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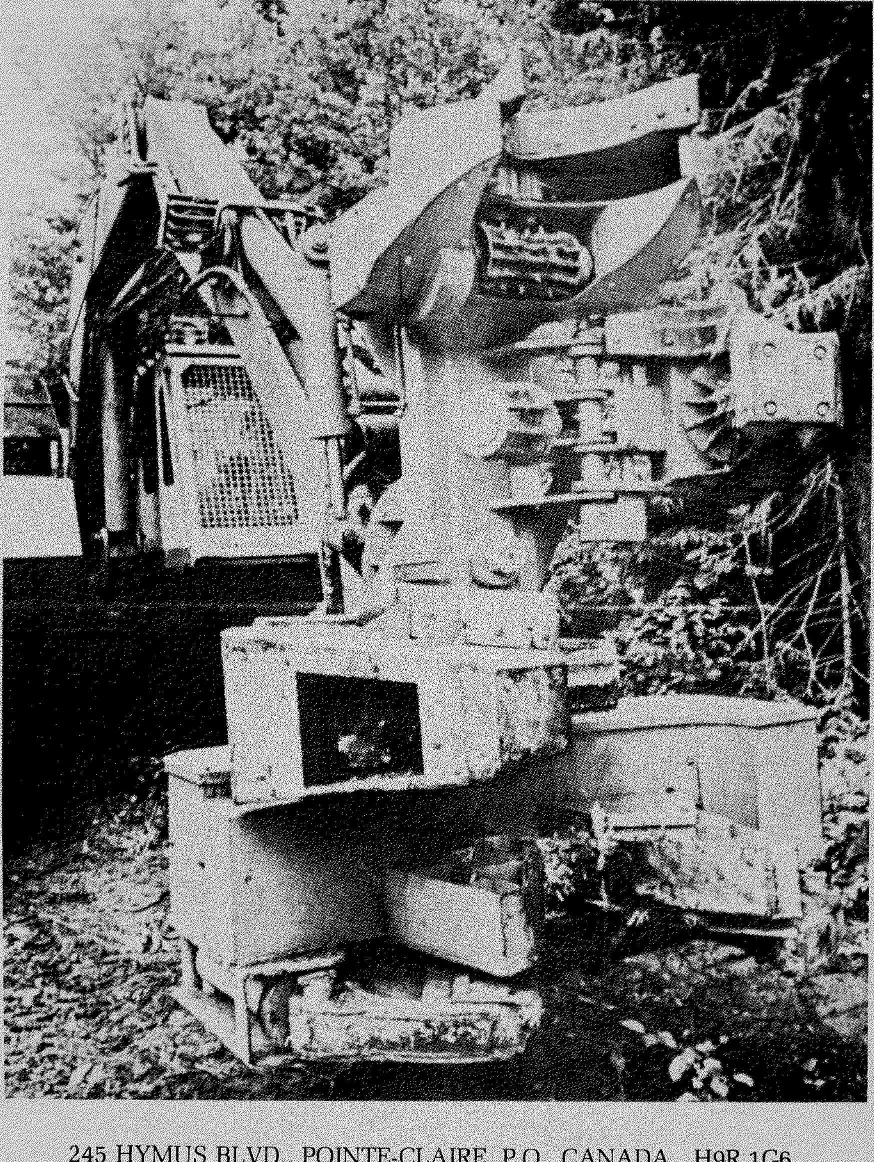
FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

Technical Report No. 3
April 1976

Evaluation of Lajoie "Fibre-Flow" Harvester Head

E. Heidersdorf



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Foreword

This report on the Lajoie "Fibre-Flow" Harvester Head is one in a series included in the project "Evaluation of New Logging Machines". The objectives of this project are the description of new logging machines and their evaluation as to technical characteristics and potential productivity under measured conditions. Estimates of operating costs for the Lajoie head have been omitted from this report, since several carriers are available for the machine. FERIC's evaluations are designed to assist future users in appraising the current status and prospective value of specific logging machines, thus facilitating the choice among available alternatives.

Details of the study procedures and analyses have been omitted from this report to keep it brief. Further details of the study will be supplied on request.

Grateful appreciation is extended to the personnel of Northern Timber Limited, Fredericton, New Brunswick, and to Fraser Companies Limited, Edmundston, New Brunswick, for their cooperation and help during the study.

All quantitative data throughout the report are given in Imperial units. The SI (Système International) equivalents are appended within parentheses.

Table of Contents

Summary

Priced at approximately $35,000 installed, the Lajoie "Fibre-Flow" Harvester Head is a harvesting attachment that can be mounted on a number of standard knuckle-boom carriers. The Lajoie head is equipped with a topping shear and thus can produce *bunches* of both tree-length and short wood.

Interest in the Lajoie head stems mainly from the manufacturer's unique application of a solenoid-controlled hydraulic circuit located entirely within the harvester head. This arrangement substantially reduces the number of pipes and hoses going to the head, thereby potentially reducing repair downtime. To date, the machine has been used only in trial demonstrations. Once it is in regular production on an operation, FERIC plans to monitor availability.

