two disk saw principles to golf. High inertia is like driving for show, while the high torque is similar to putting for dough. Sometimes it's easier to use an approach shot than try and blast your way onto the green from 300 yards out.

Thank you and I look forward to meeting with you during the show.

DENIS' DELIMBERS AND DIRECTIONAL FELLING HEAD[1]

Roger Legault[2]

Abstract: Since the beginning of forestry mechanization, several methods and products have been developed. Some of them have immediately proved to be reliable values, such as stroke delimbers. Over the years, delimbers were improved to become real multi-purpose machines for the forest operator.

Felling operations are mechanized as well. The directional felling techniques offer to the worker profitability, while keeping in mind the importance of forest regeneration.

Indeed, the need to protect forestry resources involves new restraints in terms of equipment. An attempt to reach the new targets of forestry policies: the feller-delimber.

FOREWORD: OVERALL VIEW OF EQUIPEMENTS DENIS INC.

Denis' enterprise was established in 1946, in the small village of Barraute, Québec, where Jean Denis opened a blacksmith's shop. Twenty years later, his son joined him to create an incorporated society: Equipements Denis Inc.

Since then, the Company continued to grow and became, with no doubt, the most important manufacturer of stroke delimbers in North America.

The Company changed a lot. The head office is now located in St.Hyacinthe, Québec, with a branch office in Kamloops, B.C. Sales representatives cover the national and international markets. Denis' products are sold on the five continents.

Equipements Denis is a subsidiary company of Le Groupe Denis which is also involved in sawmilling equipment with Swecan International, located in Lanoraie, Québec.

THE PASSAGE TO THE MECHANIZATION

During the 1960's and 70's, as we all know, the logging industry went through various stages of mechanization. Changing from the hand operated chain-saw for delimbing trees to equipment was a major step for the logging industry.

The enterprises mechanized their delimbing operation for several reasons. In many areas, good qualified manpower was hard to find, and the increased demand for fiber created a need for equipment that would produce more wood with less people. There was also a reason of safety. An operator could produce more while sitting in the comfort and safety of a machine as compared to running a chain saw under adverse weather conditions, and finally there was the economics of the whole thing. Delimbing several small trees at the same time as compare to single stem delimbing was more profitable.

Stroke delimbers were introduced in the field and since then more than a 1000 units have worked and are still working in the forests of North America, Australia, New Zealand and Europe.

THE STROKE DELIMBERS

There are basically two kinds of stroke delimbers. There is the single piece boom that we find in lengths of 50 or 60 feet, and the telescopic delimber. The basic principle of a stroke delimber is to grab the tree by the butt and to slide the delimbing head along the stem, knocking the branches off untill the right topping diameter is reached, and then to pile the delimbed tree at roadside.

The boom is activated back and forth by a hydraulic motor connected to a sprocket that turns on the drive chain of the boom. The boom is supported by a cable system to prevent excess flexing of the boom.

The telescopic stroke delimber works basically under the same principle than a one-piece-boom delimber except that a secondary boom slides in the main boom. The small boom is activated by a system of pullies and cables. The major advantages of the telescopic delimber are the increased delimbing speed and the reduction of the machine tail swing.

Adaptation of carriers to delimbing operation

Delimbers can be installed on both wheeled or tracked carriers. Carriers have to be of a certain size. Minimum weight of 45,000 pounds. They need to have a minimum requirement of 110 H.P. and have minimum hydraulic capacity of 55 GPM pump.

Now, an excavator has to go through a series of modifications in order to be adapted to its new task and to the forest ground conditions.

First of all, the machine has to be modified hydraulically and electrically for better energy distribution for the various functions of delimbing. Often counterweights have to be added to increase stability of the units. In many cases, an extra fuel tank is used as counterweight giving at the same time greater autonomy. Plating under the engine and port swivel has to be fitted to prevent sticks from damaging the various components of the machine. Finally, other features such as catwalks, wood troughs mounted on bearings, "quick access" doors, cab pressurizers and cab protection contribute to the operator's comfort and safety and facilitate maintenance.

Every different make of carriers, being different from each other, undergoes a rigorous engineering study. The modifications are designed for each case to obtain a perfect delimber/carrier combination. For example, in designing a pivot for a new carrier, certain criterias have to be respected.

1. The distance between the butt plate of the delimber and the tracks of the machine has to be of a minimum of 18". Delimbed stems do not pile

[1]Presented at the Annual Council on Forest Engineering, Ste.Foy, Québec, September 14, 1988.

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up on the carrier.

2. The`working position angle of the delimber has to be 40° or more to increase work efficiency close to the machine.

3. And finally, piling height: a distance of 144 inches from the ground to the base of the carriage has to be respected.

Evolution of delimbers

Delimbers like everything else go through a series of modifications during their evolution. Many features were added to the original designs, making delimbers more efficient.

The first Denis delimbers introduced in the 70's were model "T" delimbers. This model has a fixed butt plate and a tree deflector. It was designed to delimb short trees in Eastern Canada and United States. Today, the model "T" is still very popular where trees do not exceed 60 feet and delimbing can be done in single stroke.

The models "K" and "KS" were introduced to answer the demand of the loggers of the West, where trees are generally larger. A need for a quick way to bypass the trees brought the design of a delimber with sustaining ring capable of delimbing unlimited lengths.

Then the series 2000 was introduced. This model features an articulated base boom allowing fast and easy change from the working to the transport position. All functions are activated from the operator's station. The 2000 model is prefered when frequent moves of the machine are required on public highways.

Finally, this year the series 3000 was introduced: a funnel type delimber, a unit that regroups major features of the other models, a funnel type integral structure that allows the repositioning of the delimber closer to the center of gravity of the carrier for better weight distribution and less strain on the components.

Our goals in the series 3000 is to combine two types of delimbers into one series, one common base boom for the telescopic and the one piece boom delimber.

More than delimbers...

Several options can be added to both telescopic and single piece boom delimbers, converting them into multi-purpose machines.

For example: the development of the topping saw allowed for topping of larger diameter trees without any fiber damage.

By fixing a trimming butt saw on the carriage, it becames possible to eliminate butt rot right on the job, thus avoiding costly and unnecessary transportation.

With these new devices, it then became feasible to process wood at roadside. This function became really efficient when electronic measuring devices were developed. "High tech" measuring device with encoder, decoder and readout system ensures a reliable and precise log measurement.

The new 3000 series represents another step towards optimization of delimbing operations. It is the result of every effort made to develop the "perfect match" between delimbers and carriers.

DIRECTIONAL FELLING

Traditional mechanized felling methods

Felling machines, just like delimbers, have gone through many changes during their evolution. Different size machines, undercarriages, boom lengths, protection packages and felling heads have been tried in the forests of Canada and United States.

