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FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

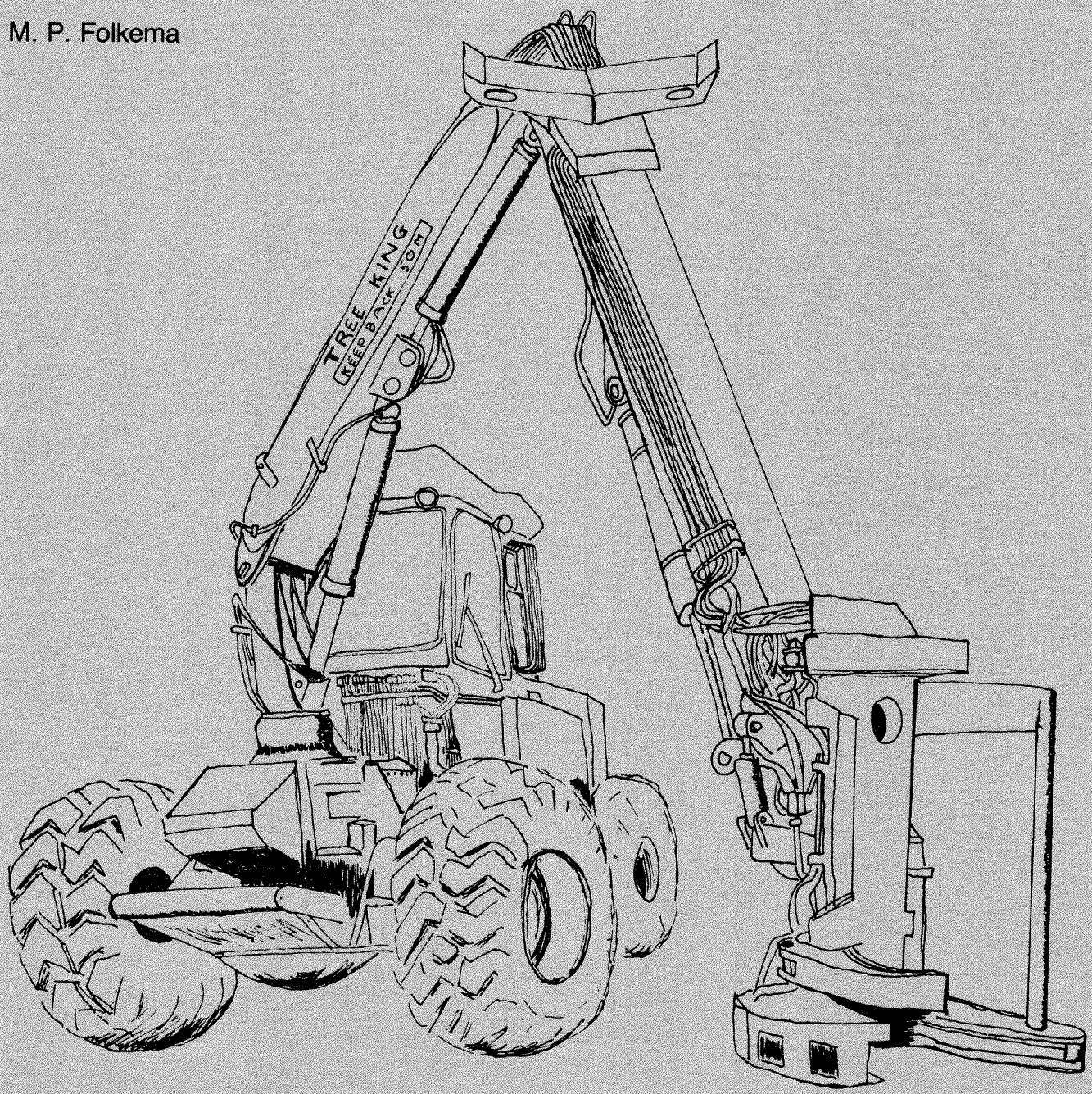
INSTITUT CANADIEN DE RECHERCHES EN GENIE FORESTIER

Technical Report No. TR-13

April 1977

Evaluation of Kockums 880 'Tree King' Feller-Buncher

M. P. Folkema



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Foreword

This report, which describes a study of certain technical and operating characteristics of the Kockums 880 Tree King, is designed to assist future users in appraising the machine's current status and prospective value.

Short-term studies such as this one cannot fully explore the long-term productive potential of machines that may later work under a broad range of conditions. Moreover, the ultimate success of a new machine will depend not only on its productivity, but also on its mechanical availability and the cost of maintenance. Hence, FERIC plans longer term follow-up studies of the Kockums 880 Tree King. The information obtained will be distributed as a supplement to the technical report.

Due to the uncertainties in predicting future machine costs, the examples presented in this report should be regarded simply as *examples* of realistic expectations. Readers should adapt FERIC costing procedures and nomograms to their own operating conditions.

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

Grateful appreciation is extended to company personnel of Abitibi Paper Company Ltd., Lakehead Woodlands Division, Thunder Bay, Ontario, and to Kockums Limited, Guelph, Ontario, for their cooperation and help during the study.

Technical assistance provided by FERIC employee E. Vajda is also gratefully acknowledged.

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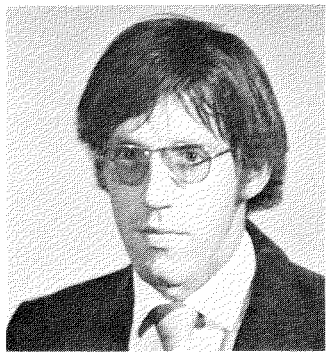

M.P. Folkema received his B.Sc. Forestry from Lakehead University in 1973. From 1973 to 1975 he was employed by the forestry department of Saskatchewan Forest Products Corporation. In 1975, he joined the staff of FERIC in Pointe Claire, Quebec, to work on machine evaluations and related projects.

He is a member of the Canadian Institute of Forestry and of the Woodlands Section, Canadian Pulp and Paper Association.

Summary

The Kockums 880 Tree King is a wheeled feller-buncher that is capable of high productivity under a wide variety of conditions. The machine was originally designed in Sweden, where more than 150 units are now in operation. The machine has recently been introduced to the North American market.

Interest in the Tree King, which is priced at $138,000, has resulted mainly from a number of design and operating features: the optional chain saw felling head, the oscillating front axle, and the comfortable, air-conditioned operator's cab. The chain saw felling head is of particular interest for the harvesting of sawlogs, since damage to butt logs is eliminated.