The evaluation of the productive potential of the Lajoie head when producing tree-lengths was carried out in a stand predominantly stocked with balsam fir (*Abies balsamea* (L.) Mill.) on the timber limits of Fraser Companies Limited, Edmundston, New Brunswick.

The average harvesting time per tree was 104 cmin (1.04 min), for an average production of 58 trees per productive machine hour (PMH). The average volume per tree was 5.7 ft^3 (0.16 m^3). Average productivity, as calculated from average time and average volume per tree, was 3.3 cunits (9.2 m^3) per PMH.

Total harvesting time was significantly influenced by the volume per tree and by operator differences. An increase of 1 ft^3 (0.03 m^3) in volume per tree resulted in a 3 cmin increase in harvesting time. The difference between the two operators observed, both of whom were employees of the manufacturer, was 15 cmin per tree.

When adjusted for the tree size and feed roll speed encountered during the Fraser study, results from an earlier study indicated an average productivity of 2.6 cunits (7.3 m^3) per PMH during production of 8-foot (2.4 m) bolts.

In general, limbing quality and efficiency were good during the study. However, some problems did arise during the processing of trees with crooks, forks, large branches, or clusters of branches. The manufacturer is designing an optional device which should eliminate some of these difficulties.

Since this machine may be used in the production of sawlogs, shear damage to the butt ends of the tree-lengths produced was examined. In general, the measured damage did not exceed what would be considered normal trim for sawlogs.

The bunching ability of the machine is excellent, easily permitting the use of grapple skidders.

The Lajoie's major weakness would appear to be its large size and weight, 5,200 lb (2,400 kg), precluding the use of smaller, lower-priced carrier units and contributing to the incidence of high stumps.

Sommaire

La tête abatteuse-ébrancheuse "Fibre-Flow Lajoie" peut être installée sur la plupart des véhicules à flèche articulée. Son prix d'achat, comprenant l'installation, est d'environ $35,000. La présence de ciseaux d'étêtage permet un empilement compact des tiges et des billes de 8 pi (2.4 m), ce qui entraîne un meilleur rendement des débusqueuses à grappin.

Sa caractéristique principale consiste en l'application d'un système hydraulique à commande par solénoïde situé à l'intérieur de la tête d'abattage, éliminant ainsi un bon nombre de boyaux pour une réduction possible de temps d'arrêt.

L'étude a été faite lors de démonstrations sur les opérations de "Fraser Companies Limited", Edmundston, Nouveau-Brunswick, dans un peuplement dense de sapin baumier (*Abies balsamea* (L.) Mill.). Dès que cette machine sera en production régulière, FERIC se propose d'en étudier la disponibilité.

Une production moyenne de 58 arbres en longueur ou 3.3 cunits (9.2 m^3) par heure de travail fut obtenue en regard d'une durée moyenne par cycle de travail de 104 cmin (1.04 min) et d'un volume moyen par tige de 5.7 pi^3 (0.16 m^3).

La durée totale du cycle fut surtout influencée par le volume des tiges et la différence entre les deux opérateurs, lesquels étaient des employés du fabricant. Un accroissement de 1 pi^3 (0.03 m^3) du volume des tiges faisait augmenter cette durée totale de 3 cmin et la différence entre les opérateurs la faisait varier de 15 cmin.

Compte tenu des modifications apportées aux rouleaux d'entraînement ainsi que des conditions de peuplement des opérations de la compagnie Fraser, une étude antérieure permet de prévoir un rendement de 2.6 ct (7.3 m^3) par heure de travail lors de la production de billes de 8 pi (2.4 m).

En général, un ébranchage complet fut obtenu et seuls les arbres fourchus et difformes causaient des problèmes. Un dispositif spécial assurant un meilleur rendement du système d'ébranchage est à l'étude.

Les dommages causés par les ciseaux furent évalués puisque cette tête abatteuse-ébrancheuse peut être utilisée pour les billes de scia-

ge. La perte de volume est considérée comme acceptable pour la plupart des industries de sciage.

Les désavantages de cette tête d'abattage se retrouvent à la fois dans sa dimension et son poids. Sa dimension empêche l'opérateur de sectionner la tige au niveau du sol et son poids limite l'utilisation de porteurs plus légers et moins coûteux.

Introduction

Manufactured by Lajoie Enterprises Ltd., Grand Falls, N.B., the Lajoie "Fibre-Flow" Harvester Head is basically a harvesting attachment which can be mounted on several standard carriers. In productivity, the Lajoie head appears comparable to similar machines on the market. Its competitive advantage lies in the potential for increased availability, reduced maintenance cost and greater versatility. The Lajoie can produce bunches of both tree-length and short wood, thereby showing the versatility required in multi-product logging. Its bunching ability allows for increased efficiency in the subsequent skidding phase of the operation. The potential increased availability stems from the unique application of a solenoid-controlled hydraulic circuit located entirely within the harvester head. This arrangement may lead to savings in terms of hydraulic hose wear.