The most common way to mechanically harvest trees in North America today is with a feller-buncher, a machine that will cut a tree, accumulate several small ones if necessary and then bunch them in a group for further skidding to roadside. As we all know, most of the trees felled today have to be cut with a saw felling head.

Now, for a machine to be able to accomplish all the various functions of felling and bunching, and at the same time have sufficient power to run a 6000 pounds saw felling head, you need a big machine. You need at least 50,000 to 75,000 pounds of iron, H.P. and hydraulic power to accomplish these functions. All this power means dollars: a minimum investment of $400,000 to half million dollars before you can even think of felling trees.

Directional felling

There is different way to put trees on the ground: directional felling, a method that has been used for years in Scandinavia but has not yet been fully introduced and tried in North America.

By directionally felling your trees, large or small, you can reduce the size and weight of your felling head, you can reduce the size of your carrier thus reducing your investment and your operation cost.

Let's compare the two different systems. For the purpose of this study, we compared a 21 inches cutting capacity directional felling head mounted on a 15,000 pounds tracked carrier with a 21 inches cutting capacity disc felling head mounted on a 50,000 pounds machine.

	DIRECTIONAL	FELLER-BUNCHER
Compare HEIGHT................	9 feet	...... 11 feet
Compare WIDTH.................	8 feet	...... 10 feet
Compare GROUND PRESSURE........	4 psi	.... 6 psi
Compare CUTTING CAPACITY...	21 inches	.... 21 inches
Compare FUEL CONSUMPTION.....	1,3 gph	...... 6,5 gph
Compare INVESTMENT..........	$145,000	..... $400,000
Compare COST PER YEAR.......	$160,000	..... $360,000
Compare COST PER TREE..........	$0.53	.... $0.63

As you can see, the cost per tree shows a $0.10 advantage per tree for the directional felling head on mini-excavator.

This short comparison is not meant to downgrade the family of large fellers-bunchers but only to show that directional felling heads have their place in this logging industry and that they are profitable.

Directional felling heads with small carriers offer other advantages that cannot be neglected even though it is difficult to assess a dollar value to them.

1. Lighter carriers will operate in swampy terrains and deep snow where larger machines will have difficulties.

2. Lighter carriers will also create less ground disturbance than the heavier machines.

3. Chain saw cutting with directional felling heads will not damage the regeneration as much as the "swater type" disc cutting heads.

In a near future, Denis will add to the actual D-55 (21 inches cutting capacity) two new directional felling heads: a 12 inches cutting capacity head for felling of small trees and plantation thinnings, and a larger cutting capacity head designed to cut the larger hardwood and softwood up to 32 inches. Mechanical felling of large diameter trees growing on the step slopes of Western Canada and U.S.A. will then be possible.

FELLER-DELIMBER

Government policies orientation

Now that we covered separately the subject of stroke delimbers and directional felling heads, let's look at what we get when we combine the two different machines: a feller-delimber.

New government policies and company regulations lead us to think that a larger percentage of forest will be harvested in the future in a different way that what is the most common today in U.S.A. and Canada. There seems to be a greater interest in delimbing or processing at the stump.

The feller-delimber

For the past year, Denis has been testing a new concept in the northern woods of Quebec. By adapting a 21 inches directional felling head to a shortened telescopic boom delimber, it becomes possible to cut and delimb trees directly at the stump.

Let's look at a few advantages of a machine of this type.

1. First of all it eliminates logging residues at roadside.

2. The machine has a 35 feet boom reach which means that a 70 feet swatch can be cut.

3. The distance between skidding trails can be increased therefore reducing ground disturbance.

4. A better protection of the regeneration can be expected due to less travelling and movements of the carrier.

5. The machine can create a mat of branches and tops in front of its tracks therefore has the possibility of harvesting wet and soft grounds.

6. Skidding or forwarding behind the machine will be improves due to bigger loads.

Denis will continue testing and developing this unit throughout the remainder of the year.

CONCLUSION

What can we expect of the forest industry tomorrow? Forest harvesting methods are in constant evolution, the needs of the loggers change accordingly. The forest equipment manufacturers must be attentive to the needs of the industry in order to propose the adequate tools.

To keep a close relationship with the industry has always been an important factor of Denis' philosophy. We intend to continue applying this philosophy, to pay attention to your evolution and to manufacture machines ahead of the requirements of the forest workers.

Forestry Tire Trends[1]

R. N. Klaas[2]

Abstract: Since the 1960's rubber tired equipment used in forestry application has grown in usage. The purpose of this paper is to review tire trends that have already been experienced and to review future trends that we see developing.

Tires used on forestry equipment have made and continue to experience significant changes. The primary usage has been with conventional tire sizes, however, we are now seeing flotation tires gaining in popularity and the concept of duals being evaluated. Our purpose in this paper is to follow some of the trends for these tires and point out where we see them heading.

In the 1960's conventional size agricultural tires identified by an industry code of R1 were used on skidders. The benefits of a skidder equipped with rubber tires could be seen, but it was evident a more rugged tire design, compound and construction was needed to survive the tough forestry service. As a result, LS2 and LS3 tires were developed and quickly gained acceptance in the field.

If we compare the R1 to the LS2 and LS3, we have the following:

	R1	LS2	LS3
Lug Depth	100	130	200
Base Rubber	100	180	180
Sidewall Rubber	100	250	250
Steel Shield	No	Yes	Yes

As can be seen, the LS2 and LS3 tires feature deeper lugs, increased rubber gauge and a steel shield feature for increased resistance to puncture.

The LS2 design is the most popular and widely used line of forestry tires. Taking this design and showing a profile (Figure 1), illustrates some of the key features of this type tire.

[1]Presented at the Council on Forest Engineering Annual Meeting, September 13-15, 1988, Auberge des Gouveneurs, Ste. Foy, Quebec.

[2]Department Manager, Heavy Duty Tire Engineering, Firestone.

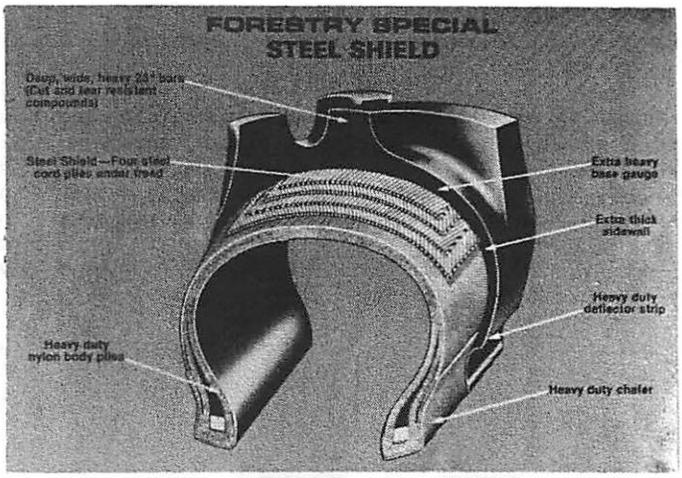

Figure 1

The LS2 has the following:

- Deep, wide, tread lugs with cut resistant rubber to provide long wear and minimize tread chunking and tearing in severe forestry service.
- Heavy gauge base and sidewall rubber to provide increased resistance to cutting.
- Heavy duty deflector strip so the tire conforms to the rim contour and debris is not picked up at this interface.
- Heavy duty chafer to assure good tire durability in the lower sidewall area.
- Nylon body ply fabric taking advantage of this cord's strength, impact resistance, flex resistance, and continued integrity even when exposed to the elements.
- Steel shield wire tread plies that extend across the tire's tread width for resistance to puncture.