A FERIC study of the Kockums 880, equipped with a chain saw felling head, was carried out on the operations of Abitibi Paper Co. Ltd. near Beardmore, Ontario. The machine was operated by an employee of Kockums Ltd. who was considered to be an excellent operator. Time studies were made in three distinct stands. The stand and productivity factors are summarized in Table 1.

The chain saw felling head functioned very effectively during the study. Time required for cutting varied in relation to tree size; thus large trees were cut more slowly. The number of chain sharpenings/replacements per shift depends mainly on the ground conditions and the skill of the operator. The manufacturer's claims of three or four chain sharpenings per shift do not seem unreasonable.

Generally, the maintenance cost for chain saws are expected to be somewhat higher than for shears, mainly because saws are more susceptible to operator abuse and to damage from rocks and other objects.

On many Canadian operations there is a growing concern about lumber losses resulting from damage to the butt logs caused by hydraulic shears, particularly during the winter months. The Kockums 880 chain saw felling head provides one alternative to the use of shears. At the present time the chain saw felling head is not available as a separate unit.

Cost projections for the Tree King, based on both favourable and unfavourable estimates of other cost factors ranged from $5.10 to $13.11 per ct ($1.80 to $4.63/m^3).

The Kockums 880 appears to be a stable machine capable of working on rough ground or moderate slopes. However, the terrain in the study area was not sufficiently steep to fully test the machine's stability. Observations of several Kockums 880's working in the B.C. Interior indicate that in some cases it may be feasible to operate on slopes up to 30%, depending on tree size and other related factors.

When working in a lowland black spruce site, the machine encountered some flotation problems. Larger, wider tires are available for the Tree King, which should help to reduce this problem.

An ergonomic appraisal of the Kockums 880 rated the machine high in operator safety and comfort, reflecting the fact that the machine was built to conform to the stringent Scandinavian regulations concerning the operator's work place. Noise levels in the cab with the machine running full throttle reached 84 dBA, well below the maximum permissible limits established by the U.S. Department of Labor.

Table 1. Stand Factors and Productivity

	Stand 1	Stand 2	Stand 3	Average
Average volume per tree, ft^3 (m^3)	5.1 (0.14)	9.1 (0.26)	5.0 (0.14)	5 3 (0.15)
Merchantable trees per acre (ha)	395 (976)	149 (368)	436 (1077)	398 (983)
Unmerchantable trees per acre (ha)	negligible	94 (232)	20 (49)	16 (40)
Trees per productive machine hour (PMH)	154	113	158	150
Productivity, ct (m^3) per PMH	7.8 (22.1)	10.4 (29.4)	7.9 (22.4)	8.0 (22.6)

Sommaire

L'engin forestier Kockums 880 Tree King est une abatteuse-empileuse montée sur roues et capable d'une haute productivité dans les conditions les plus diverses. Cet engin a été conçu en Suède où plus de 150 unités sont actuellement en opération. Il a été récemment mis sur le marché nord-américain.

Le Tree King, qui se vend $138,000, suscite de l'intérêt à cause de certaines de ses caractéristiques de conception et d'opération, notamment: la tête abatteuse à scie mécanique, qui est optionnelle, l'axe avant oscillatoire et la confortable cabine à air climatisé du conducteur. La tête abatteuse à scie mécanique est particulièrement intéressante dans le cas de la récolte des bois destinés au sciage puisque tout dommage aux billes de souche est éliminé.

FERIC a effectué une étude de l'engin Kockums 880 sur une aire de coupe de la Compagnie de Papier Abitibi Ltée, près de Beardmore, Ont.; l'engin, équipé d'une tête abatteuse à scie mécanique, était conduit par un employé de Kockums Ltd. considéré comme excellent conducteur. Des études de temps furent faites dans trois peuplements différents. Les caractéristiques des peuplements ainsi que les facteurs de productivité sont résumés dans le tableau 1.

La tête abatteuse à scie mécanique a très bien fonctionné lors de cette étude. Le temps requis pour la coupe variait selon la grosseur des arbres, fréquence d'affûtage de la chaîne où son remplacement dépend principalement des conditions de terrain et de la compétence du conducteur de la machine. Selon le manufacturier, il ne serait pas déraisonnable qu'il faille affûter la chaîne trois à quatre fois par quart de travail.

En général, le coût d'entretien des scies mécaniques devrait être un peu plus élevé que l'entretien des cisailles parce que les scies sont plus susceptibles d'être endommagées par le maniement abusif du conducteur ou par les roches et autres objets.

Sur plusieurs sites d'exploitation forestière au Canada, on s'inquiète de plus en plus des pertes de bois résultant des dommages causés aux billes de souche par les cisailles hydrauliques, particulière-

ment durant les mois d'hiver. La tête abatteuse à scie mécanique du Kockums 880 offre un substitut aux cisailles. Pour le moment, la tête abatteuse à scie mécanique n'est pas disponible comme pièce séparée.

Les estimations de coût pour le Tree King, basées sur l'évaluation la plus favorable et la plus défavorable des autres facteurs de coût, varient entre $5.10 et $13.11 par cunit ($1.80 à $4.63/m^3).

Le Kockums 880 semble être un engin stable, capable de travailler sur un terrain difficile ou sur des pentes modérées. Toutefois, les pentes où la machine travaillait n'étaient pas assez raides pour permettre une appréciation adéquate de sa stabilité. Les observations faites sur plusieurs Kockums 880 opérant à l'intérieur de la Colombie Britannique indiquent que dans certains cas, ces engins peuvent travailler sur des pentes allant jusqu'à 30%, dépendant de la grosseur des arbres et d'autres facteurs connexes.

Quelques problèmes d'enlisement furent notés lorsque la machine travaillait sur des terres basses d'épinette noire. Des pneus plus gros et plus larges seraient une solution à ce problème.

D'après une étude ergonomique, la Kockums 880 est hautement cotée en ce qui a trait à la sécurité et au confort du conducteur, ce qui signifie que la machine a été construite en conformité avec les règlements scandinaves les plus sévères relativement au lieu de travail du conducteur. Le niveau de bruit dans la cabine lorsque le moteur tourne à pleine vitesse a atteint 84 dBA, soit un niveau bien inférieur à la limite maximale permise par le Département de Travail des États-Unis.

Tableau 1. Caractéristiques des peuplements et facteurs de productivité.