To assess these claims, FERIC studied the Lajoie head in September 1975 on an operation in central New Brunswick. The machine was later modified to double the flow rate of hydraulic oil to the motors driving the spiked feed rolls used in limbing. Since this modification was expected to improve the machine's productivity, the head was again studied in November 1975 on an operation in northern New Brunswick. The results presented in this report refer to the later study only, with some reference to the earlier study for comparison. Since all the results relate to these two case studies, the results should be applied elsewhere with due caution.

Technical Information

The Lajoie harvester head may be mounted on any standard knuckle-boom carrier capable of furnishing 50 Imp. gpm (225 ℓ/min) at 2000 to 2500 psi (14000 to 17000 kPa). During this study, the unit was mounted on a Drott 40-LC tracked carrier. The head can produce both tree-length and 8-foot wood.

The harvesting head basically consists of:

- a scissor-type hydraulic shear capable of felling trees up to 17 in (43 cm) at the butt,
- two tree holding arms mounted just above the butt shear,
- three curved limbing knives,
- four spiked drive rolls, two being mounted on the grab arms and two on the main frame of the head, and
- a scissor-type topping shear with an 8-inch (20 cm) capacity.

The functions of the head are regulated by electric solenoid-controlled, pilot-operated control valves, all contained within the head itself. These valves are activated from a control console, located inside the cab of the carrier, via an electric cable with 12 circuits, using only 2 to 4 A at 12 V.

The Lajoie head studied weighed approximately 5,200 lb (2,400 kg). The price of the head is about $35,000 installed.

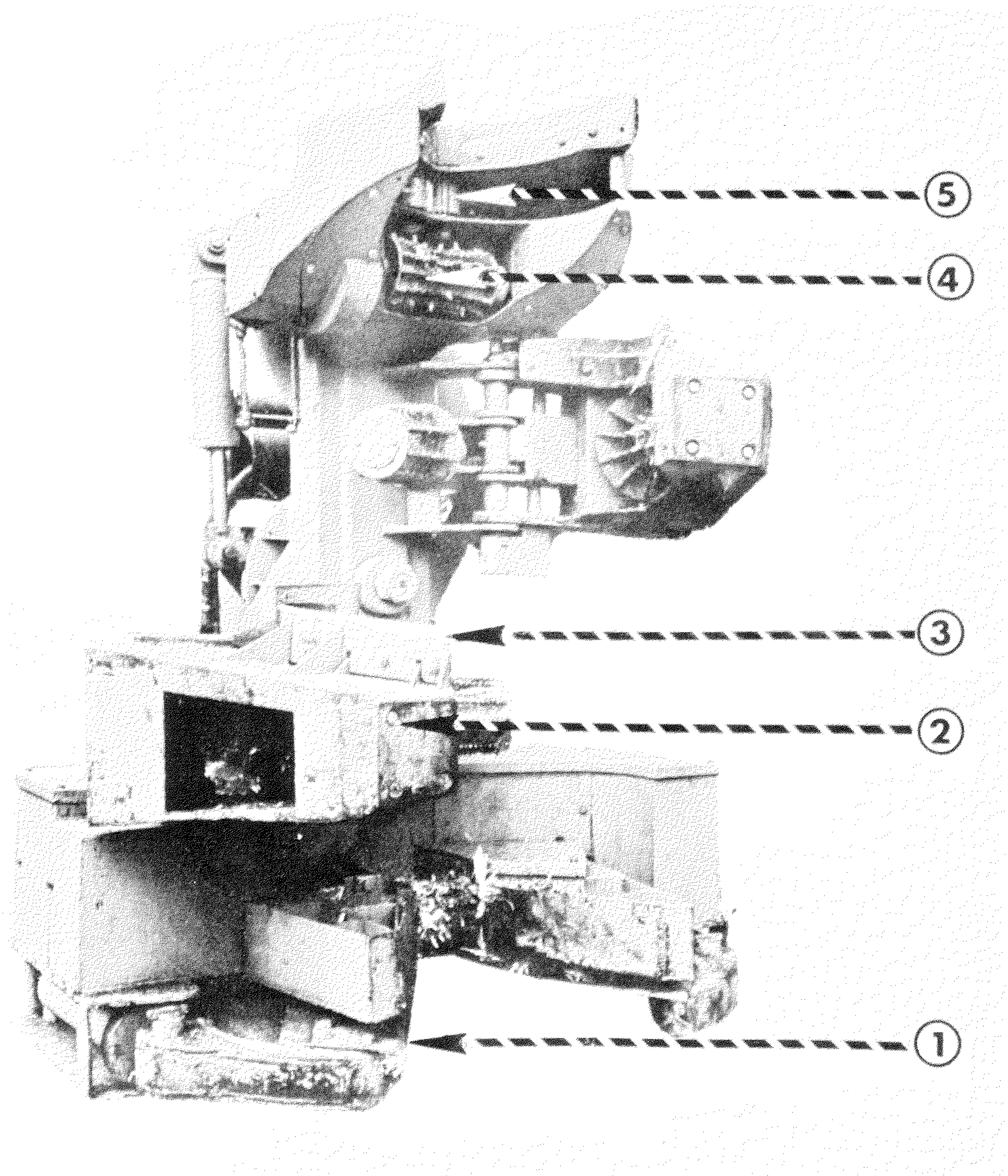

Fig. 1. The Lajoie "Fibre-Flow" Harvester Head. The main components are: (1) hydraulic butt shear — 17 in (43 cm) capacity; (2) holding arms; (3) curved limbing knives; (4) spiked feed rolls; and (5) topping shear — 8 in (20 cm) capacity.