The steel shield feature is mandatory for satisfactory forestry performance. To quantify the advantages of a steel shield, we can plunger a tire with a one and one-quarter inch diameter steel rod as shown in Figure 2.

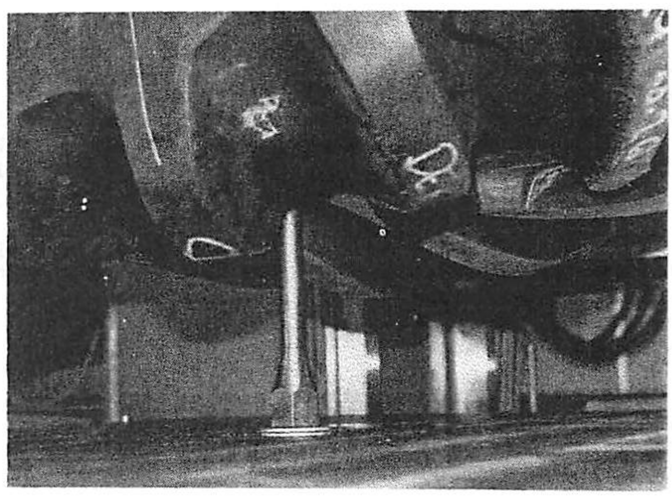

Figure 2

As the plunger is forced into the tire, deflection and force are recorded to determine plunger energy.

It can be seen in Figure 3 that steel shield wire tread plies give a 60% increase in plunger energy over nylon tread plies. Our experience has indicated that this laboratory plunger energy data correlates very well with actual field performance

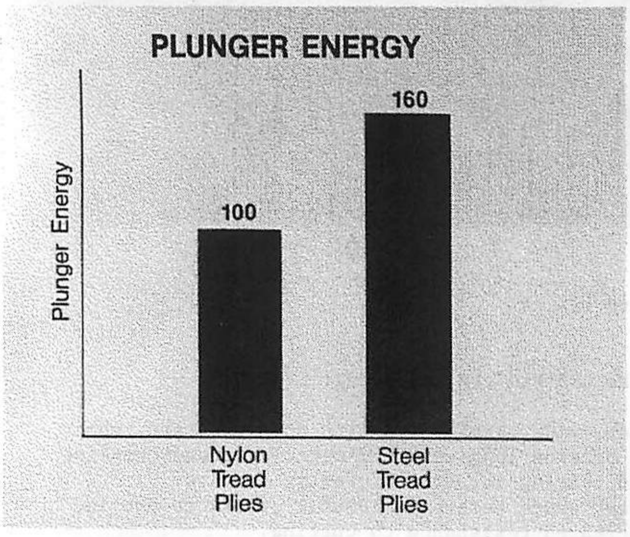

Figure 3

The LS2 tire design has evolved into numerous sizes. A list of these sizes is as follows:

Size	Ply Rating
18.4-26	10
23.1-26	10, 14
28L-26	10, 14, 18
16.9-30	10
24.5-32	12, 16
30.5L-32	12, 16
35.5L-32	16
18.4-34	10
37.5-39	20
43.5-39	24,32

The most popular sizes have been the 23.1-26 and 28L-26. A significant trend that is occurring is that where the 10 ply rating tire was the standard, the 14 and 18 ply ratings are being used more widely to compensate for larger skidders, higher horsepower and increased use of grapples.

The other trend, when reviewing the list of sizes, is that usage of the 32" rim diameter tires has increased, specifically the 24.5-32, the 30.5L32, and the 35.5L-32. As can be seen, these tire sizes also show the availability of going to the higher ply ratings.

The LS3 line of tires, with its premium lug depth, have more specific application in muddy, soft terrain and the number of production sizes are more limited. They are as follows:

28L-26	10 Ply Rating
30.5L-32	12 Ply Rating

The next area we would like to explore is Flotation tires. These wider than conventional size tires can provide two basic operational advantages. First of all they will provide increased flotation and mobility in wet, soft conditions due to their larger footprint. Secondly, they provide increased stability, allowing hilly areas to be worked that previously were inaccessible by skidder. This is primarily due to the inherent greater lateral stability of lower profile tires and the wider vehicle stance provided by wider tires.

It would be well for us to clarify the size nomenclature of flotation tires. A popular size is the 67x34.00-25. The numbers indicate the following:

67 - Nominal tire diameter (in.)
34.00- Nominal tire width (in.)
25 - Rim diameter (in.)

To compare a conventional tire to a flotation tire, we show a 28L-26 conventional next to a 66x43.00-26 flotation in Figure 4.

Figure 4

If we compare the dimensions and footprint area of these two tires, we have the following:

	28L-26	66x43.00-26
Diameter (in.)	64.5	66.5
Width (in.)	28.1	43.0
Footprint Area (sq. in.)	350	474

Obviously, the flotation tire is wider and provides a larger footprint that provides greater mobility.

Traction tests have been run on conventional versus flotation tires in muddy, soft areas and the wider tires show improvements as illustrated in Figure 5.

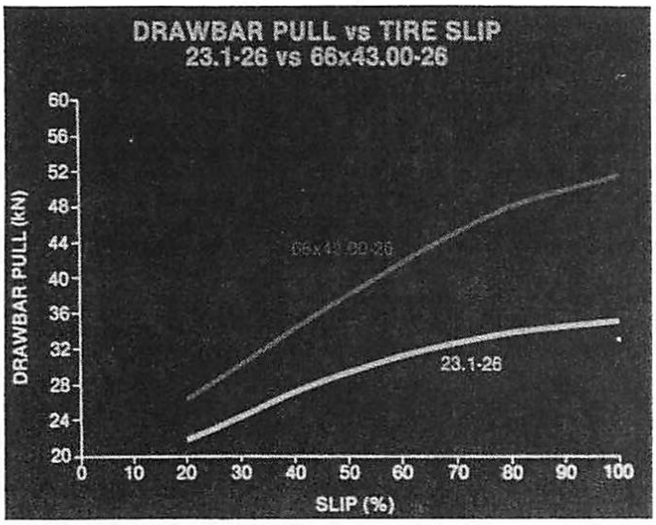

Figure 5

The improved stability of flotation tires is the result of increased lateral stability inherent in wider low profile tires, and a wider vehicle stance. Tests were run comparing the conventional and flotation tires to determine lateral spring rate. As shown in Figure 6, the flotation tire provides increased resistance to side forces.

