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INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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Using Circular Saw Felling Heads to Reduce Butt Splitting Damage and Increase Productivity

M.P. Folkema and P.G. Mellgren

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143 PLACE FRONTENAC, POINTE CLAIRE, QUE., CANADA H9R 4Z7
2112 WEST BROADWAY, VANCOUVER, B.C., CANADA V6K 2C8

PREFACE

In 1977, at the request of several Member companies having sawmill operations, FERIC initiated a project to find a solution to the problem of wood splitting damage caused by the use of hydraulic shears.

The first step carried out during the winter of 1977-78, was to test a Swedish chain saw felling head mounted on a Drott 40 tracked carrier. The mechanical reliability of this felling head proved unacceptable by industry standards. From this and other studies FERIC concluded that an "ideal" non-shear felling head had to be simple, rugged, mechanically reliable, and have a productivity at least similar to hydraulic shears.

During this same period Member companies frequently stated that mechanized felling with shears had not reduced their felling costs as compared to manual felling using chain saws. FERIC realized that to achieve real cost savings from mechanized felling a substantial increase in felling production was required.

The twin objectives of eliminating butt splitting damage and substantially increasing the felling productivity were merged into a single project. This report outlines that project and the degree of success attained in meeting the above objectives.

Grateful appreciation is extended to the following companies and their personnel for their support of and involvement with this project:

Abitibi-Price Inc., Thunder Bay, Ontario.
Domtar Inc., Dolbeau, Québec.
Harricana Métal Inc., Amos, Québec.
Koehring Canada Ltd., Brantford, Ontario.

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SUMMARY

The use of a large, rugged circular saw, driven by a powerful hydraulic motor and utilizing the flywheel principle (kinetic energy) to sever trees was first tested in Canada by Prince Albert Pulpwood Ltd. in 1976. The above felling principle, used on their A-Line Swather, permitted the continuous felling of small diameter trees using a saw carrier moving at 3-4 km per hour.

Due to the observed lack of wood splitting damage and the high production potential from using this method FERIC initiated a project to determine if a boom-mounted version could be built. Two manufacturers, Koehring Canada Ltd., and Harricana Métal Inc. co-operated with FERIC in the building and testing of suitable prototypes.

Production results, using a 45^{o} offset Koehring circular saw on a Koehring 620 tracked carrier during a 2½ week trial near Thunder Bay, Ontario in late 1981, indicated an average productivity of 191 trees/PMH, or 18.2 m^3/PMH, based on an average tree size of .095 m^3. This was estimated by company personnel to be 15 to 20% higher than for a similar, shear-equipped feller buncher. The above results were preliminary in nature: FERIC personnel anticipate that with further improvements to the carrier's hydraulic system, and with more operator experience, that the future productivity of this machine will likely be considerably higher.

The Harricana circular saw on a John Deere 693A tracked carrier was tested near Dolbeau, Québec during January and February 1982. Limited time studies by FERIC indicated a productivity of 72 trees/PMH, or 22.3 m^3/PMH, based on an average tree size of 0.31 m^3. The lower trees per PMH for the Harricana circular saw was due to the larger tree size, adverse operating conditions (deep snow, +25% slope), and to the 2-step duty cycle of this head. The felling head must first be extended to each tree, then a second hydraulic action slides the sawhead forward, severing the tree. In spite of the lower trees per PMH, the resulting productivity (m^3) was higher for the Harricana sawhead.

For both felling heads butt splitting damage was minimal or non-existant. Why? There were no bending stresses placed on the trees during felling since the trees were not grappled until they were fully severed. Also, the "sawing" action caused no wood compression damage.

Results to date indicate that, compared to chain saw or auger felling units the circular saw assembly is much simpler since it is comprised of only a few basic parts. It is also more rugged and can thus more easily be used for brushing. Due to its mechanical simplicity and ruggedness it is expected that the mechanical reliability of the circular saw will be high, similar to shears. Other advantages of the circular saw unit include the capability to fell "hard" hardwoods, even in frozen conditions, with lower stumps, as compared to shears.

INTRODUCTION AND BACKGROUND

Fibre Damage from Shears

Lumber trim losses resulting from butt splitting caused by the use of hydraulic shears on tree fellers has long been recognized as a serious problem by Canada's sawmills and plywood/veneer mills. Since the early 1960's, when shears were first used in the forest, butt splitting caused by shears has resulted in product down-grading, higher trim levels and lost profits for the mills (see Fig. 1). On pulpwood operations the wood splitting damage is often not important. However, since logging operations are becoming more integrated (producing pulpwood plus sawlogs/veneer logs) the problem has taken on increased importance.

Fibre damage due to the use of shears costs the Canadian sawmilling industry millions of dollars annually. For example, in one area, the northern Interior of British Columbia it was reported that single-blade tree shears were used to fell over 50% of the timber. Reports from the sawmill industry indicated that shears damaged 3% of the merchantable wood (yearly average). The 1975 sawmill output for that area was 2.2 billion fbm; trim losses due to shear damage were thus estimated at 35 million fbm. This amount was downgraded to pulp furnish from higher-value lumber [1]. Assuming a value difference of $130 between a thousand fbm of lumber and a similar amount of wood in chip form, the loss due to shear damage in the northern Interior of B.C. would be $4.5 million annually.

An extensive study of both single and double-bladed ribbed shears several years ago verified that trim losses due to shears, particularly during the winter, are high. Takla Logging of Prince George, B.C., in a test at -20°C, measured butt damage at 3.6% of the tree-length volume scale or 11.4% of the lumber from 5.6-m butt logs [2].

Johnson and St. Laurent [3] of the Eastern Forest Products Laboratory (FORINTEK), Wiklund [4] , and Arola [5] have investigated the effects of blade thickness (thicker blades cause more damage), wood temperature (damage increases with decreasing temperatures), shearing stresses, etc.