	Peupl. 1	Peupl. 2	Peupl. 3	Moyenne
Volume moyen par arbre pi^3 (m^3)	5.1 (0.14)	9.1 (0.26)	5.0 (0.14)	5.3 (0.15)
Arbres marchands à l'acre (ha)	395 (976)	149 (368)	436 (1077)	398 (983)
Arbres non-marchands à l'acre (ha)	négligeable	94 (232)	20 (49)	16 (40)
Arbres par heure-machine productive (HMP)	154	113	158	150
Productivité, ct (m^3) par HMP	7.8 (22.1)	10.4 (29.4)	7.9 (22.4)	8.0 (22.6)

INTRODUCTION

Kockums 880 Tree King feller-bunchers for the North American market are assembled by Kockums Limited at Guelph, Ontario. The Tree King has been in regular use in Sweden for about 2 years, where, at the time of writing, approximately 150 were in operation. Only recently has the machine been available for North American distribution. The Kockums 880 studied by FERIC was equipped with a chain saw felling head and was one of the first machines operating in Canada.

Technical Information

The Kockums 880 Tree King is a wheeled feller-buncher consisting of a carrier equipped with a felling unit mounted on a knuckle boom. It is powered by a 156 hp (116 kW) engine, and has a torque converter, a power shift gearbox and mechanical drive on all wheels. The frame is articulated and the front axle is oscillating.

The knuckle boom has a 19.7 ft (6 m) out-reach. The felling unit is available with a chain saw having a maximum cutting capacity of 23 in (58 cm) and a ¾ in (1.9 cm) kerf, or with a Brundell-Jonsson (BJ) shear with spherical blades, having a cutting capacity of 20 in (50 cm).

The Tree King weighs approximately 33,000 lb (15,000 kg) and is normally mounted on 23.5 x 25, 16-ply tires. High flotation tires, 30.5 x 32, are available for soft ground operations. The current selling price (f.o.b. Guelph, Ontario) is approximately $137,000 if equipped with the BJ shear, and $138,500 if equipped with a chain saw felling head. The BJ shear is supplied to the Canadian market by Forano Ltd. and is available in limited quantity. More detailed manufacturer's specifications are presented in Appendix A.

FIELD WORK

The Kockums 880 Tree King was studied by FERIC during a 3-day period in October 1976 on the limits of Abitibi Paper Company, Ltd., near Beardmore, Ontario. The primary objective of the study was to assess the productivity of the feller-buncher in different stands under measured conditions and operating factors. During the study the machine was operated by an employee of Kockums (Sweden) Ltd., who proved to be an excellent and highly motivated operator.

On this operation the felled trees were usually placed into small bunches of three to five trees for subsequent skidding by choker skidders. Chain flail delimbing and manual topping were carried out at roadside.

The field study was conducted in three stands located in the same general area. Stand and terrain characteristics are summarized in Table 2.

Operating Sequence

The operating sequence of the feller-buncher consists of the following elements;

Moving — the machine moves into a position from which it can harvest one or more trees. The machine can harvest a swath up to 39 ft (12 m) wide. Normally, the swath width is approximately 29 ft (9 m).

Felling — the felling boom is extended to a tree. The grab arms close around the tree, which is then sheared or sawn at the stump. The tree is lifted vertically and swung so that it can be placed in a bunch. On this operation bunches were located perpendicular to the cutting face. Generally, bunches are at a 20-35° angle to the feller-buncher travel with the butts facing the landing to facilitate extraction (flow) by a clam or grapple skidder.

Brushing — the felling boom is used to knock over or fell saplings and unmerchantable trees.

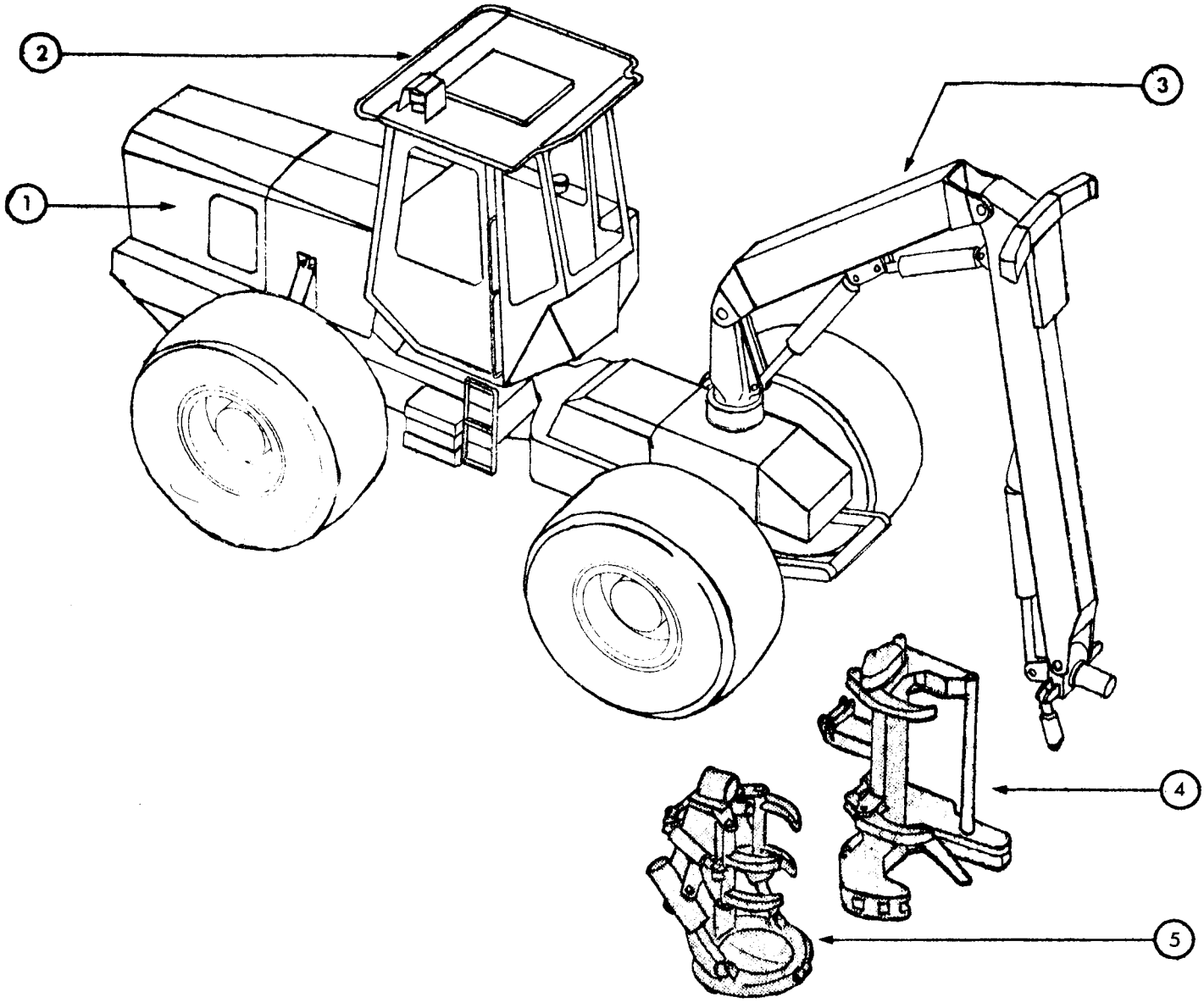

Fig. 1. The Kockums 880 Tree King. Main components are: 1. 156 hp (116 kW) Scania diesel engine 2. cab with roll-over protection 3. felling boom 4. optional — 23 in (58 cm) Kockums chain saw felling head 5. 20 in (50 cm) BJ spherical shear felling head.