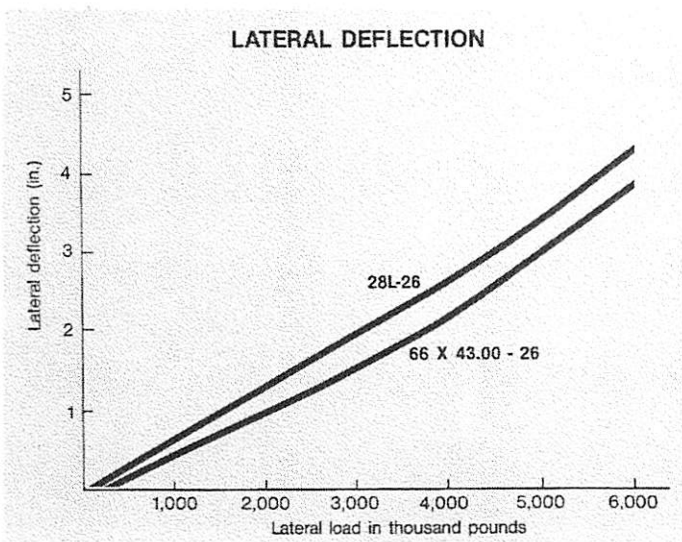

Figure 6

Considering the vehicle width, Figure 7 shows a skidder with conventional 30.5L-32 tires with a maximum vehicle width of 124". If we equip that same skidder with 66x43.00-25 flotation tires, the maximum vehicle width becomes 150" as shown in Figure 8. Obviously, the wider the stance, the more stable the vehicle.

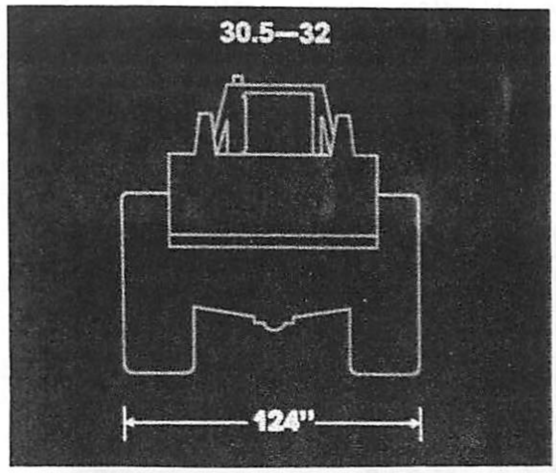

Figure 7

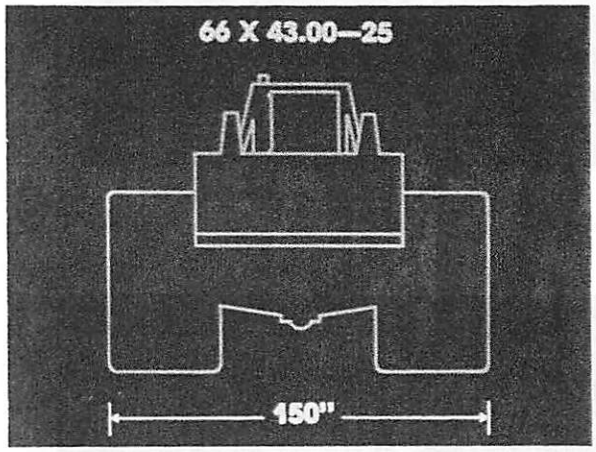

Figure 8

Flotation tires have demonstrated many advantages. They are as follows:

- Significant fuel savings
- Increased productivity
- Improved stability on slopes
- Less soil compaction
- Significant reduction in ground disturbance
- Smoother, softer ride
- Wide tires on a smaller machine could, depending upon conditions, perform the same job as a larger machine on conventional tires.
- Increased access to areas previously inaccessible with conventional equipment.

With their increased usage, the sizes of Flotation tires available for forestry application have increased. These sizes are as follows:

Size	Ply Rating
67x34.00-25	10, 14
67x34.00-26	10, 14
66x43.00-25	10
66x43.00-26	12
66x50.00-26	10
73x44.00-32	12
68x50.00-32	10, 16

As in the conventional sizes, it is well to point out that there is a trend toward higher ply ratings also in the flotation line.

Considerable discussion and application has been done comparing singles, duals and flotation in forestry service. Looking at a skidder schematic on single 24.5-32 tires shown in Figure 9 shows the vehicle width of 115 inches. Figure 10 then shows the same skidder with dual 24.5-32 with an overall width of 168 inches.

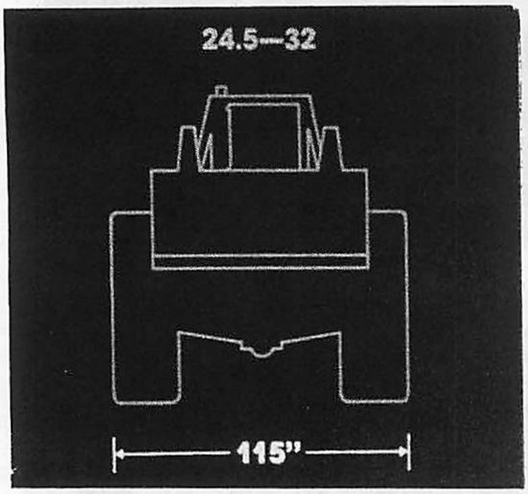

Figure 9

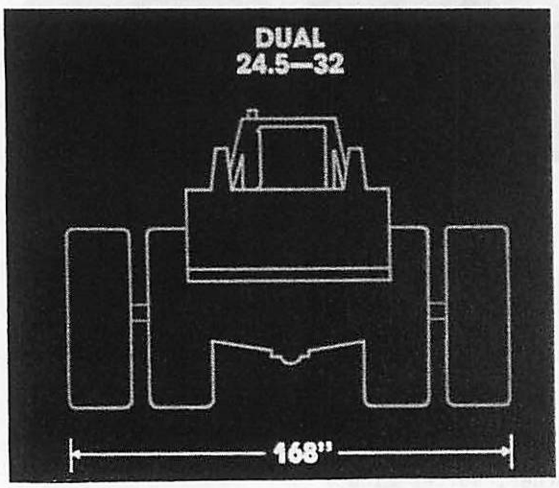

Figure 10

This arrangement allows this user the flexibility of using singles in dry service and applying duals in wet, muddy service. We have reviewed some of the more pertinent operating parameters on the various single, dual and flotation tire combinations and offer the following tabulation as a scoresheet on how it affects skidder performance. The ratings show a number 1 to be best and a number 3 to be the least desirable.