Research work on improved shears has resulted in several innovations which can reduce wood splitting damage. For example, the ribbed shear blades designed by the Western Forest Products Laboratory (FORINTEK) have been useful in reducing splitting damage [1]. Other innovations include double-tapered shear blades, inclined shear blades and curved shear blades. However, in frozen wood these "improved" shears have not substantially reduced the damage.

Figure 1. Wood damage from various felling machines, 1: Cat 950 harvester, Thunder Bay, Ont., June 1975; 2: QM Tractor-mounted shear, Okanagan Falls, B.C., Feb. 1977; 3: Earl's Para Shear feller buncher (F.B.), Okanagan Falls, B.C., March, 1977; 4: Drott 40 F.B., Dryden, Ont., Feb. 1978; 5: Repeated shearing attempts are evident on this stump, Drott 40 F.B. Timmins, Ont., Jan. 1977, Kockums 880 with chainsaw felling head, Prince George, B.C., March 1977.

Research work on shears has also indicated that bending loads (pressure) applied to a tree by the grapples on the felling head (while a tree was being sheared) were responsible for many of the long splits that occur in the logs. Improved operating techniques and design modifications were required to overcome this problem. NOTE - the same type of splits frequently occur with chain saw felling heads. This is because the saw head operator may have to bend the tree being cut to keep the saw kerf open, to prevent the sawbar or chain from being pinched.

Chain Saw and Auger Felling Heads

As stated earlier "improved" shear blade design has not substantially reduced wood splitting damage in frozen wood conditions. Other methods of mechanical felling such as the chain saw and auger-type felling heads were studied by FERIC several years ago see if they provided a viable solution to the wood splitting problem.

During the winter of 1977/78 FERIC arranged and monitored a 2½ month trial of a Cranab 55 chain saw felling head modified for mounting on a Drott 40 tracked feller buncher [6]. This, plus other FERIC studies of chain saw felling heads [7, 8, 9] have indicated that although these heads can be used for felling trees they have many disadvantages: chain saw felling heads have many small parts, are much more fragile than shears, usually require highly-trained and conscientious operators (willing to carry out adjustments and repairs such as periodic tightening of chain replacement or sharpening of the sawbar and chain etc.), and are often too complex (e.g. electrical circuitry in the felling head) for field mechanics to repair. As a result chain saw felling heads suffer from high levels of mechanical downtime.

Although the disadvantages of chain saw felling heads are widely recognized, they continue to be widely used, particularly in the B.C. Interior. Chain saw heads are used there on both feller bunchers and feller directors. In eastern and central Canada chain saw felling heads are used on only a few operations.

The auger-type felling head has also been closely studied by FERIC [10]. Although the auger felling head has proved to be quite reliable on a number of operations the auger head shares many of the disadvantages of chain saw felling heads. It can be easily damaged, it must be sharpened frequently, plus it requires a careful, conscientious operator. Although it has had some success in the larger trees of the B.C. Interior and the Kootenay region of B.C. it has seldom been used in the smaller trees of central and eastern Canada. The Drott auger is designed to fell large trees (60-cm capacity), which results in a longer duty cycle, as compared to smaller (shear-type) felling heads.

The report on FERIC's 1977/78 study of the Cranab 55 chainsaw felling head (referred to above) concluded:

"A non-shear felling head that is mounted on the end of a boom should be designed to withstand considerable stress (e.g. for brushing or pushing over unwanted trees). The head should also be simple, rugged in design, and be mechanically reliable. Although the (Cranab) felling head did not satisfy these requirements, the knowledge gained from the trial was useful and can be applied elsewhere. FERIC will therefore continue its search for suitable non-shear felling heads and concepts [6]".

The opportunity to continue the search for a suitable non-shear felling head came with the development of the A-Line Swather.

The A-Line Swather

The concept of high-speed, continuous felling of trees was proposed by Per Mellgren in 1969 (Can. Pat. 808661). Unfortunately, there were no practical tests carried out at that time. Quite independently, in 1976, Messrs. Bruce Hyde and Wayne Tyndall at Prince Albert, Sask., began experimenting with high speed, continuous felling and proved the concept did work in practical operation. In 1977, an experimental machine (Can. Pat. 1029283) demonstrated its capability to fell, collect and bunch trees at a rate of 10 to 30 trees per minute in dense stands [11, 12]. FERIC became directly involved with the A-Line Swather project in 1977; Per Mellgren provided design and engineering assistance for many improvements required on the machine.

The experimental machine (see Fig. 2) used a large, 1630-mm diameter, 19-mm thick circular saw, mounted on the side of a continuously-moving carrier, to fell small diameter (10-18 cm d.b.h.) trees. The saw was driven by a hydraulic motor through a rugged right-angle gear at about 800 r.p.m. The pump of the hydro-static system was driven by a separate diesel engine, mounted on the trailer unit. Due to the high kinetic energy that was built up in the sufficiently-heavy rotating saw it was observed that even large trees were cut almost instantly, without slowing down the forward velocity of the machine, which travelled at 3 to 4 kilometres per hour.