Operating Sequence

The operating sequence of the harvester consists of the following elements, all manually controlled:

Moving — the machine moves into a position from which it can harvest one or more trees. The machine normally harvests a swath about 18 to 25 ft (5 to 8 m) wide along the cutting face, though with the Drott carrier, a maximum reach of 36 ft (11 m) is possible.

Felling — the felling boom is extended to a tree, the felling head positioned and the tree sheared at its base. The sheared tree is lifted vertically and swung to a convenient processing area, where it is tilted into a horizontal position.

Processing — the spiked feed rolls are activated, forcing the tree past the limbing knives. In the production of the tree-lengths, the tree is fed through the head until the desired top diameter is reached. At this point the operator activates the topping shear, removing the top, while the stem is retained by the holding arms. The feed rolls are then reversed, pulling the tree back through the head to approximately the stem's centre of gravity. The processed stem is then dropped into a bunch beside the machine. A resting arm mounted on the side of the carrier is used to support long stems while processing tree-lengths.

When producing 8-foot wood, the head is positioned to feed the tree against a butt plate mounted on the front of the carrier. The operator then places the boom into a fixed position which puts the butt shear one bolt-length from this plate, thereby allowing him to buck the tree into bolts as it is fed through the head. He usually estimates the length of the final bolt by eye and severs it with the top shear.

Brushing — the felling head is used to break or knock over saplings and unmerchantable trees which obstruct felling or moving. Large unmerchantable trees are cut with the shear and dropped beside the machine.

Productivity

The Lajoie "Fibre-Flow" Harvester Head mounted on a Drott 40-LC carrier was studied by FERIC in November 1975 while on trial on the limits of Fraser Companies Limited, Edmundston, New Brunswick. During the study, the machine was producing bunches of tree-length wood. Information concerning condition and operating factors is presented in Appendix A, Table 1.

Results: The average harvesting time per tree was 104 cmin,* for an average production of 58 trees per productive machine hour (PMH). Mean volume per tree was 5.7 ft^3 (0.16 m^3). Average productivity, as calculated from average time and average volume per tree, was 3.3 cunits (9.2 m^3) per PMH.

Analysis: The effects of various operating and environmental factors on the times of elements of the harvesting cycle were evaluated through linear regression analysis. The total harvesting time per tree was significantly influenced by volume per tree and operator differences. An increase of 1 ft^3 (0.03 m^3) in volume per tree resulted in a 3 cmin increase in harvesting time. However, any increase in volume per tree also increased productivity accordingly. There was a 15 cmin-per-tree difference in harvesting time between the two operators observed. Both were employees of the manufacturer and were considered to be good operators. Surprisingly, the more experienced man was the slower, mainly due to an increased occurrence of minor mechanical breakdowns while he was operating during this study. However, he tended to operate the machine more smoothly during the felling and processing cycles and was actually 4 cmin *faster* during processing.

A breakdown of total time into its elements may be found in Appendix B, along with details concerning the relationship of these elements to various operating and environmental factors.

*1 cmin = 1 centiminute = 1/100 minute

Also included is a production nomogram which converts the total time per tree to volume per PMH, or shift, within the limits of the study conditions. Since the nomogram was developed from the conditions of this study, caution should be exercised in applying it to other situations.

Modification Effect: The main objective of the second study was to assess the effect of the increased feed roll speed on processing time. With the same operator and after adjusting for differences in tree size, the modification decreased processing time by some 25% and increased productivity by 10%, compared to the earlier study.

8-Foot Wood: Even though the machine was not producing 8-foot wood during the study, average productivity may be estimated using information from the earlier study and assuming that the increase in feed roll speed affects processing time similarly for tree-lengths and 8-foot wood. Results from the September study then indicated that the average total time for tree-lengths (104 cmin) would be increased by some 29 cmin in the production of 8-foot wood. This would increase the average total time to 133 cmin and result in an anticipated average 8-foot production rate of 2.6 cunits (7.3 m^3) per PMH.

General Comments

Limbing: On the Lajoie, four spiked feed rolls limb the stems by driving them past three curved limbing knives. During the study, the limbing quality was excellent, aided by the increased feed roll speed and the semi-frozen nature of the branches. However, even though the occurrence of hang-ups was reduced by 50% from the earlier study, some difficulties still occurred.

Problems arose during the processing of trees with crooks, forks, large branches (> 1 in (3 cm)) or clusters of branches. Total harvesting time for such problem trees increased by 35% to an average of 140 cmin. On crooked trees, improper alignment of the stem in the feed rolls tended to neutralize some of their driving force. In the other situations, the feed rolls did not generate sufficient momentum to drive the fork or branches past the limbing knives, and the tree would hang up at that point. This problem appeared to be due to inadequate gripping ability of the spiked rolls and not to insufficient power.