Table 2. Stand and Terrain Factors

Factors	Stand 1	Stand 2	Stand 3
Average DBH, in (cm)	6.8 (17)	8.7 (22)	6.8 (17)
Average volume per tree, ft^3 (m^3)	5.1 (0.14)	9.1 (0.26)	5.0 (0.14)
Merchantable trees per acre (ha)	395 (976)	149 (368)	436 (1077)
Unmerchantable trees per acre (ha)	negligible	94 (232)	20 (49)
Saplings per acre (ha)	240 (592)	76 (188)	25 (62)
Roughness	level	hummocks	level
Maximum sustained slope, %	negligible	±15	±15
Other factors	lowland black spruce	—	some windfalls
Species composition	black spruce 94% balsam fir 6%	white spruce 56% poplar 33% balsam fir 6% white birch 5%	black spruce 67% jack pine 29% poplar 4%

black spruce (*Picea mariana* (Mill.) B.S.P.)
balsam fir (*Abies balsamea* (L.) Mill.)
white spruce (*Picea glauca* (Moench) Voss)
white birch (*Betula paperifera* Marsh.)
jack pine (*Pinus banksiana* Lamb.)
poplar (*Populus spp.*)

RESULTS

Productivity

The Kockums 880 feller-buncher performed well during the study, with only a few minor mechanical delays. The results of the time study are summarized in Table 3.

In stand 1, the Kockums 880 felled and bunched trees at a rate of 154 trees per productive machine hour (PMH). Average productivity as calculated from average time and average volume per tree, was 7.8 ct (22.1 m^3) per PMH.

Table 3. Summary of Productivity Data

	Time per tree, cmin			
	Stand 1	Stand 2	Stand 3	Stands 1, 2 & 3
Moving in the stand	10	17	7	9
Brushing	1	1	1	1
Felling cycle	26	35	28	28
Delays	2	0	2	2
Total time per tree	39 ±7.2	53 ±13.0	38 ±8.3	40 ±8.5
Number of trees harvested	384	62	469	915
Trees per productive machine hour (PMH)	154	113	158	150
Productivity, ct (m^3) per PMH	7.8 (22.1)	10.4 (29.4)	7.9 (22.4)	8.0 (22.6)

±x = Standard deviation

In stand 2, the rate of felling and bunching was lower, due to the presence of a large number of unmerchantable hardwoods. The machine produced at a rate of 113 trees per PMH. However, due to the higher average volume per tree in this stand productivity averaged 10.4 ct (29.4 m^3) per PMH.

In stand 3 (Figure 2) the Kockums machine averaged 158 trees per PMH, for an average productivity of 7.9 ct (22.4 m^3).

For stands 1 and 3, the felling cycle averaged 27 cmin. In stand 2, the felling cycle was longer (35 cmin), mainly because the large number of residual trees in this stand made the bunching of trees more difficult (see Figure 3 (right)).

The moving time in the stand, including time spent returning to the front of the cutting strip, varied considerably among the three stands. The Kockums 880 spent 10 cmin per tree moving in stand 1, 17 cmin in stand 2, and 7 cmin in stand 3. The prolonged moving time in stand 2 resulted from the lower tree density and from the large number of residual unmerchantable trees.

Bunch Sizes

On this operation, choker skidders were used for skidding the full trees to roadside. Most of the bunches were small to facilitate

Fig. 2. The Kockums 880 operating in stand 3.

Fig. 3. (left) Felled trees were usually placed in small bunches. (right) Stand 3. Poplar windfalls were easily traversed by the Kockums 880.

choking, with an average of only 3.9 trees per bunch. Usually the Kockums operator placed the bunches on windfalls or stumps for easier choking.

If large bunches were required from the Kockums 880, the machine would have to carry some of the trees to the bunch. An earlier study of the Drott feller-buncher [6] has shown that volume per bunch can be increased substantially (i.e. from 54 to 96 ft^3 (1.5 to 2.7 m^3)) with only a very small increase on the harvesting time per tree. It is expected that the above relationship would also exist if large bunches were required from the Kockums 880.

While the formation of large bunches may decrease the feller buncher's productivity slightly, it may also lead to significant increases in productivity for subsequent grapple skidding.

In certain situations it may be desirable to place the trees in bunches directly behind the feller-buncher. This practice is not possible with the Kockums 880, which has a 270° slewing angle, but is possible with feller-bunchers having a 360° slewing angle.

Stump Height

The stump heights in two of the stands cut by the Kockums 880 were measured, and were found to average 4.9 in (12 cm). The stump heights were slightly higher than for most shears. Since the chain saw is more susceptible to damage from striking rocks and other obstacles, as compared to hydraulic shears, there will usually be a trade-off between increased chain maintenance cost and low stumps. Figure 4 shows typical stump heights observed on the operation.

Fig. 4. Typical stump heights in the study area resulting from cutting by the Kockums 880 chain saw.

GENERAL COMMENTS

This section includes general information on ergonomics, mechanical problems, costs, and a comparison of various feller-bunchers, not limited to the results of this FERIC field study.

Chain Saw vs. Shears

The chain saw felling head, which features automatic oiling at the end of each cutting stroke, functioned very effectively during the study. According to Berg *et al.* [2] the Kockums 880 equipped with a chain saw

felling head was only marginally slower than when equipped with spherical shears, in cutting trees under 12 in (30 cm) dbh (see Fig. 5). Positioning times did not vary significantly between shears and saw heads.