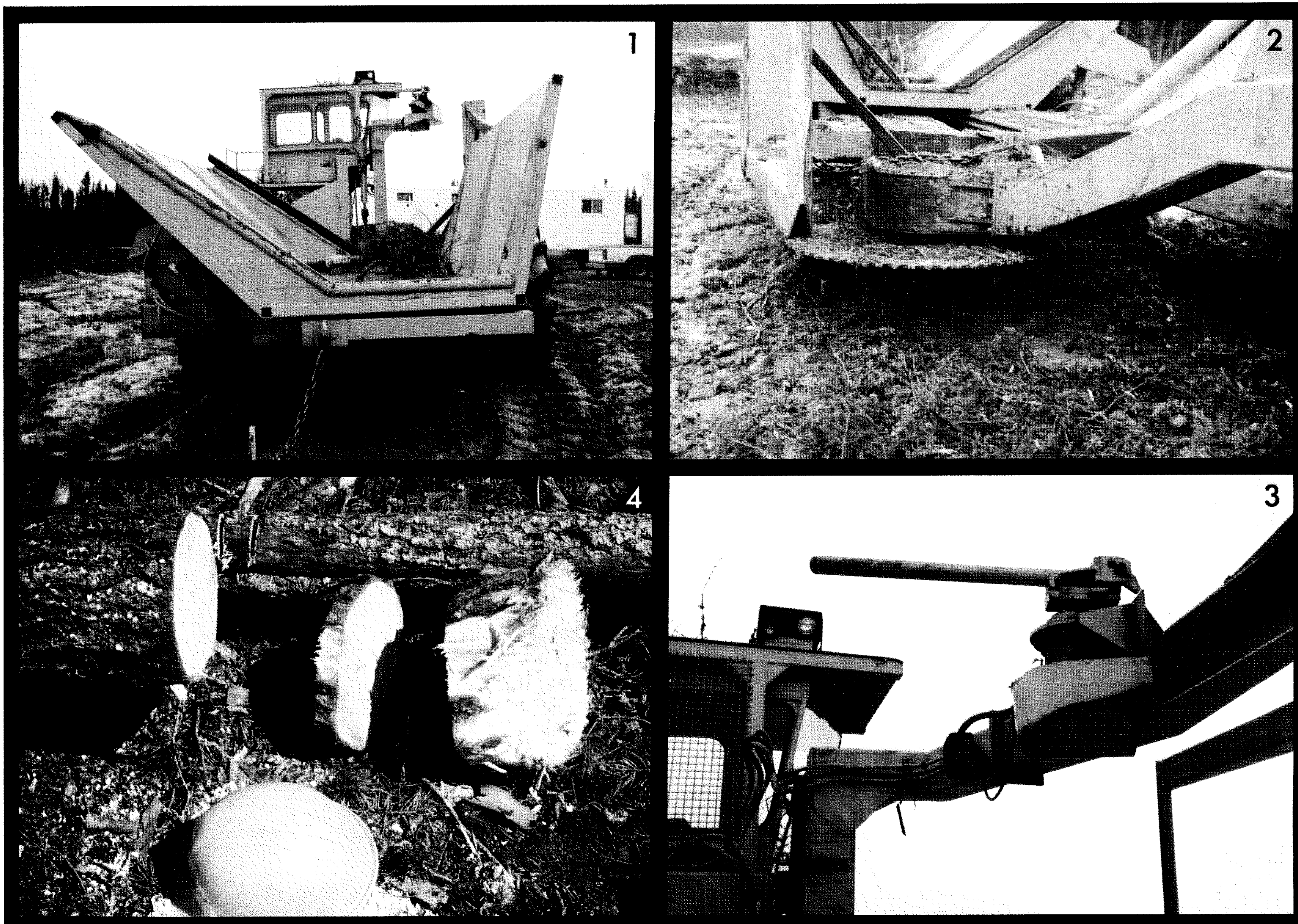

Figure 2. The A-Line Swather (1979). 1: rear view of machine; 2: the circular saw and the "tree selector" (see arrow) that selects trees to be "in" or "out" of the cutting swath; 3: tree pusher (arrow) - a swinging arm that directs the trees into the basket behind the saw; 4: the rough, frayed appearance of felled trees was superficial - it was mainly caused by bolts mounted on top of the saw.

Observers of the A-Line Swather noted that the cutting and tearing action of the swather saw gave a rougher surface than the one obtained with a standard slasher saw, but that it caused little splitting. In early 1979, FERIC initiated a study to determine whether the circular saw could be used to overcome the butt splitting problems resulting from shears. By using a chainsaw to remove a series of discs from the end of trees felled by the A-Line Swather it was found that about 90% of the trees had less than 5 cm of butt damage (see Fig. 2). About 10% of the tree butts did show varying degrees of splitting. This was attributed to bending forces placed on these trees by the "tree selector" a large guide that extended in front of the circular saw to select trees to be "in" or "out" of the cutting swath and by the "tree pusher" a swinging arm that directed the trees into the basket behind the saw (see Fig. 2). The field study also showed that the rough, frayed appearance of the cut (see Fig. 2) was superficial and was mainly caused by studs mounted on the upper surface of the saw.

Planning the Boom-mounted Version: The A-Line Swather, however, was not designed for felling larger trees or for operating on rough or rocky ground. Therefore FERIC decided that a boom-mounted felling head with a circular saw would be desirable. To this end a series of preliminary and engineering drawings were prepared by FERIC. Initially, Koehring Canada Ltd. of Brantford, Ontario, and later, Harricana Métal Inc. of Amos, Québec were approached by FERIC to build prototype units so that the concept could be tested. These two manufacturers were selected because both already produced shear-type felling heads with accumulator arms; these felling heads could be modified to allow the installation of circular saws. In addition both manufacturers were fully aware of the butt splitting problem caused by shears and had tried to find their own solutions to this problem: Koehring Ltd., had begun to market a chain saw felling head; Harricana Métal were testing a chain saw felling head developed in France.

Both manufacturers agreed that alternatives to shears (i.e. chain saw and auger felling heads) had not been entirely successful in Canada, and that another solution was required. Both companies recognized the potential advantages of the circular saw felling head, and proceeded at their own cost and at their own pace, to develop a suitable test unit.

KOEHRING'S CIRCULAR SAW

Development and Initial Results

Koehring Canada Ltd. was approached by FERIC in May 1979 to build a prototype circular saw felling head, on the basis that it could prove to be a viable new product. Preliminary and engineering drawings were provided by FERIC.