When such limbing problems occurred, the operator would often attempt to limb the tree by reversing the feed rolls, placing the tree in an upright position, opening the grab arms and letting the tree drive itself past the limbing knives through gravity. In most instances, this method proved quite satisfactory. Also, the manufacturer has available an optional device to aid in troublesome limbing conditions. This attachment consists of a powered spiked roller, pivoted to the side of the carrier, which drives the tree over the resting arm.

Limbing efficiency was higher during production of tree-lengths than during the production of 8-foot wood. When limbing for tree-lengths, sufficient tree momentum is generated to reduce the occurrence of hang-ups.

Wood Damage: During harvesting, wood damage resulted from several causes:

- Since the harvester produces tree-length wood, and thus potential sawlog material, the shear damage to the butt ends of the tree-lengths produced was examined during the September study. The measured damage compared favourably with results from other harvesting machines using conventional double-bladed scissor-type shears [5, 6, 7] and, in most cases, did not exceed what would be considered normal trim for sawlogs. However, unless shear sharpness and alignment are maintained to the extremely high level observed during the study, shear damage may be expected to increase. Details of the shear damage assessment may be found in Appendix C.

- During limbing, the spiked feed rolls caused severe gouging to trees which became stuck in the head due to crooks, forks, or excessive branchiness. This problem has been greatly alleviated by the increase in feed roll speed.
- Another cause of damage was stem breakage due to the stresses created by the cantilevered position of the trees during processing. This problem was especially prevalent in the earlier study, when many trees were diseased.

Stump Height: To protect the shear blades, they were mounted on the upper surface of the blade frame, approximately 5 in (12 cm) above the lower frame surface which contacts the ground (see Figure 1). With this mounting, therefore, there is an inherent increase in stump height of an equivalent 5 in (12 cm). The shears can be mounted on the lower surface of the frame, but increased blade damage should be expected.

Winter operation of the Lajoie may result in high stumps due to the size of the harvester head itself. The contact area of the lower assembly is large enough (>2,500 in^2 (1.6 m^2)) to prevent penetration under certain snow conditions. Also, the entire lower surface of the head is flat, and snow will therefore be compressed rather than moved aside.

In winter, high stumps may also create serious obstacles to the movement of the carrier. During the study, the carrier sometimes rode up onto stumps and hung there since it could not develop sufficient traction in the 3 in (8 cm) of snow to free itself. The operator was then forced to use the boom to push the machine off. These delays doubled the moving time over that in the earlier study under dry, snow-free conditions.

Ergonomics: Measurements were made of the levels and frequencies of noise generated by the Drott 40 carrier. With the engine at full throttle, sound pressure levels averaged 84 dBA and 81 dBA respectively with cab door open and closed. Both these values fell well below the current permissible limit for continuous exposure now in force in the U.S.A. and in some parts of Canada. Additional results of the noise measurement may be found in Appendix D, Figures 4 and 5.

The toggle-operated electrical controls for the processing head are located compactly and are easy to operate (see Figure 2). However, the operator also has to operate the four principal fool pedals and three principal handlevers of the Drott 40 carrier. One operator on the machine studied described his work as "tedious" but not "too strenuous".

Bunching Ability: The use of a separate shear for topping meant that the trees were held in the grab arms at all times, allowing for control in bunching the stems. The operators observed took great care in arranging their bunches, both tree-length and 8-foot in the earlier study. Such practice adds somewhat to the total harvesting time per tree but may result in substantial time savings in the subsequent skidding or forwarding stage. The neat tree-length bunches would easily permit the use of grapple skidders (see Figure 3).

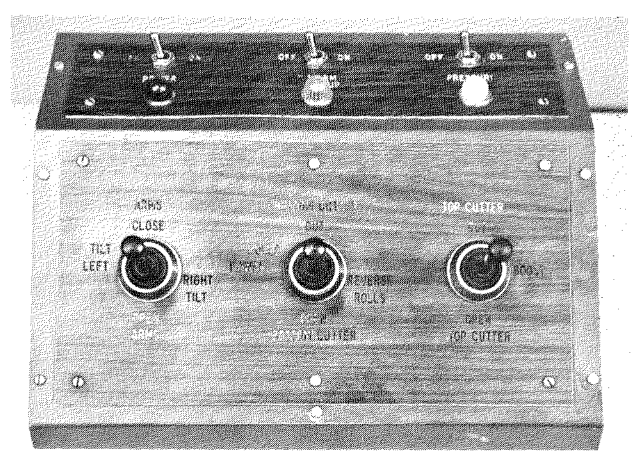

Fig. 2. Electrical control console.