	Singles	Duals	Flotation
Machine Durability	1	3	2
Clearance Width	1	3	2
Productivity	3	1-2	1-2
Fuel Consumption	3	1-2	1-2
Vehicle Stability	3	1-2	1-2

We have rated some of the duals and flotation as a toss-up in many areas. Although the jury is still out on which will be the most popular option, it appears to us at this time that the flotation tires will have the greatest acceptance.

In conclusion, we have seen and continue to experience many interesting applications and trends for tires used in forestry equipment. The most dominant trends occurring now are the use of higher ply rating tires, the use of large size tires, and the increasing popularity of the wider flotation tires. All these trends are in line with the equipment getting larger and more powerful, increasing productivity, extending work seasons, and working in new areas previously not accessible.

We find these trends very interesting and look forward to continuing to providing tires that will meet the forestry equipment requirements.

Chunkwood Production from Dead and Stagnant Material[1]

Leonard R. Johnson and Harry W. Lee[2]

Abstract: Chunkwood was produced from two types of material: residue left after logging and whole trees cut from stagnant stands of timber. The experiments involved recovery, processing, and hauling of the material. Hauling costs were calculated at various haul distances and with three hauling options. Production costs using a dump truck with 30 cubic yard box averaged $66 per dry ton at a 25 mile haul; costs averaged $43 per dry ton for whole trees at this distance.

Keywords: Wood energy, Mechanization

Chunkwood is a unique product that has been under development for several years in the United States and the Scandanavian countries. Chunks vary in size with the diameter of the piece being processed and can be chipped to depths of 2.5 to 4.5 inches. Chunkwood is more dense than whole tree chips or hog fuel, and because of this, can be transported more efficiently than these products. Keeping the material in a chunk form also retains options for the production of products other than energy. Other chunkwood advantages include safer and more efficient storage (Karsky, 1987). The larger chunks allow air flow through the stored wood, decreasing the chances of spontaneous combustion and increasing the amount of drying while in storage. Increased combustion efficiency could also occur in wood burning units designed to handle larger chunks of wood. The product can be produced in the woods with equipment similar to whole tree chippers.

A chunkwood chipper was used to process logging residue and trees from stagnant timber stands. Two general methods were used to move the material from the woods to the processing point. Residue left after commercial timber harvest was moved to the roadside in a modified dozer piling operation. Earlier studies had suggested this as an efficient way to move the non-uniform residue material to an accessible point for processing. The second type material involved whole trees from a dense, stagnant timber stand. Trees were felled with a feller-buncher and skidded with a grapple skidder.

Objectives of the project involved documentation of the production, problems, and costs associated with delivery and processing of these two types of material.

The chunkwood was delivered to a wood-fired electrical generating station in Kettle Falls, Washington, owned by the Washington Water Power Company. The Kettle Falls station burns wood biomass in a system with 50 megawatts of capacity. A test burn of the material was conducted in an attempt to identify handling problems with the material and to determine any combustion benefits of the larger chunkwood pieces.

The project was funded through the U.S. Department of Energy, Pacific Northwest and Alaska Regional Bioenergy Program. Participants included the University of Idaho, the Colville National Forest, and the Washington Water Power Company.

DESCRIPTION OF EQUIPMENT

Equipment used in the study is not unique to timber harvesting. Dozer piling was conducted with a Kamatsu Model 65 crawler tractor with brush blade. The dozer pushed material into decks at roadside, but the decks could not be easily reached by the loading unit on the chunkwood chipper. An intermediate sorting and piling operation was required. A long boom cable crane was used to sort chippable and unchippable material and to pile the chippable pieces in decks that could be reached for chipping.

Felling on the whole tree recovery site was accomplished with a Caterpillar Model 227 feller-buncher equipped with a Rotosaw felling head. The Model 227 feller-buncher is a tracked machine with the felling head mounted at the end of a hydraulic boom. Rotosaw manufactures several felling heads designed to cut the trees with a series of small steel cups located on a rotating disk. The cup edges serve as the cutting surface and can be rotated periodically to expose a new cutting edge. The Rotosaw is one of several saw-head alternatives to traditional feller-buncher shears. Skidding operations from the feller-buncher utilized a John Deere Model 640 wheeled skidder with swinging grapple.

The chunkwood processing concept was developed in the United States by the U.S. Forest Service through the North Central Forest Experiment Station in Houghton, Michigan (Arola, et.al, 1983) and the Missoula Technical Development Center (Karsky, 1987). The prototype chipper used in this study involved modification of a Morbark Model 18 whole tree chipper. The chipping disk has been replaced with a involuted disk cutter assembly. The cutter wheel and cutting blades are positioned horizontally in the machine. Either two or three equally spaced blades can be used in chipping.

Chunk size can be controlled to some extent by the amount of blade offset on the chipper disk and by the feed rate of material to the chipper. Chunks are too heavy to be blown into the hauling unit so an outfeed conveyor is used to move material away from the chipper. Required power per ton for chunkwood is estimated at one third that needed to produce whole tree chips (Karsky, 1987).

Hauling was constrained by the road system accessing the two study units. Road width and curve radii limited the type of haul unit that could negotiate the curves to three axle trucks without long trailers. Because of the desire to keep the chunkwood separate from the usual hog-fuel

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[1]Presented at the 11th Annual Council on Forest Engineering Meeting, Ste. Foy, Quebec, September 13-14, 1988.

[2]Professor and Assistant Professor of Forest Engineering, Forest Products Department, Univ of Idaho, Moscow, ID.

loads at the Washington Water Power generating station, the units also had to be capable of unloading themselves. Although the haul capacity was relatively small 12 cubic yard dump trucks were used to haul the chunkwood. The trucks were modified with sideboards to allow 16.4 cubic yards of capacity. The analysis also considers the costs of other types of haul vehicles that would meet the curve and width limitations of the roads.

Hourly machine and labor costs for these machines are presented in Table 1. These rates represent either the contracted rate for work on the project or a developed rate based on typical machine costs in the intermountain west region of the United States. Costs for the chipper were based on estimates of the investment costs for a production model of a chunkwood chipper. These include a $135,000 initial investment and five year life, comparable to current costs for whole tree chippers. A lower initial investment in the chipper because of lower power requirements could reduce this initial cost.

SITE CONDITIONS

Study sites were located on the Colville National Forest in northeastern part of the state of Washington, with recovery operations conducted in July, 1987. Sites were approximately 5 acres in size. Slopes were gentle, averaging 7 percent and ranging from 0 to 25 percent. The residue recovery site had been harvested the previous season (1986) and was originally scheduled for dozer piling as a means of slash disposal. The whole tree recovery site was part of a proposed commercial timber sale that had not sold because of the number and density of small sized stems. Conditions for the two sites and the amount of recovered chunkwood are summarized in Table 2.