MARK I: In June 1981, a Koehring circular saw felling head was mounted on a Koehring 620 tracked carrier. Initial tests, observed by FERIC, were carried out in a small woodlot near Brantford, Ont. The results were encouraging: large hardwoods and softwoods up to 50 cm d.b.h. were felled; there was no apparent butt damage; the grab arms did not need to be closed until after a tree was fully severed. Some operating problems did occur; modifications were required to the controls. However, better stand conditions plus a better operator were required to test the saw's potential.

MARK II: The Mark I unit was modified by adding a 45^{o} adaptor on the back of the felling head (see Fig. 4). This offset the opening for the saw 45^{o} to the right side of the operator, allowing him to use a "scything" technique, that is cutting several trees in a single, but interrupted-at-intervals, side-to-side swing of the boom. After filling the head with trees the boom was swung back to its normal dumping position thereby dumping the trees.

The advantage of the above technique is that the felling head does not have to be positioned on every tree by extending or swinging the knuckle-boom and/or by moving the carrier. The side-to-side "scything" technique is thus much faster. A possible disadvantage of the 45^{o} offset felling head is that the machine must dead-walk back to the start of each pass unless it is encircling the stand.

In July 1981, a second circular saw felling head was built by Koehring. Testing was carried out in August on the logging operation of Mr. Clemence Bernier near Matagami, Québec. Since an electrical fire destroyed the Koehring 620 tracked carrier on which the saw head was mounted, the head was removed and installed on another 620 carrier. This machine was observed by FERIC in Thunder Bay, Ontario.

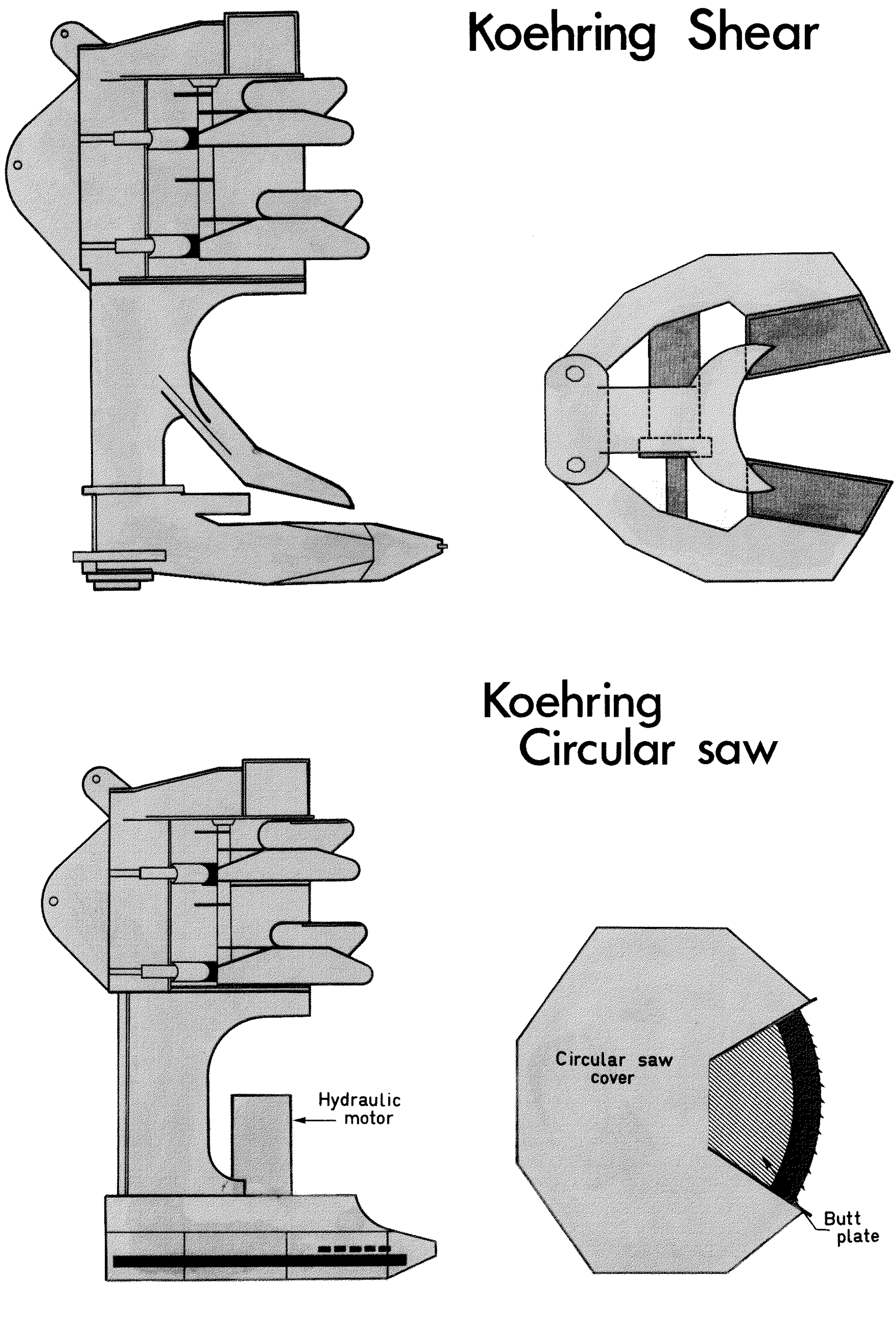

Figure 3. Development of the Koehring Circular Saw. Above: standard Koehring shear felling head; below: modifications required for the circular saw (in blue).

Figure 4. Koehring 620 with 45° offset circular saw felling head, 1: felling and bunching at Abitibi-Price Inc., Thunder Bay, Ont.; 2: top view, showing side-to-side "scything" technique; 3: front view of felling head; 4: occasional saw contact with rock (as shown) had little effect on the saw's cutting ability; 5: close-up of saw design.

Koehring Trial - Thunder Bay, Ont.