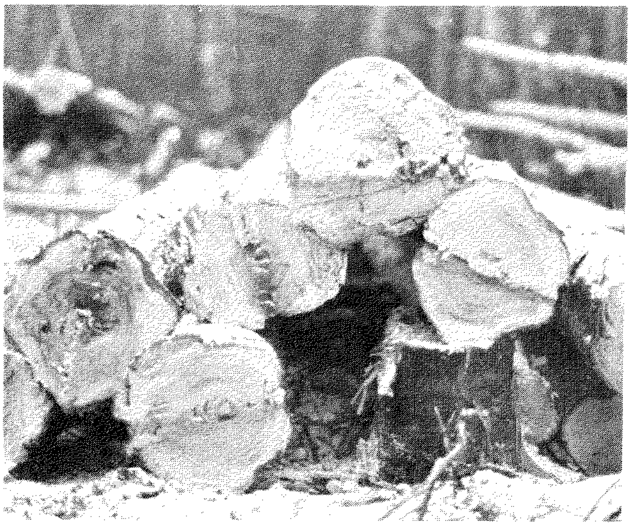

Fig. 3. The Lajoie head produces neat bunches of tree-length wood.

General: Since all valves and hoses for shears, clamps, and feed rolls are contained within the harvester head itself, only a pressure and a return line are required between the head and the hydraulic pump on the carrier. This facilitates mounting the head onto the carrier's boom and decreases the amount of hose and pipe exposed to flexing and damage.

However, this advantage is somewhat tempered by the weight that these valves add to an already heavy head. The head weighs 5,200 lb (2,400 kg), thereby precluding the use of smaller, lower-priced carrier units.

Conclusions

The Lajoie "Fibre-Flow" Harvester Head is a versatile machine that fits into the trend toward multi-product logging. It can harvest either tree-lengths or bolt-lengths, permitting fuller utilization of the timber. The machine does have its weaknesses, its massive size possibly being the most important. However, the unit studied was still a prototype, and some of the unfavourable features observed may be modified on production units.

The productivity observed was somewhat lower than that reported in studies of two similar harvesting machines [2, 3]. However, those machines merely windrowed the tree-lengths, rather than bunching them as the Lajoie did.

It is too early to tell if the manufacturer's claim of increased availability will be substantiated, since this can only be determined over a longer period of observation. The Lajoie machines are now working in trial demonstrations. As soon as one of these machines goes into regular operation, FERIC plans to monitor its availability and long-term production.

APPENDIX A

TABLE I

Average Condition and Operating Factors

Factor	Imperial Units Mean	S.D.	Range	S.I. Units Mean	S.D.	Range
DBH, in (cm)	7.5	1.8	5-16	19	4.6	13-41
Volume per tree, ft^3 (m^3)	5.7	4.1	1.3-33	.16	.12	.04-.93
Merchantable stand volume, ct/acre (m^3/hectare)	31			220		
Number of merchantable trees per acre (hectare)	750			1850		
Slope	8% side slope					
Snow depth, in (cm)	3			7.5		
Species distribution, % of stems	Fir 85% Spruce 15%					
Branchiness, * % of sample	Class 1 — 47% Class 2 — 31% Class 3 — 22%					

$$\text{*Branchiness } \% = \frac{\text{merchantable length of stem bearing live branches}}{\text{total merchantable length}} \times 100$$

Class 1= 0 - 33%
Class 2= 34 - 66%
Class 3= 67 - 100%

S.D.=standard deviation
Stand factors based on two 1/40-acre (100 m^2) sample plots
Tree factors based on 207 observations

APPENDIX B

Productivity

Definition of Time Elements

1. **Moving in stand** begins when forward or backward movement starts and ends when the movement stops.
2. **Felling cycle** includes reach for tree, position and shear, and position for processing. These elements were not separated. After a move, the felling cycle begins when movement stops. If no move has occurred, the felling cycle begins when the felling head starts to swing toward a new tree after dropping the previous tree or, in short-wood, the last bolt of the previous tree, into a bunch. Felling cycle ends when the drive rolls are actuated for limbing.
3. **Processing cycle** includes limbing, bucking (in short-wood), topping and placing of trees or bolts into a bunch. These elements were not separated. The processing cycle begins when the drive rolls are activated for limbing and ends when the felling head starts to swing toward a new tree. If the processing cycle precedes a move, the processing cycle ends when movement begins.
4. **Brushing** includes the removal of saplings and brush and the felling of unmerchantable trees. For unmerchantable trees, the felling cycle is measured and recorded as brushing.
5. **Delays** include operational delays, mechanical breakdowns and personal delays. They are treated according to their duration.

0 — 5 cmin, are included in the above elements (1-4).
5 cmin — 10 min are recorded as "Delays".
>10 min are not considered as part of productive time and are therefore excluded.

TABLE II

Summary of Times per Merchantable Tree

Elements	Cmin per tree Mean	S.D.	Range	Equation	R^2
Moving in stand	14	38	0-423		
Felling cycle	43	10	23-80		
Processing cycle	31	18	14-169	17+3.0 VT — 4S* [17+106 VTM — 4S*]	.49
Brushing	8	18	0-101		
Delays	8	63	0-642		
Total time per tree (=sum of above elements)	104	23	66-239	75+3.4 VT+15S [75+120 VTM+15S]	.50

S.D. = standard deviation
VT = volume per tree, ft^3
VTM = volume per tree, m^3
S = 1 for slower operator, = 0 otherwise
R^2 = coefficient of multiple determination
* = regression coefficient significant at .05 level of significance
All unstarred regression coefficients are significant at the .001 level.
All regression coefficients in brackets use SI units of measure.
Based on 207 observations.