During the FERIC study, the Kockums saw cut 500 or more trees before requiring sharpening. It is reported that sometimes the saw may be operated for an entire shift before requiring sharpening. On this basis it would appear that the manufacturer's claims of three to four chain replacements, requiring 3 to 5 minutes each per 8-hour shift, are not unreasonable. This will, however, require a conscientious operator and good ground conditions. If the maintenance costs of saws and shears are compared, the maintenance costs for saws are somewhat higher *[8]*, mainly because saws are more susceptible to operator abuse and to damage from rocks and other objects.

In Table 4, the production rate of the Kockums 880 equipped with a chain saw is

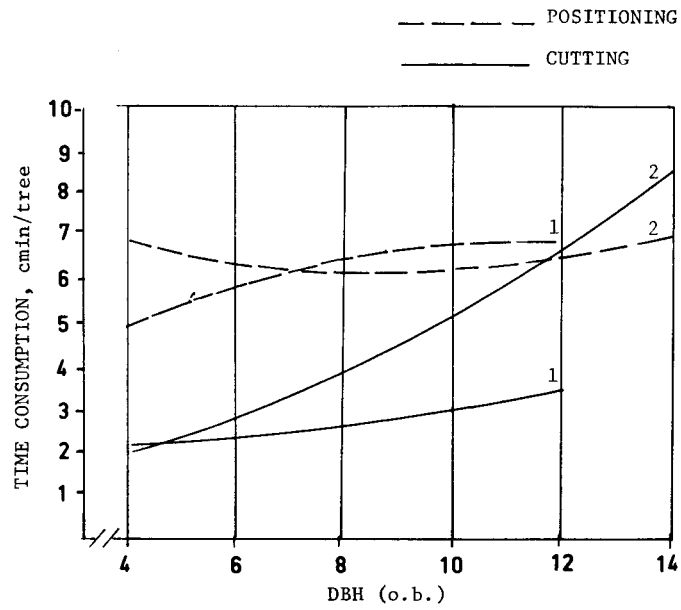

Fig. 5. Time consumption for positioning and for cutting of tree, from Berg et al. *[2]*.
1. Kockums 880, blades
2. Kockums 880, saw

Table 4. Productivity Comparison of Three Feller-Bunchers

	KOCKUMS 880 with chain saw attachment (stand 1, 2 & 3)		FORANO BJ-20 with felling shears [7]		DROTT 35 with felling shears [6]	
Operator(s) class	excellent		good		good	
Number of trees in study	915		500		1100	
Volume per tree, ft^3 (m^3)	5.3	(0.15)	3.7	(0.10)	7.3	(0.21)
Merchantable trees per acre (per hectare)	398	(983)	664	(1640)	515	(1273)
Non-merchantable trees per acre (per hectare)	16	(40)	61	(150)	38	(94)
Saplings per acre (per hectare)	115	(284)	364	(900)	108	(267)
Slope, %	±15		±15		flat	
Other factors	Some lowland black spruce (soft)		Shallow soil overlying bedrock		hard, sandy soil	
Moving in stand, cmin/tree	9		5		4	
Brushing, cmin/tree	1		4		2	
Delays, cmin/tree	2		3		2	
Felling cycle, cmin/tree	28		31		33	
Total time, cmin/tree	40	±8	43	±16	41	±13

±x = Standard deviation

compared to the production rates of two shear-equipped feller-bunchers wich were previously evaluated using similar time study techniques [6, 7]. Of the three machines, the Kockums 880 shows the highest moving time per tree, mainly because of soft ground conditions in stand 1 and the large number of unmerchantable trees in stand 2.

Mechanical Limitations

The Kockums 880 performed well on rough ground in the test area. However, the terrain in the study area was not sufficiently steep to test fully the machine's stability. Observations by FERIC personnel of a Kockums 880 working in the B.C. Interior indicate that in some cases it may be feasible to operate this machine on slopes up to 30%, depending on tree size and other related factors.

When compared to the Forano BJ-20, another wheeled feller-buncher of Swedish design, the Kockums 880 appears to be a more stable machine principally because the felling boom of the Kockums 880 is positioned in front of the cab, not behind and over the cab as with the Forano BJ-20.

A further comparison of certain design and operating characteristics for three feller-bunchers, including the Kockums 880, is presented in Table 5.

Flotation problems with the Kockums 880 were observed when the machine was operating in a lowland black spruce stand. The Kockums 880 equipped with 23.5 x 25 tires