A Koehring 620 with a 50-cm capacity circular saw felling head offset at 45° (see Fig. 4, 5) was tested in regular operation by Abitibi-Price Inc. near Thunder Bay, Ont. from Nov. 17 to Dec. 3, 1981. The results of this trial, presented in Tables 1 and 2, are based on data collected by Abitibi-Price Inc. [13]. The operator of the machine had limited experience, thus his operating technique was considerably below the optimal level.

Production - Table 2 indicates that the average productivity during the 2½-week trial period, using the side-to-side "scything" technique was 191 trees/PMH, or 18.2 m^3/PMH, based on an average tree size of 0.095 m^3. Abitibi-Price personnel considered this productivity level to be 15 to 20% higher than for a similar, shear-equipped feller buncher (presuming similar stand conditions, operator experience, etc.).

Abitibi-Price personnel also noted that the potential productivity of the Koehring circular saw had not been achieved, except during short periods when there was limited demand on the machine's hydraulic functions. A series of time studies, of 10 minutes duration each, by G. Brown of Abitibi-Price often indicated that 50 or more trees were felled and bunched during these 10-minute periods; if sustained this would have resulted in a (long-term) productivity of 300 trees/PMH. Due to hydraulic system limitations on the carrier, and to a lesser extent, limited operator experience with the "scything" technique of felling, the actual productivity (long term) was 191 trees/PMH. The short term results (300 trees/PMH) are therefore only indicative of the production that can be achieved under ideal conditions. A discussion of the Koehring 620's hydraulic system limitations follows:

The Koehring 620 with its three gear type hydraulic pumps powered with a Detroit Diesel 4-71N (107 kW (143 H.P.)) could not always perform several major needed functions simultaneously. Even when not cutting trees, the saw apparently requires enough power to cause the engine to stall when trying to swing to bunch and travel at the same time.

For severe travel requirements such as in soft ground or climbing over blowdowns, it was necessary to shut off flow to the saw. The 10 seconds required to return the saw to 1000 r.p.m. reduces machine productivity.

Table 1. Average Condition Factors - Koehring Circ. Saw Trial.

FACTOR	DESCRIPTION
Location	80 km west of Thunder Bay, Ont.
Date and duration of study	Nov. 17 to Dec. 3, 1981.
Stand type	clearcutting residual strips 100 m wide
Species	black spruce 70% jackpine 30%
Stems per hectare	1500
Volume per tree	.095 m^3
Terrain	shallow soils on flat bedrock, with soft lowland areas in between (classified 50% 1.1.1; 50% 3.1.1.*)
Slope	flat
Snow depth	nil to 0.1 m
Average temperature	0 to -10^{o}C

* Mellgren, P.G. Terrain Classification for Canadian Forestry, Can. Pulp & Paper Assoc., December 1980.

Table 2. Production Summary - Koehring Circ. Saw Trial.

Machine and Operations		
Scheduled hours, SMH	(HR)	105
Productive hours, PMH	(HR)	58
Non-mechanical delays*	(HR)	31
Mechanical delays	(HR)	16
Availability		85%
Utilization		55%
Production		
Volume, m^3		1107**
Trees		11 590
Trees per m^3		10.5
Trees per PMH		191
Volume per PMH, m^3		18.2

* Non-mechanical delay was comprised of: 9.5 hr - operator familiarization with machine, 5 hr - machine stuck, 4 hr - no operator due to snowstorm, 1.5 hr - no fuel, 11.0 hr - mainly visitors.

** Scaled volume.

Brush and Unmerchantable Trees - The Koehring circular saw easily cleared away brush and (small) unmerchantable trees in the cutting area by utilizing the saw, but not the grapple arms. In comparison, chain saw and shear felling heads usually sever such trees by going through a complete felling cycle. The Koehring circular saw had a definite advantage in this respect.

Butt Damage - There was no significant amount of butt shatter experienced during the trial (this was important to Abitibi-Price since all sawlog material went to their sawmill in Thunder Bay). The grapple arms did scar a few trees but this was mainly due to the unfamiliarity of the operator with the machine.

Downtime - Most of the downtime during the trial was due to minor adjustments to the wiring, pressures, etc., as this was a prototype. There was one broken hose to the lower accumulator arm and one saw change for a Koehring Ltd. design and strength study; no saw sharpening was required.

Improvements Required:

1. Modification of the hydraulic system (eg. torque-controlled (HP-controlled) variable displacement pumps, closed-loop saw drive) was required since the Koehring 620 was underpowered for simultaneous use of major hydraulic functions.

2. Consideration should be given to using an integral saw of single-piece construction.

3. Re-design of the gooseneck support arm, since accumulated trees were not positioned back far enough in the head. These trees and their branches sometimes interfered with trying to accumulate additional trees. NOTE: Trees are grabbed with the accumulator arms only after they have been severed, not before, as with a shear-equipped feller buncher.

HARRICANA'S CIRCULAR SAW

Development and Initial Results

In early 1980, FERIC staff made a proposal to the management of Harricana Métal to modify their shear felling head to permit the installation of a circular saw. The proposal was accepted and the Mark I prototype unit (see Fig. 5) was built and tested during the next several months.

The carrier designated by Harricana Métal was the John Deere 693, which had a limited hydraulic flow capacity (two gear pumps) providing a flow of 5.3 L/s. Due to this limitation Harricana Métal decided initially to use a thin (fragile) circular saw, since it required less hydraulic flow (torque) than the heavy, rugged, integral saw recommended by FERIC. NOTE: The addition of a third hydraulic pump on the John Deere 693 was considered at this time, but was rejected due to anticipated marketing problems for existing carriers if the unit was successful.

Mark I - This first unit was directly mounted to the boom. A standard .6-cm thick circular saw with approximately 100 inserted teeth was used for this (and for the Mark II and III prototype stages). The Mark I was field tested in June 1980 but several saw-related problems were evident: The narrow kerf of the saw resulted in saw binding if the saw head was not moved horizontally; breakage or loss of the inserted teeth occurred easily.