MODIFIED DOZER PILING

Movement of logging residue to a landing through a modified dozer piling operation is less sensitive to the wide ranges in size and uniformity of pieces common in logging residue than movement of the material with a more conventional skidding vehicle. Six study blocks, with maximum dozing distances ranging from 100 to 300 feet, were established. Units averaged 1 acre in size. The line intersect method of down and dead inventory was used to estimate the amount of residue per unit area before and after recovery. These quantities were shown in Table 2. Material averaged 19.7 bone dry tons before recovery and 3.1 tons after. Material had been drying in the field for a year and had a low moisture content of 15.5%.

Dozer production and costs on the six units are presented in Table 3. Percent productivity for the dozer over all units averaged 95%. Dozing was contracted to an owner/operator who was highly skilled and motivated. Average dozing production rates compare favorably with production on an adjacent unit that was piled in a normal fashion. Results by unit show a trend toward lower production as the dozing distance increases, but the quantity of material pushed also appears to influence dozing times. Production rates per dry ton tend toward a maximum in the 200 foot blocks.

TABLE 1: Equipment descriptions and hourly machine and labor rates for equipment used in residue and whole tree recovery studies.

EQUIPMENT DESCRIPTION	EFFECTIVE HOURLY MACHINE AND LABOR RATE
FELLER - BUNCHER	$ 100
WHEELED SKIDDER	$ 50
CRAWLER TRACTOR	$ 60
LOADING CRANE	$ 55
CHUNKWOOD CHIPPER	$ 75
DUMP TRUCK WITH 12 CUBIC YARD BOX	$ 45
TRUCK WITH CHIP VAN	$ 55
DUMP TRUCK WITH 30 CUBIC YARD BOX	$ 45

TABLE 2: Site characteristics for residue and whole tree recovery tests with the chunkwood chipper.

	RESIDUE RECOVERY AFTER LOGGING	WHOLE TREE RECOVERY
UNIT SIZE (ACRES)	5.32	5.01
STANDING TREES / ACRE		
ALL TREES / RECOVERED	0	5028 / 2330
DOWN-DEAD VOLUME/ACRE	BEFORE/AFTER	BEFORE/AFTER
BONE DRY TONS	19.7 / 3.1	2.4 / 19.7
AVERAGE PIECE SIZE	ALL/CHIPPED	ALL/CHIPPED
DIAMETER - INCHES	5.7 / 5.3	4.7 / 6.6
LENGTH - FEET	15.5 / 10.3	44.0 / 55.0
PIECES CHIPPED	1490	3344
MOISTURE CONTENT	15.5%	46.4%
DRY TONS PRODUCED	45.5	334.3
ROUND TRIP DISTANCE (MILES)	77	50

Using an hourly cost rate for the dozer and operator of $60 per hour, the dozing costs were calculated and are also presented in Table 3. Costs per unit area and per unit of material volume or weight are quite low relative to comparable costs of recovery with a wheeled skidder. Using production functions developed in another study for a skidder moving residue under comparable conditions, costs per unit weight were calculated at $12 per dry ton at a maximum distance of 100 feet and $24 per dry ton at a maximum distance of 300 feet (Johnson and Lee, 1988).

The low costs of moving material to a road with the dozer can be offset in two ways. Dozing activity tends to break up the material and produces smaller pieces for the chipper. Production of the chunkwood chipper is significantly affected by piece length. Cost increases can also result from the condition and location of decks at roadside. Decks created in a dozer piling process are generally not uniform and can include large amounts of material not suitable for chipping. This material includes small limbs and branches lodged in bunches and larger residue pieces with the roots still attached. The dozer piled decks will generally be spread in windrows along the road and this will require frequent moves for the chipper or a supply vehicle to sort and move material from the decks to the chipper location.

The need for a separate process to sort recoverable material will depend on the mobility and type of feed mechanism on the chipper. The chunkwood chipper utilized the original loader from the Mobark Model 18 chipper, a slide-boom loader that works very well in grasping material from decks directly in front of the chipper infeed but has very limited reach to either side of the infeed area. It is also limited in the height that can be reached. The dozer decks in this study were located at the top of the cut slope of the road and were inaccessible to the slide-boom loader. Deck locations and loader limitations called for use of a separate machine to sort recoverable material from the dozer piles and to pile this material in decks at the lower edge of the road. This task was accomplished with a long-boom cable crane.

Requirements for the sorting and piling operation increased costs of delivery of material to the chipper substantially. Production times and costs associated with use of the crane are presented in Table 4. Costs associated with the crane were charged against the quantity of material eventually processed by the chunkwood chipper. Sorting and piling added $15 per dry ton to the cost of the chipped material. Total costs of dozing and sorting at the various dozing distances are also shown in Table 4. The decks resulting from sorting by the crane were relatively small forcing frequent moves for the chipper. Cost results for the chipper will show that this added significantly to the chipping cost.

Production of the chunkwood chipper in the sorted and piled residue is outlined in Table 5. Material was hauled from the chipper in 12 cubic yard dump trucks because of limited road access of the site. Larger hauling units could not negotiate the curves on the access road. An inadequate number of trucks delayed the system 40 percent of the time. An additional 15 percent of total time was spent moving the chipper between decks. Costs were calculated on the basis of productive time, total time, time without the delay waiting for trucks, and time without the delay for both trucks and chipper moves. Without the delay for trucks, chipping costs averaged $20 per dry ton. Without truck delays and chipper moves, costs averaged $15 per dry ton.

Table 5 lists "extra loader time" at 22 percent of total chipping time. This is time involved in finding and feeding new pieces to the chipper when the chipping head is running but has no wood to chip. Normal operations in whole trees allow the operator to find and feed new pieces while the chipper is processing the previous load. The small piece sizes in residue do not allow the operator enough time to combine these operations as often as in whole trees.

CHUNKWOOD PROCESSING FROM WHOLE TREES

Recovery of chunkwood from standing timber was conducted in a manner that is similar to a conventional whole tree chipping operation. Site characteristics were presented in Table 2. A timber cruise of the stand showed 5028 trees per hectare in all size classes, but only material greater than 4.5 inches was recovered. Trees in this class averaged 2330 trees per hectare. The smaller trees were felled or pushed over and were left on site. The large number of trees less than 4.5 inches is evident in the 19.7 dry tons of material left on site after harvest (Table 2).