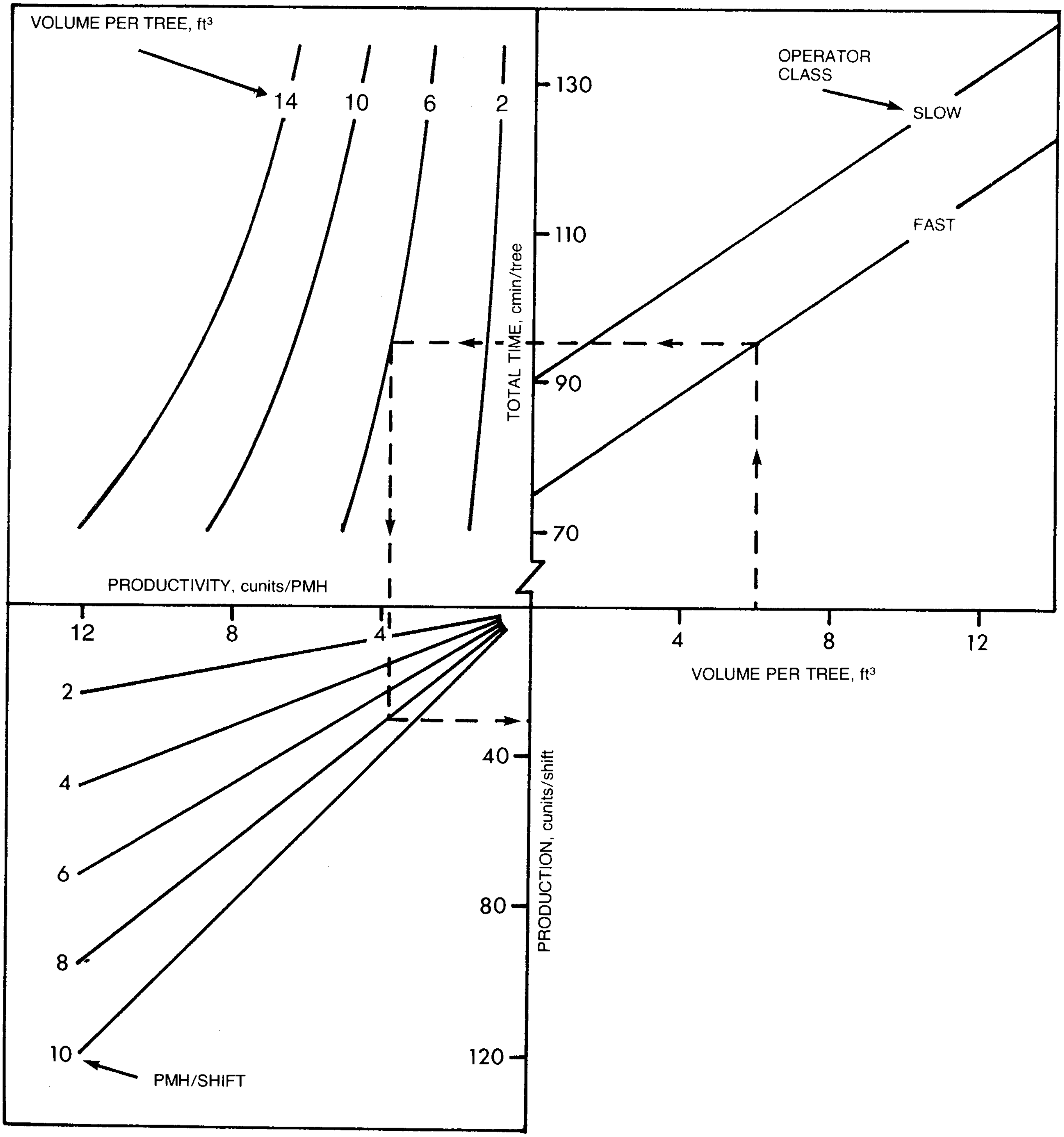

Fig. 4. Production Nomogram. CAUTION: The nomogram is based on the equation (Table II) that estimates the harvesting time for an individual tree. The average harvesting time per tree for a stand therefore equals the average harvesting times for each tree or each tree-volume class, calculated from the equation. Entering the nomogram (or equation) with the average volume per tree for a stand will underestimate the potential harvesting time per tree and thus overestimate productivity. However, the error will be small (<5 cmin per tree) if the proportion of large trees (>15 ft^3 (0.4 m^3)) in the stand is small (<5%). If the proportion of large trees exceeds this limit, then the nomogram should not be used, and stand estimates should be made by applying actual volume distributions to the equation in Table II.