Mark II - The sliding arrangement for the head, using rollers and a track was added mainly to obtain a horizontal straight-line (rather than arc-type) movement for the head. This idea worked well in subsequent tests.

Mark III - To provide better protection for the fragile saw (e.g. to avoid rocks while placing the head onto a tree) a retractable push plate, mounted below the saw, was added. The retractable push plate idea was not mechanically reliable, due to the exposed cylinders.

Mark IV - The retractable push plate was removed. Also, a protection plate, integral with the track and roller unit was added to protect the saw when in its retracted position. The main improvement however, was the installation of a much heavier, thicker (13-mm) integral (no inserted teeth) circular saw, built by Harricana. The Mark IV prototype worked well and was tested in the forest during February to April 1981.

During the remainder of 1981, a pre-production unit, based on the Mark IV prototype, was designed. Two objectives were to reduce unnecessary weight and to provide better protection for some components. The controls were also changed since a new version of the John Deere 693, which featured hydraulic over hydraulic, pilot-operated valves was now used.

Harricana Trial - Dolbeau, Québec

A Harricana circular saw (pre-production unit) mounted on a John Deere 693A tracked carrier was tested in regular operation by Domtar Inc., Dolbeau, Que., during January and February 1982. The operator observed by FERIC had one year of experience on shear-equipped feller bunchers, and was considered to be a good operator. On the day of FERIC's study he had had two weeks of experience with the Harricana circular saw unit (see Tables 3 and 4).

Production - The productivity during FERIC's time study was 72 trees/PMH, or 22.3 m^3/PMH, based on an average tree size of 0.31 m^3. Although the trees per PMH appeared to be low, this was due to the large tree size, to adverse operating conditions and, to some extent, to the 2-step duty cycle of the Harricana felling head. The mobility of the carrier was greatly reduced in the deep snow, the machine travelled up a 25% uphill slope, plus, the ambient temperature was cold (-35^{o}C). The opinion of the operator, who had operated both shear and circular saw units equipped with tree accumulators, was that the productivity for the circular saw was slightly higher (5-10%) as compared to shears, if operating in similar conditions, mainly due to the faster cutting time for the saw. The operator seldom used the tree accumulator feature due to the relatively large tree size.

Mechanical Limitations - Two mechanical limitations. were observed: when severing large trees (≥40 cm butt dia.) the circular saw sometimes stalled before completing the cut. In such cases the operator would retract the saw to permit it to regain full r.p.m.'s before re-inserting it to complete the cut. This problem could theoretically be solved by increasing the hydraulic flow (and/or pressure) to the saw motor, or perhaps by reducing the saw feed speed. A second limitation of the saw head was that it was not equipped with a tilt cylinder. FERIC personnel observed that leaning trees could usually be cut, but that improper alignment of these trees in the head could result in excessive pressure on the grab arms. A tilt feature would also be useful for working on side slopes.
NOTE: In early March, 1982 Domtar Inc. reported that the 2-month trial of the Harricana pre-production saw head had yielded good results. During January considerable downtime, due to modifications such as additional gussetting, guarding etc. was required. In Feburary, however the machine's availability and productivity was excellent.

Butt Damage and Stump Height - FERIC tests, using a chain saw to remove discs from the butts of trees felled by the circular saw indicated no measurable wood damage (see Fig. 7). Measurement of stump heights was difficult due to the deep snow. Visual observation by FERIC personnel indicated that the stump heights were acceptable by government standards. The "snow blower" effect of the circular saw contributed to the low stumps but also absorbed considerable power from the rotating saw.

Table 3. Average Condition Factors - Harricana Circ. Saw Trial.

FACTOR	DESCRIPTION
Location	80 km north of Dolbeau, Que.
Date of study	Jan. 19, 1982.
Duration	2.17 hr
Species	black spruce 95% white birch 5% (unmerchantable)
Merch. vol. per tree	.31 m^3
Merch. stems per hectare ..	900 (estimated)
Terrain	well-drained hillside, good site (classified as 1.2.2*)
Slope	regular + 25% slope**
Snow depth	1.1 m
Average temperature	$-35^{o}C$

* Mellgren, P.G. Terrain Classification for Canadian Forestry, Can. Pulp & Paper Assoc., December 1980.
** Machine travelled uphill only in FERIC's study.

Table 4. Production Summary - Harricana Circ. Saw Trial.

		Time per cycle, cmin*
Swing empty	Felling cycle	13.8
Position & sever	Felling cycle	13.2
Swing loaded & lower	Felling cycle	17.6
Moving in the stand		32.8
Brushing		6.7
Delays**		2.1
Total cycle time		86.2
Cycles/PMH		70
Trees/cycle		1.04
Trees/PMH		72
Volume per tree, m^3		0.31
Productivity, m^3/PMH		22.3

* cmin = 1/100 minute
** Delays - were due to personal delays - operator.