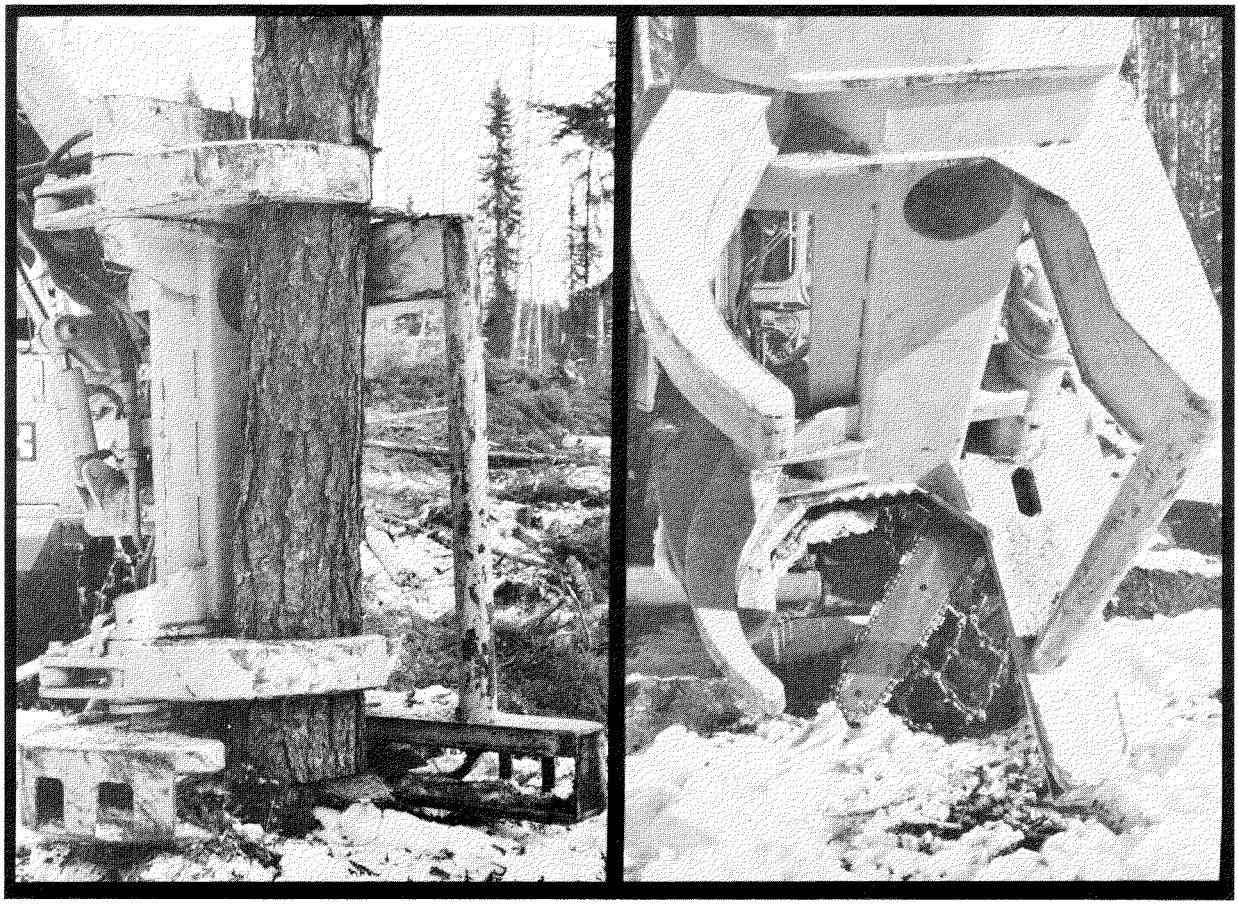

Fig. 6. The Kockums 880 saw attachment can fell trees up to 23 in (58 cm).

Table 5. Comparison of Three Feller-Bunchers

ITEM	KOCKUMS 880 TREE KING		FORANO BJ-20		DROTT 40 LC	
Carrier description	4 wheel drive, articulated		4 wheel drive, articulated		tracked	
Horsepower	156 @ 2400 rpm		123 @ 2600 rpm		157 @ 2400 rpm	
Total weight, lbs (kg)	33,000	(15,000)	33,000	(15,000)	47,000	(21,300)
Travel speed, mph (km/h)	0-18	(0-30)	0-17	(0-27)	0-1.4	(0-2.2)
Machine length, ft (m)	18.7	(5.7)	21.6	(6.6)	12.6	(3.8)
Machine width, ft (m)	9.5	(2.9)	9.8	(3.0)	9.0	(2.7)
Wheelbase, ft (m)	10.5	(3.2)	9.8	(3.0)	N/A	
Felling attachment	Kockums saw or BJ spherical blades		BJ spherical blades		Drott shear	
Cost, with felling attachment (Jan. 1977)	Saw — $138,500 Shear — $137,000		$106,000		$92,000	

with low-profile lugs (see Fig. 7) and tire chains sometimes became stuck in the soft ground. It was observed that the Kockums 880 had less flotation than the Clark cable skidders working in the same area. Larger tires are optional on the Kockums, and should help alleviate the flotation problem (see Appendix A).

During the FERIC study the Kockums 880 required no maintenance except for three tightenings of the chain saw bolts. However, it may be safely assumed that saw-felling maintenance costs are somewhat higher than those for shear felling [8].

The spherical blades of the BJ felling shear (not observed on this operation) are useful in reducing shear damage since they are designed to induce the stress during cutting into the stump, minimizing damage in the butt end of the tree [7].

Ergonomics

An ergonomic appraisal of the Kockums 880 rated the machine highly in operator safety and comfort; the machine was built to conform to the more stringent Scandinavian regulations concerning the operator's work place.

Mounting and Alighting: The operator is able to climb in and out of the cab with relative ease using the retractable steps and well-placed hand holds.

Visibility and Lighting: The visibility from the cab is very good. The large window on the front of the cab is equipped with compressed air windshield wipers.

Eight wide-beam lights fitted beneath the flange of the cab roof provide the illumination for night operation.

Controls and Working Posture: The operator's area in the cab is well planned and generally meets the recommendations of the "Ergonomic Checklist" [4]. The adjustable Bostrom Viking 300 seat provides a firm and comfortable working place for the operator. When felling, the most frequently used controls are within the optimum reach of the operator. The multi-function servo controls are well positioned for operating with the elbows resting on the chair arms. The actuating force required for these servo controls lies within the recommended limits 1-4 lb_f (5-20 N).

Working Climate and Exhaust Emission: The Kockums 880 is supplied with an air conditioner as standard equipment. If necessary, the sliding windows on the side of the

Fig. 7. The Kockums 880 equipped with standard tires and tire chains. Note the low-profile lugs on these tires.

cab can be opened. Exhaust emissions entering the cab are not expected to pose a problem.

Noise: Levels and frequencies of noise were measured inside the cab when the machine was stationary at roadside.

The measured noise levels fell well below the current permissible limit for continuous exposure now in force in the U.S.A. and parts of Canada. The results are summarized in Table 6 and more details are presented in Appendix C.

Expected Costs

The machine costs presented below are based on a realistic range of costs that may be expected in view of the uncertainties entering into some of the estimated values.

In practice, some machine users have experienced higher maintenance costs and lower utilization than expected. Hence, a 'realistic' range of costs is often difficult to

Table 6. Average and Maximum Sound Pressure Levels (dBA)

	Idling		Full Throttle	
	Ave.	Max.	Ave.	Max.
Inside Cab Door Closed	76	76	83	84

predict. The most important feature of the cost calculations presented here is that they permit the reader to use his own expectations for crucial and uncertain factors.

The total cost ($/ct) may be calculated from the following equation:

$$\$/ct = \left[\left[\frac{I}{L}\left(1 + \frac{i\,(N+1)}{2}\right) + M + W\right]\frac{100}{U} + F\right]\frac{1}{P}$$

where:

Known Values

I = Purchase price: $138,000
F = Fuel (including hydraulic fluid): $3.50/PMH
W = Operator's wages: $7.00 per SMH (including fringe benefits)
N = Depreciation period: 4 years
i = Interest and insurance factor: 0.13

Estimated Values (based on eastern Canadian conditions)

	Favourable	Unfavourable
L = Economic life of machine (SMH)	16,000	12,000
U = Utilization, percent	80%	60%
M = Maintenance cost (100% and 150% of fixed costs, $/SMH)	11.42	22.86
P = Productivity, ct/PMH	8	6

Using the above values in the equation gives the following results:

	Favourable	Unfavourable
Total cost, $/PMH	$40.80	$78.67
Total cost, $/ct	$5.10	$13.11

Cost Nomogram

The cost nomogram shown in Fig. 8 presents the above equation graphically. The two examples illustrate the use of the nomogram to solve the equation for the two given sets of conditions. The cost differences indicate the importance of effective maintenance, high utilization and the production per machine hour.