APPENDIX C

Shear Damage

Damage from the hydraulic shear used for felling is important when the tree-lengths produced are to be used as sawlogs. Therefore, the extent of damage on a sample of sound trees was assessed during the September study, using a visual technique for detecting splits and cracks. The results of the study are presented in the table below. The measured damage compared favourably with results from other machines using conventional double-bladed scissor-type shears, where damage length averaged from 8 to 14 in (20 to 35 cm) [5, 6, 7]. This may be partly because the shear blades were new, sharp, and properly aligned.

TABLE III

Summary of Shear Damage

Sample size	40 trees (62% spruce, 35% fir, 3% pine)
Ambient temperature when cut	approximately 70°F (21°C)
Minimum butt diameter (i.b.) range	4-12 in (10-30 cm)
Average damage length	6 in (14 cm)
Range damage length	2-28 in (5-70 cm)
Average volume lost	0.13 ft^3 (3,770 cm^3)
Percent of merchantable volume lost	3.4%

APPENDIX D

Noise

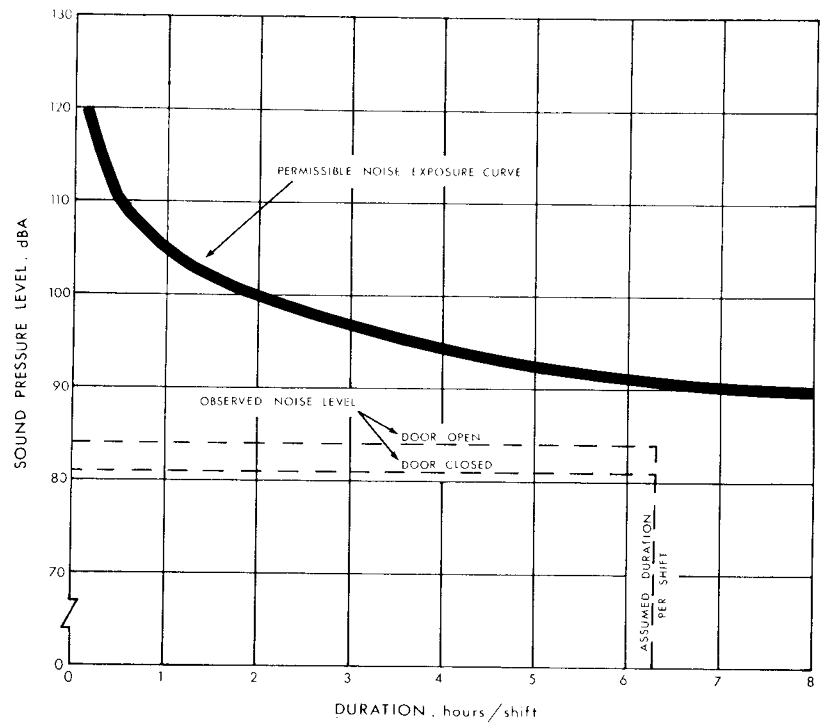

Fig. 5 Observed average noise level (dBA) inside the cab (door both open and closed) plotted by estimated exposure time, compared to the current permissible exposure curve of the U.S. Department of Labor (1). All observations with engine at full throttle.

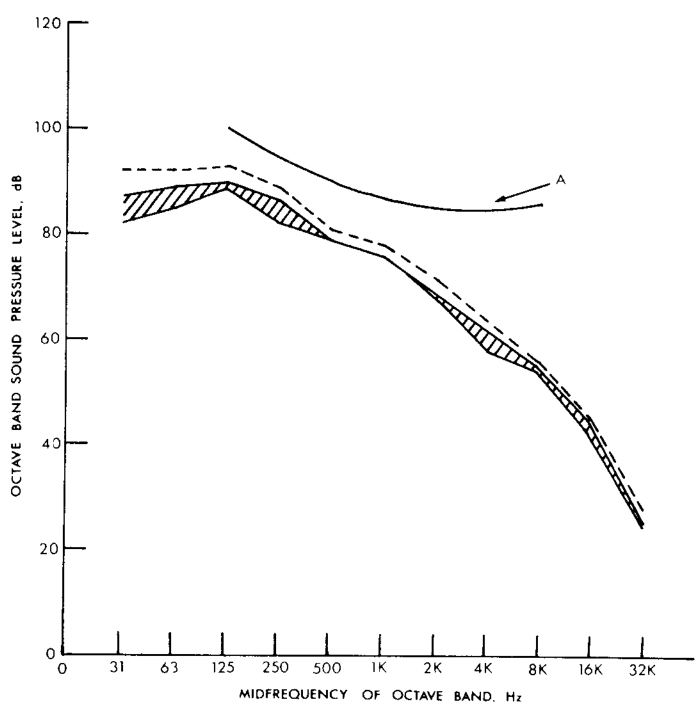

Fig. 6 Observed noise levels in octave bands. The hatched area shows average levels and the dashed line the maximum levels. Curve A shows the damage risk curve for one exposure per day of duration less than 6 hours to 1-octave band of noise. This curve is interpolated from Kryter. *et al.* (4).

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