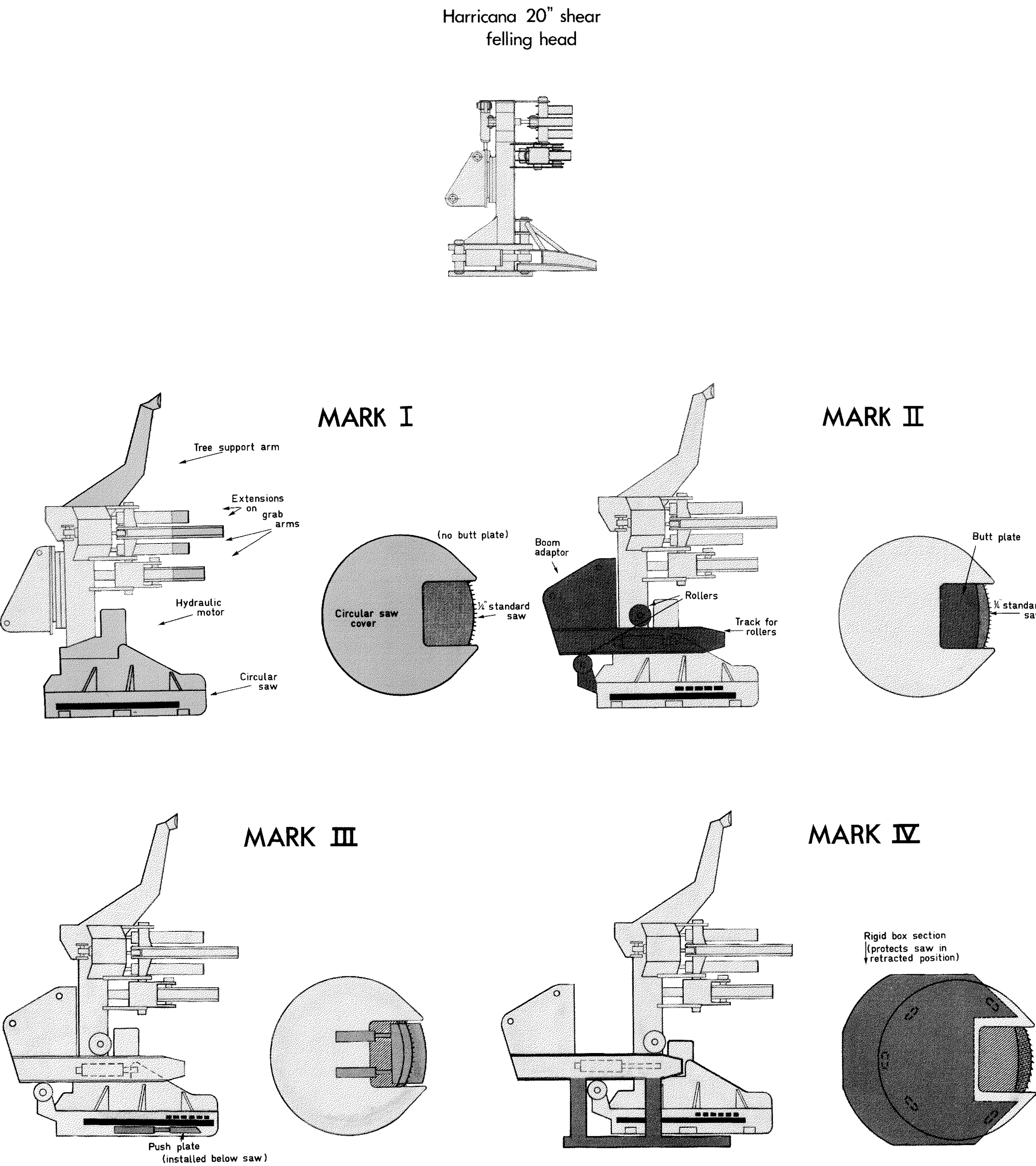

Figure 5. Development of the Harricana Circular Saw Felling Head. Colours are used to show new components.

Figure 6. Harricana Circular Saw on John Deere 693A Carrier; 1: felling and bunching at Domtar Inc., Dolbeau, Qué.; 2: top view; 3: oblique view of the saw felling head; 4: close-up of saw and head design; 5: no butt splitting was observed.

CONCLUSIONS

The preliminary results when using the Koehring and Harricana circular saws indicate that:

1. Butt splitting damage was usually non-existant. This was because there was no bending stress placed on the tree during felling; the grapples did not grab the tree until after it was fully severed. Due to the "sawing" action there was no wood compression damage even in sub-zero weather conditions.

2. Production was up to 20% higher than for shears. Abitibi-Price personnel stated that the Koehring 620 with its 45° offset circular saw, when using a "swathing" felling technique produced 15 to 20% more than a similar, shear-equipped feller buncher in the same stand. This difference in productivity can be expected to increase to 50%, or more, if additional hydraulic system capacity becomes available for the 620 feller buncher, and as additional operator experience is obtained. Additional hydraulic system capacity would permit simultaneous operation of several major hydraulic functions.

   The productivity of the John Deere 693 with the Harricana circular saw was considered by Domtar personnel (and FERIC) to be slightly higher (5-10%) than production obtained with the same carrier using the Harricana shear. The basic duty cycle of this saw was similar to shears because this head was front mounted; thus the boom had to be extended to each tree. A second hydraulic action caused the saw head to move forward, severing the tree. Since two separate actions were required, as opposed to one for the Koehring 45° offset saw, the Harricana had a longer duty cycle.

   Although no specific studies have been done by FERIC to prove this point, it is likely that for larger trees (e.g. over 30 cm dbh) the productivity of the Koehring and the Harricana felling heads will be similar, since trees must be felled and bunched one at a time.

3. Simplicity, Durability and Mechanical Reliability. Compared to chain saw or auger felling heads the circular saw was much simpler since it was comprised of only a few parts (i.e. saw, shaft, bearings and hydraulic motor). The absence of electrical functions on the circular saw felling head also help to "keep it simple".

The circular saw felling head appeared to have a durability similar to shear-equipped feller bunchers. Thus it could easily be used for brushing, pushing over dead or unwanted trees, etc. This is often not possible with chain saw or auger units. Furthermore, undergrowth can be easily and quickly cut using the circular saw.

Due to its simplicity and durability the mechanical reliability of the circular saw head is expected by FERIC to be similar to shear felling heads. For example, a 19 mm-thick circular saw on the A-Line Swather in Saskatchewan was used off and on for 4 years before it required replacement. The saw motor, shaft and bearings during this same period caused virtually no downtime.