Material was cut and bunched with a Caterpillar Model 227 feller-buncher with a Rotosaw felling head prior to the arrival of the chipper. Production averaged 0.43 scheduled minutes per tree or 1116 trees in an 8 hour shift. Trees were piled in bunches averaging 14.4 pieces. Production times and costs of the feller-buncher are presented in Table 6 and are based on the quantity of material chipped. The developed production equation shows the influence on feller-buncher production of the distance between trees as indicated by the move distance in feet and the percent slope of the site. Costs average $5.96 per dry ton or $ 0.71 per chipped tree.

TABLE 3: Costs of dozer piling based on quantities of material from down and dead inventories.

--- BASED ON SCHEDULED HOURS ---

	DRY TON PER ACRE	DOLLARS PER ACRE	DOLLARS PER DRY TON
100 FT UNIT	11.1	83	7.40
150 FT UNIT	15.0	68	4.60
200 FT UNIT A	27.8	98	3.50
200 FT UNIT B	18.5	69	3.80
250 FT UNIT	8.6	115	13.30
300 FT UNIT	25.8	116	4.50
TOTAL / AVERAGE	16.7	93	5.20
CONVENTIONAL	15.1	91	6.00

TABLE 4: Production and cost of preparing dozer piled material for chipping with a cable crane.

	TOTAL TIME MINUTES	PERCENT OF TOTAL TIME
PRODUCTIVE TIME	569.6	77.3%
DELAY TIMES	167.3	22.7%
TOTAL	736.9	100.0%
PRODUCTION COST	$ 14.88 / DRY TON	

TABLE 5: Production times and rates for chunkwood chipper when chipping dry material from dozer piled area.

PRODUCTION: 45.5 DRY TONS 15.5 PCT MOISTURE
1490 PIECES 21 LOADS

	PCT OF TIME	DRY TON / HOUR	$ / DRY TON
CHIPPING TIME	13.3	16.85	4.45
EXTRA LOADER TIME	22.2		
TOTAL PRODUCTIVE	35.5	6.33	11.85
MOVE CHIPPER	15.4		
WAIT FOR TRUCKS	40.3		
OTHER	8.8		
TOTAL DELAY	64.5		
TOTAL TIME	100.0	2.25	33.40
WITHOUT TRUCK DELAY		3.76	19.94

TABLE 6: Production and time statistics for feller buncher working in whole trees for chunkwood chipper.

NUMBER OF TURNS / TREES	2026 / 2811		
QUANTITY CHIPPED	334	DRY TONS	

	MINUTES / TURN	MINUTES / TREE	PCT OF TOTAL
PRODUCTIVE	0.52	0.38	88.8
DELAYS	0.07	0.05	11.2
TOTAL	0.59	0.43	100.0

PRODUCTION AND COST	TREES / HOUR	DRY TONS / HOUR	$ / DRY TON
	141	16.8	5.96

PRODUCTION EQUATION: R-SQUARE = 0.27

$$\text{TREE/HR} = 180 - 9.0\ (\text{MOVE DISTANCE IN FEET}) + 0.18\ (\text{MOVE DISTANCE IN FEET})^2 + 86.7\ \text{Ln}\ (\text{PIECES CUT/TURN})$$

The wheeled skidder worked directly with the chipper and was affected by all chipper delays. The largest of these delays involved a wait for the arrival of trucks. Cycle times and production rates for the skidder are presented in Table 7. Production and costs per dry ton are based on the quantity of material chipped. If delays waiting for trucks could be eliminated, costs to deliver bunched trees to the chipper would average $5.42 per dry ton. With the elimination of truck delays, the production rate of the chipper would exceed that of the skidder, and the skidder would become the slowest production unit in the system. At this point the use of two skidders would be more cost effective than the use of a single skidder.

Chipping production and cost in whole trees are presented in Table 8. If the delay waiting for trucks is eliminated, productive time of the chipper averaged 92%. Productive time might not be this high if the truck delays had not allowed additional time for maintenance and clean up of the chipping area. Costs of chipping without the delay for trucks averaged $6.20 per dry ton. Note that the time spent in extra loading operations averaged 3.3% compared to 22.2% in residue. This reflects the ease of feeding the well decked, long pieces present in the whole tree operation.

Production equations for the chunkwood chipper were developed from data on the weight and number of pieces involved in each truck load. The equations predict the production rate for chipping and for chipping and extra loading time in dry tons per productive machine hour. These equations are presented in Table 9. Average piece size has a predictable effect on production. Larger pieces result in higher production rates. Average moisture content of the pieces has a negative effect on the production rate. Higher moisture contents result in lower production. This reflects the production measure of dry tons per hour and the difference in moisture content between the residue (15.5%) and the recently cut trees (46.4%). Aside from the difference in piece size, the type of material, residue or whole trees, did not have a significant effect on actual chipping time. The chipper performed equally well in both types of material. The type of material did affect the extra loading times, however, reflecting the additional time requirement to gather and feed smaller residue pieces.

HAULING OPTIONS AND COSTS

Cost of hauling of processed material from the woods will be affected by the type of haul vehicle and the density of the material. A chip van 40 to 45 feet in length is normally used to haul whole tree chips from the forest in the United States. Narrow access roads with tight turn radii on curves can constrain hauling to vehicles with a shorter

TABLE 7: Production and time statistics for grapple skidder used to feed material to the chunkwood chipper.

NUMBER OF TURNS / TREES	175 / 2518	
QUANTITY CHIPPED	334	DRY TONS
AVERAGE TRAVEL DISTANCE	572	FEET

	MINUTES / TURN	PCT OF TOTAL
TRAVEL UNLOADED	2.09	8.4
LOAD GRAPPLE	0.68	2.7
TRAVEL LOADED	2.03	8.1
DECKING	0.28	1.1
TOTAL PRODUCTIVE	5.09	20.4
EXTRA HANDLING OF TREES	2.74	11.0
CLEAR BRUSH	3.32	13.3
WAIT FOR CHIPPER/TRUCKS	12.55	50.3
OTHER	3.07	5.0
TOTAL DELAY	19.89	79.6
TOTAL TIME	24.98	100.0
WITHOUT WAIT FOR TRUCK	12.42	

PRODUCTION AND COST:	TREES / HOUR	DRY TONS / HOUR	$ / DRY TON
SCH HRS	34.6	4.59	10.90
W/O TRK DELAY	69.5	9.23	5.42

PRODUCTION EQUATION: R-SQUARE = 0.65

$$\text{TURN TIME IN MINUTES} = 2.53 + 0.004\ (\text{AVERAGE SKID DISTANCE IN FEET}) - 0.083\ (\text{SLOPE IN WHOLE PERCENT}) + 0.00008\ (\text{PIECES PER TURN}) + 0.13\ \text{Ln}\ (\text{DECK HEIGHT IN FEET})$$

TABLE 8: Production times and rates for chunkwood chipper chipping whole trees after felling and skidding.