The cost nomogram (Fig. 8) can be useful to readers who wish to predict the cost of wood (at the stump) for their own operations, if a Kockums 880 is used. The reader should plot his values directly onto Fig. 8 in the following manner:

Start with the purchase price and proceed to the machine life and the depreciation period. The expected maintenance costs are plotted next (variation in maintenance costs between companies is substantial and is usually subject to some uncertainty). Next, the operator's wages are plotted, followed by machine utilization, which finally results in the total cost of wood per cunit.

CONCLUSIONS

The Kockums 880 is a feller-buncher that combines the requirements of high productivity and a high degree of operator comfort in one machine.

Features such as air conditioning, arm-rest-style controls and low noise levels help to provide a comfortable and attractive workplace for the operator. These features may allow the operator to work for longer periods without fatigue and may also encourage more operator (labour) stability. The additional productivity resulting from the above features may also serve to make this machine more cost competitive when compared with other, lower-priced feller-bunchers.

The Kockums 880 is capable of high productivity with either the chain saw or the BJ shear attachment. Usually mechanical and stand characteristics will determine the upper limit of productivity for the machine. The operator's skill and motivation will determine how closely actual productivity approaches the limit.

The Kockums 880 has a definite advantage over the tracked machines in the speed at which it can travel to and from the cutting

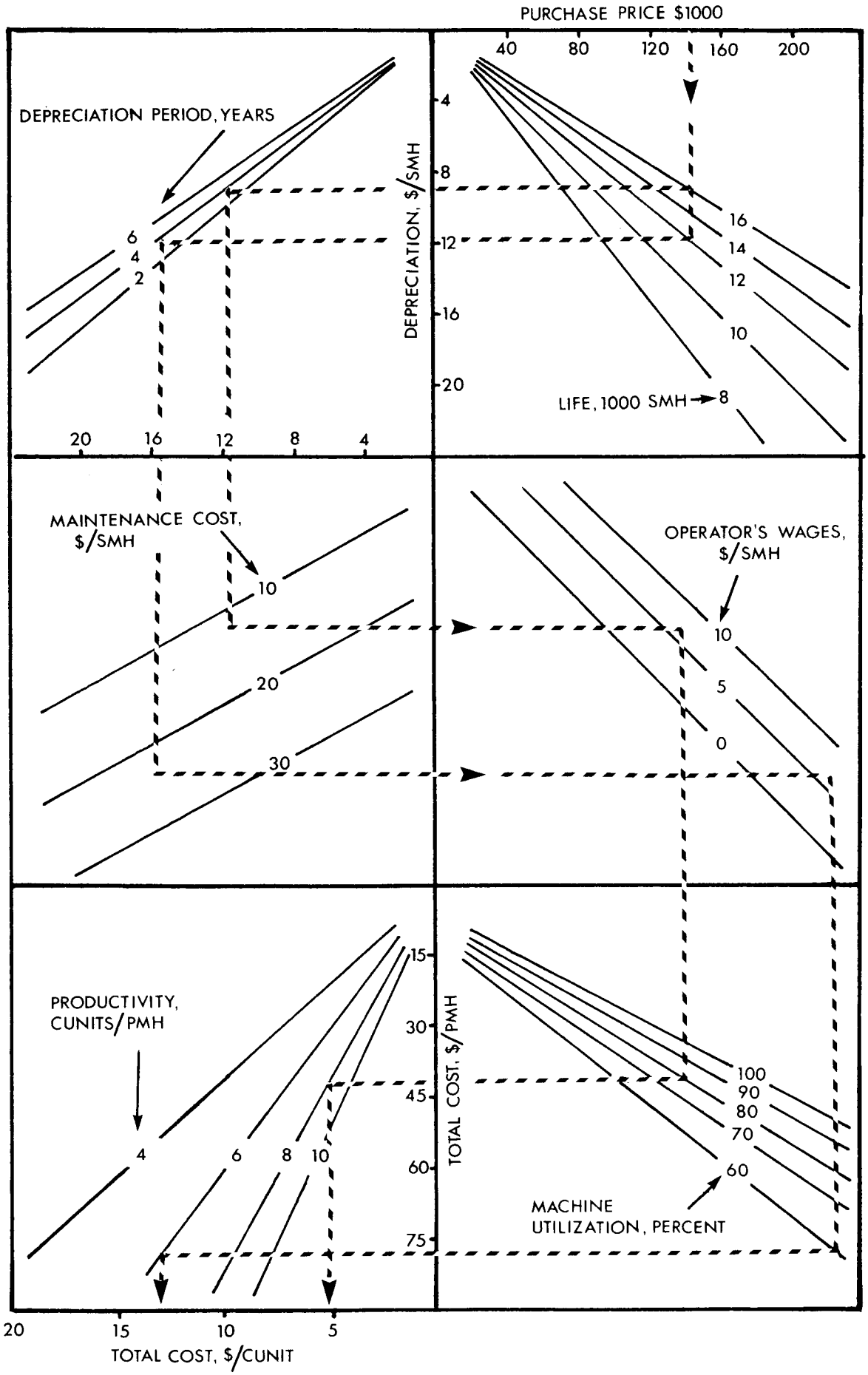

Fig. 8. Cost Nomogram

area. However, tracked machines exhibit flotation advantages when operating on soft ground. The stability of the Kockums when operating on rough ground or slopes compares favourably with that of other wheeled feller-bunchers.

Wood damage caused by hydraulic shears is recognized as a problem on many operations where sawlogs are produced. The Kockums 880 is a good machine for the harvesting of sawlogs, since cutting damage is virtually eliminated with the use of the saw attachment.