Although the Harricana, with its sliding track arrangement provides a more bulky design than the Koehring saw head, the Harricana design provides better protection for the saw teeth from rocks. The Harricana saw is also less likely to be damaged from being dropped onto stumps or if the boom is used to push the machine. Additional experience is required before the relative merits of each design can be fully evaluated.

4. Felling Large Frozen Hardwoods with Lower Stumps. Conventional shears usually have great difficulty felling large, dense hardwoods (e.g. American beech, sugar maple, etc.). Frozen wood conditions often make it difficult to cut these trees during the winter with shears. Shear felling head maintenance costs due to blade breakage, improper blade alignment, pin and bushing wear etc. when cutting "hard" hardwoods can be high (see Fig. 8). Valley Forest Products Ltd., Nackawic, N.B., when visited by FERIC in December 1981, reported that repair costs to the shear felling head on their Koehring Feller Forwarder (KFF) ranged from $5.00 to $10.00 per PMH, due to problems with shearing "hard" hardwoods [14].

   Preliminary results using a Koehring circular saw on the KFF at Nackawic, N.B. (Dec. 1981) indicated that beech and sugar maple up to 46 cm in diameter at the stump could be cleanly severed. Furthermore, the circular saw produced a lower stump; unlike the Koehring shear it did not have to cut above the butt flare.

The results achieved to date with circular saw felling heads have been encouraging. However these results should be regarded as preliminary in nature. Both Harricana Métal Inc. and Koehring Canada Ltd. are planning further changes to their respective felling heads. This will likely result in further improvements in reliability and productivity. FERIC plans to provide machine evaluation reports on both the Harricana and Koehring units during the next year.

Figure 7. Butt splitting damage studied at Dolbeau, Qué. Trees shown were felled by the Harricana circular saw felling head.

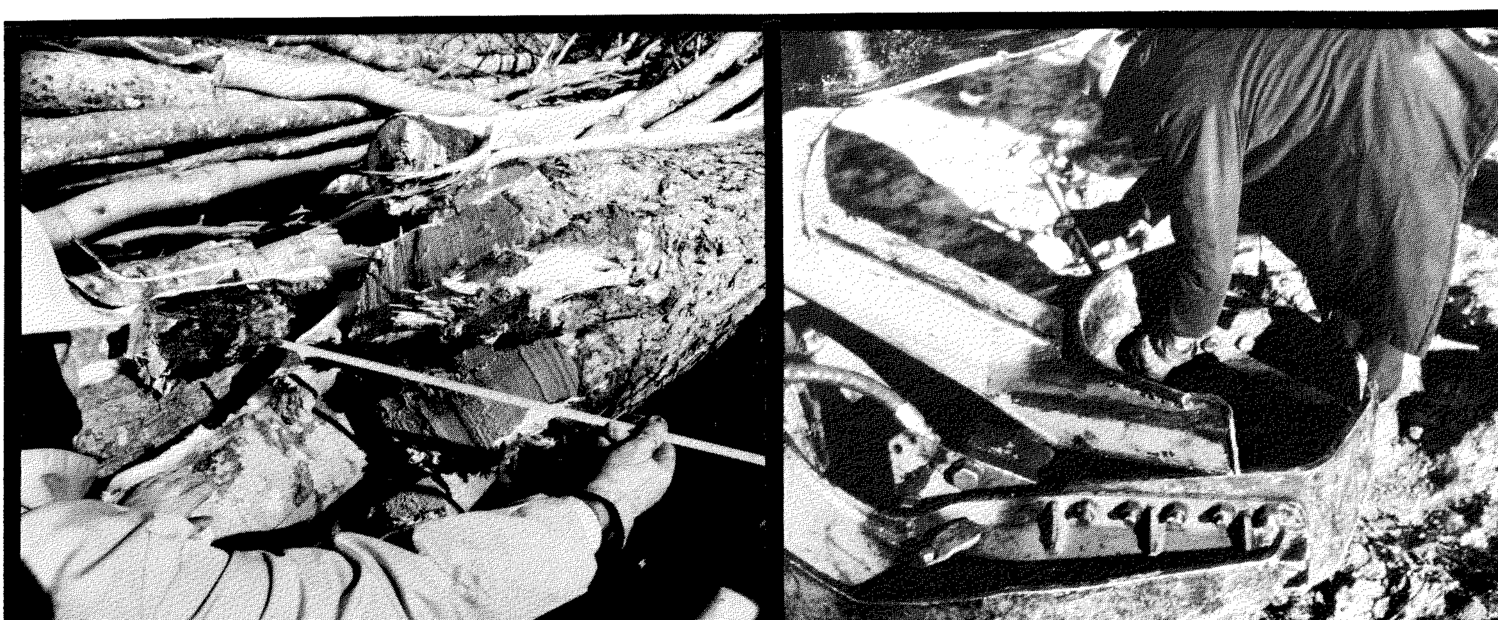

Figure 8. Shear head maintenance costs when cutting frozen 'hard' hardwoods can be high. Left: repeated attempts were required to fell this sugar maple using a shear-equipped KFF at Nackawic, N.B. Right: if high shearing forces are required, high shear maintenance costs often result.

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APPENDIX I

CONVERSION TABLE

1 cm	1 centimetre	: 0.39 inch
1 m	1 metre	: 3.28 feet
1 km	1 kilometre	: 0.62 mile
1 m^3	1 cubic metre	: 0.353 cunit
1 L	1 litre	: 0.22 Imperial gallon : 0.26 American gallon
1 L/s	1 litre per second	: 13.20 Imperial gallons per minute : 15.85 American gallons per minute
1 kg	1 kilogram	: 2.20 pounds
1 kW	1 kilowatt	: 1.34 horse-power : 3,425 BTU
1 kPa	1 kilopascal	: 0.145 pounds per square inch
1 lx	1 lux	: 0.093 foot-candle : 0.093 lumen per square foot
^{o}C	degree Celsius	: $\frac{5}{9}$ (^{o}F-32)