PRODUCTION:	334	DRY TONS	46.4	PCT MOISTURE
	3344	PIECES	157	LOADS

	PCT OF TIME	DRY TON / HOUR	$ / DRY TON
CHIPPING TIME	25.1	17.72	4.23
EXTRA LOADER TIME	3.3		
TOTAL PRODUCTIVE	28.4	15.66	4.79
OTHER	2.9		
MAINTENANCE	5.5		
WAIT FOR TRUCKS	63.2		
TOTAL DELAY	71.6		
TOTAL TIME	100.0	4.45	16.84
WITHOUT TRUCK DELAY		12.09	6.20

TABLE 9: Regression equations for the production rate of the chunkwood chipper.

DRY TONS / CHIP HR: R-SQUARE = 0.42

TON / HR =
22.8 - 0.19 (% MOISTURE CONTENT)
+ 0.02 (PIECE WEIGHT IN LBS)
- 252 (1 / PIECE WEIGHT)

DRY TONS / CHIP-LOAD HR: R-SQUARE = 0.71

TON / HR =
22.2 - 0.14 (% MOISTURE CONTENT)
+ 0.04 (PIECE WEIGHT IN LBS)
- 2.67 (TYPE: 1, WHOLE TREE) X 3
2, RESIDUE

wheelbase, however. Hauling from the two study sites was affected by the access roads and had to be done with dump trucks. The trucks were fitted with 12 cubic yard metal boxes fitted with sideboards so that they could be loaded to 16.4 cubic yards of capacity. Hauling costs were also developed for a truck with chip van, and a three axle dump truck with 30 cubic yard box.

One of the stated advantages of chunkwood over a product like whole tree chips is the increased density of the material. The densities of whoe tree chips, chunkwood, and 18 inch firewood were measured and expressed in pounds per cubic foot of container volume and cubic feet of solid wood per cubic feet of the hauling container. The densities of these three products are presented in Table 10. Impact of these densities on load capacities of the hauling options are also shown. The percentages of legal load capacity are based on the legal loads in the states of Idaho and Washington. Legal loads are expressed in gross weight per axle of the haul vehicle as well as total weight of the load. The relatively low percentages of legal load shown in Table 10 reflect the primary problem with hauling a processed wood product like whole tree chips or chunkwood from the woods. Although the container volume is completely filled, the hauling unit could legally carry additional weight.

Hauling costs with three products and hauling options are presented in Table 11. Chunkwood presents significant savings in haul costs over the whole tree pulp chip, but does not match the hauling efficiency of the firewood product. The firewood would probably require additional processing at the point of end use, however, while pulp chips and chunkwood could be used directly. Cost per dry ton-mile is higher in whole trees than in residue because of the higher moisture content.

TOTAL SYSTEM COSTS

Total system costs for recovery, chipping, and hauling in the two areas are presented in Table 12 at various hauling distances. These are costs for a system balanced with the number of skidders, chippers, and trucks that product lowest total cost. Two skidders will be required in the whole tree operation to match production of the chipper and trucks. Calculations of the number of trucks required to balance chipper production resulted in non-integer values. Costs were compared for an even number of trucks greater and less than the calculated value. The lowest cost combination was selected.

Total costs in the residue material at a 25 mile haul (50 miles round trip) is estimated at $63 per dry ton when hauling with chip vans and $66 per dry ton when hauling with the 30 cubic yard dump truck. The costs in whole trees are $34 per dry ton with the chip van and $37 per dry ton with the 30 cubic yard dump. The higher costs in residue reflect the lower production rate of the chipper in that material. This production difference also accounts for the relatively small difference between costs with the chip van and the dump trucks.

TABLE 10: Load capacities and percent of legal load capacity utilized by haul unit options

RESIDUE ::::	PULP CHIPS	CHUNK WOOD	FIRE WOOD
LOAD RATIOS:			
LBS WOOD/ CUFT CONTAINER	7.25	9.89	14.50
CUFT WOOD/CUFT CONTAINER	0.25	0.34	0.50
PERCENT OF LEGAL LOAD CAPACITY USED:			
TRACTOR WITH CHIP VAN	46.3	63.2	92.6
12 CU.YD. DUMP TRUCK	15.8	21.6	31.6
30 CU.YD. DUMP TRUCK	26.7	36.4	53.4
WHOLE TREES ::::			
LOAD RATIOS:			
LBS WOOD/ CUFT CONTAINER	7.25	9.60	14.50
CUFT WOOD/CUFT CONTAINER	0.25	0.38	0.50
LOAD CAPACITY USED			
TRACTOR WITH CHIP VAN	73.0	96.7	146.1
12 CU.YD. DUMP TRUCK	25.0	33.0	49.9
30 CU.YD. DUMP TRUCK	42.1	55.8	84.3

TABLE 11: Cost of hauling residue and whole trees processed as pulp chips, chunkwood, and firewood.

	$ / DRY TON-MILE		
RESIDUE ::::	WITH PULP CHIPS	WITH CHUNK WOOD	WITH FIRE WOOD
TRACTOR WITH CHIP VAN	0.407	0.299	0.204
12 CU.YD. DUMP TRUCK	1.004	0.736	0.502
30 CU.YD. DUMP TRUCK	0.624	0.457	0.312
WHOLE TREES ::::			
TRACTOR WITH CHIP VAN	0.343	0.259	0.172
12 CU.YD. DUMP TRUCK	1.172	0.885	0.586
30 CU.YD. DUMP TRUCK	0.685	0.517	0.342

TABLE 12: Total cost of chunkwood recovery, processing, and transportation with a balanced system. Travel speeds for trucks are the same for chunkwood from residues and whole trees.

	ROUND TRIP DISTANCE 50 MILES		75 MILES	
SYSTEM COST	NO. TRK	$ / DRY TON	NO. TRK	$ / DRY TON
RESIDUE ::				
TRUCK / VAN	1	63	2	68
12 CU.YD DUMP	3	81	4	97
30 CU.YD.DUMP	2	66	3	74
WHOLE TREES ::				
TRUCK / VAN	3	34	3	39
12 CU.YD. DUMP	9	56	13	72
30 CU.YD. DUMP	5	43	8	50

CONCLUSION

The economic feasibility of recovery of chunkwood from logging residue and overstocked, stagnant timber stands will depend on the demand and market for fuel wood. A current oversupply of mill residues in the intermountain region of the United States has driven the price for hog fuel to very low levels. Wood chips and residue directly from the forest cannot compete with these low prices. Given the relatively high recovery costs, location of the recovery sites relative to the end user will be extremely important to economic feasibility of recovery operations.

The chunkwood chipper performed very well in both tests. Production rates and costs were comparable to those achieved in the manufacture of whole tree pulp chips. These costs were found even when using rather conservative estimates for the cost of a production model chipper. When targeted for uses other than the pulp mill, chunkwood will have several distinct advantages in transportation and use over the more traditional pulp chip.

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