APPENDIX A

MANUFACTURER'S SPECIFICATIONS

General Dimensions

	ft	m
Length (bumper to bumper)	18.9	5.7
Width	9.5	2.9
Height	13.1	4.0
Ground clearance	1.6	0.5
Wheelbase	10.5	3.2
Track	7.5	2.3

Engine

Type	Scania D8 4-stroke diesel
No. of cylinders	6
Max. output @ 2400 rpm	156 hp (116 kW SAE)
Fuel tank capacity	47.3 gal (215 l)

Power Train

Gearbox	Clark powershift — torque converter
No. of speeds	3 forward — 3 reverse (hi & low)
Travel speed	0-18 mph (0-30 km/h)
Axles	Bevel gearing and planetary hub reductions
Differential	Mechanical or no-spin

Tires

Standard	23.5 x 25 in (16 ply) grader lug
Optional	30.5 x 32 in (16 ply) forestry special
Optional	Gunnebo tire chains

Steering System

Cylinders	2 double-acting
Articulation	± 40%

Weight

Front axle	13,600 lb (6000 kg)
Rear axle	19,800 lb (9000 kg)
Total	33,000 lb (15000 kg)

Hydraulic System

Tank capacity	54 gal (245 l)
Pump capacity @ 2400 rpm	26.4, 30.8, 40.7 gal/min (120, 140, 185 l/min)

Felling Head

Shear capacity	max. 19.7 in (50 cm)
Shear weight	2950 lb (1338 kg)
Saw capacity	max. 22.9 in (58 cm)
Saw weight	2500 lb (1134 kg)

Electrical System

System	24-V
Battery	150 A hr
Generator	AC, 45 A

APPENDIX B

PROCEDURE FOR EVALUATING PRODUCTIVITY

To assess the productivity of the Kockums 880, time studies were carried out covering as wide a range of tree and stand factors as possible. Productive time of the machine was divided into the following elements:

Moving in stand: begins when forward or backward motion starts and ends when movement stops.

Felling cycle: begins when movement stops, or when the felling head starts to swing towards a new tree. The felling cycle stops when the grapple arms are opened releasing the tree.

Brushing: includes the removal of saplings and brush and the felling of unmerchantable trees. For the latter, the felling cycle is timed and recorded as brushing.

Delays: include operational delays, mechanical breakdowns, and personal delays. They are treated in different ways depending on their duration.

0-5 cmin:	are included in the first three elements.
5 cmin-10 min:	are recorded as delays.
> 10 min:	are not considered as part of productive time (PMH) and are therefore excluded.

APPENDIX C
NOISE

Figure C.1 shows the observed dBA values plotted over an estimated exposure time during a shift. The exposure time is calculated using an 8-hour shift and assuming a utilization of 90%. Also plotted on Figure C.1 is the permissible exposure curve adopted in 1969 by the U.S. Department of Labor [1]. This curve assumes a continuous period of noise of specified length. The noise of the Kockums 880 is somewhat variable during operation, which is an advantage over continuous noise.

Observed sound pressure levels within octave bands are illustrated in Figure C.2. The hatched area shows the range of average levels which were obtained with the machine running (door closed) at full throttle and idling.

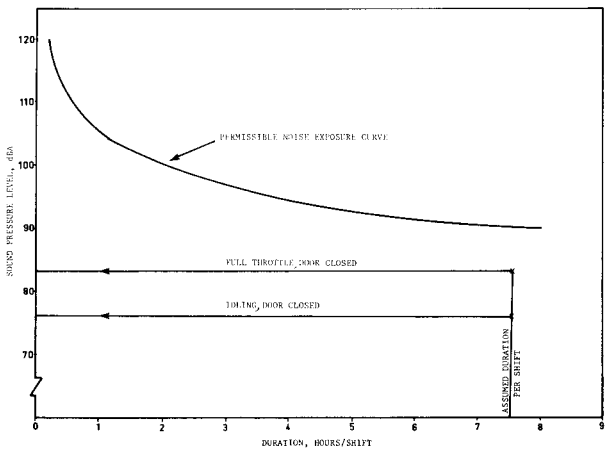

Fig. C.1. Observed average noise level (dBA) inside the cab (door closed) plotted by estimated exposure time, compared to the current permissible exposure curve of the U.S. Department of Labor [1].

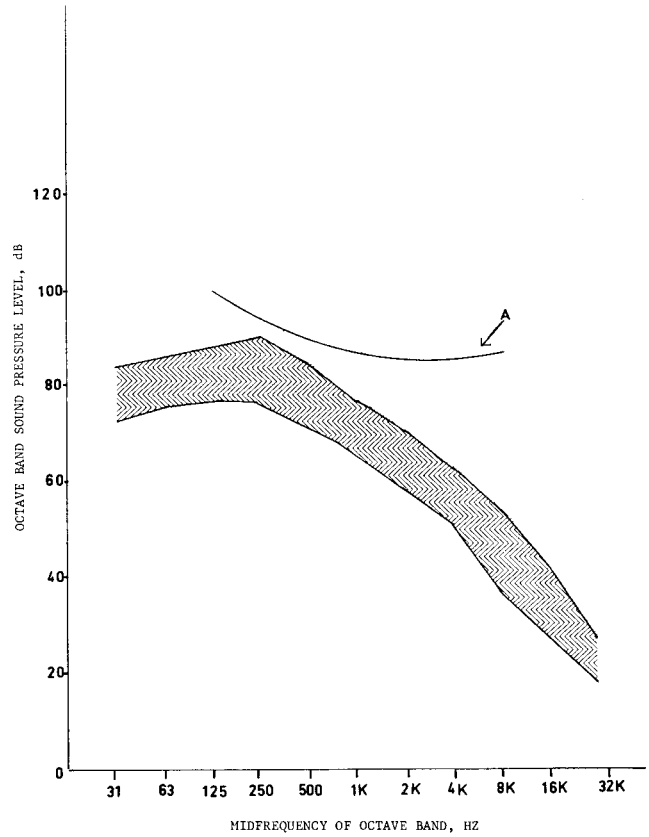

Fig. C.2. Observed noise levels by octave bands. The hatched area shows the range of average levels (idling and full throttle) with door closed. Curve A shows the damage risk curve for one exposure per day of duration less than 6 hours to 1 octave band of noise. This curve is interpolated from Kryter, et al. [5].

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TR-2 The Logging Development Corporation Processing Head, Model 421. FOLKEMA, M.P., LEGAULT, R. Jan. 1976. pp. 17. $2.00.

TR-3 Lajoie "Fibre-Flow" Harvester Head. HEIDERSDORF, E. Apr. 1976. pp. 16. $2.00.

TR-5 Timmins "Fel-Del" Harvester Head. FOLKEMA, M. P., NOVAK, W. P. June 1976. pp. 33. $2.00.

TR-7 Koehring Feller-Forwarder, Model KFF. LEGAULT, R. Sept. 1976. pp. 24. $2.00.

TR-8 Cable Logging Systems in Interior B.C. and Alberta. COTTELL, P. L., McMORLAND, B.A. and WELLBURN, G. V. Sept. 1976. pp. 48. $6.00.

TR-12 Farmi JL 30 Logging Winch. FOLKEMA, M.P. Jan. 1977. pp. 22. $2.00.