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

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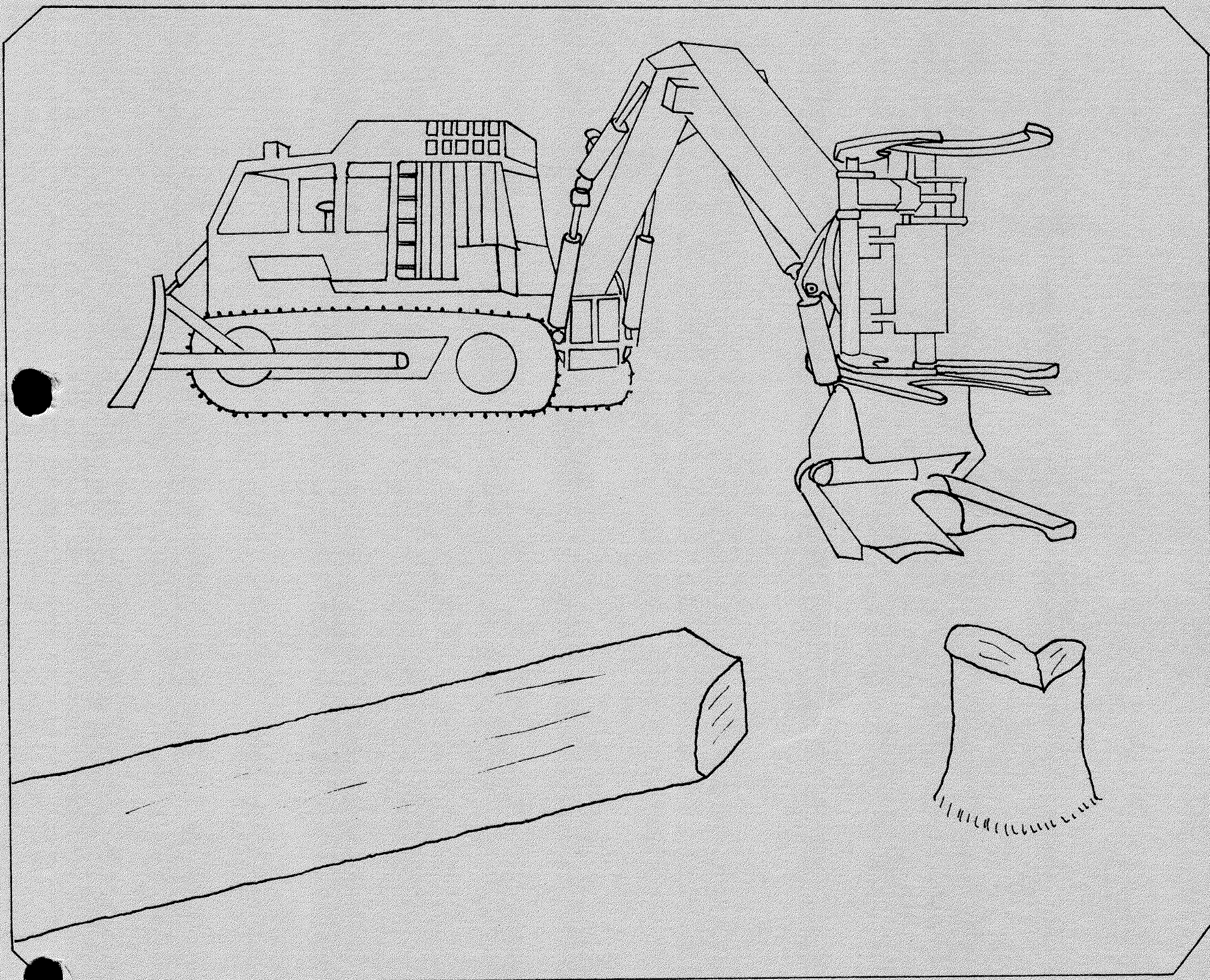
September 1977

Evaluation of Earls ParaShear Feller-Buncher

L.H. Powell and D.W. Myhrman



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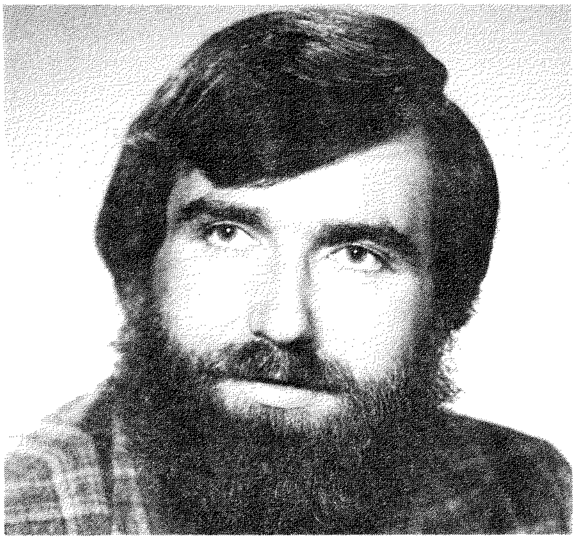
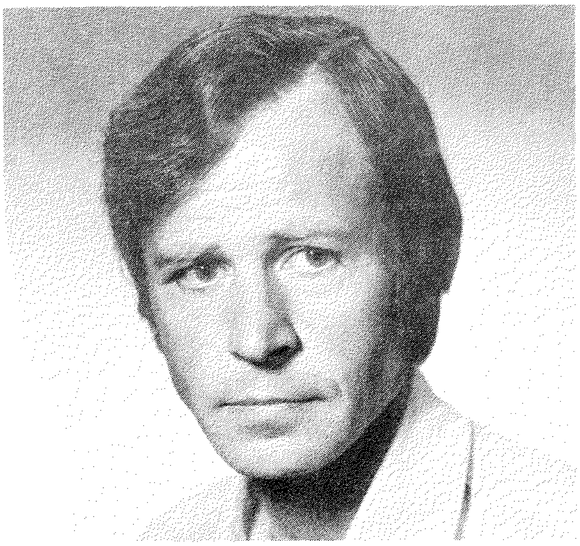


L. H. Powell received his B.Sc. Forestry from the University of Wales in 1968. He joined the Woodlands Research Division of the Pulp and Paper Research Institute of Canada in 1970 to work on logging machine evaluations and related projects. He moved over to FERIC when that organization was formed in 1975, and transferred to the Vancouver office in late 1975. He is a member of the Association of B.C. Professional Foresters, the Canadian Institute of Forestry and the Woodlands Section, Canadian Pulp and Paper Association.



Dag W. Myhrman graduated in 1960 from the Mechanical Engineering Faculty of the Royal College of Technology in Stockholm, Sweden. He took an appointment with Svenska Rotor Maskiner AB, where he worked on design and testing of hydraulic transmissions for heavy-duty vehicles. He joined the Logging Research Foundation (Skogsarbeten) in 1967 as leader of the mechanical engineering research program. In the fall of 1975 he joined FERIC for a two-year period, to work on logging equipment design and development.

FOREWORD

This report, which describes a study of certain technical and operating characteristics of the Earls ParaShear feller-buncher, is designed to assist potential 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 the wood it produces. Due to 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 to their own operating conditions.

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

Grateful appreciation is extended to company personnel of Pope and Talbot, Ltd., Midway, B.C., Northwood Properties, Ltd., Division of Northwood Mills Ltd., Okanagan Falls, B.C., Spruce Valley Contracting Ltd., Penticton, B.C., and Earls Industries Ltd., Vancouver, B.C.

The authors also gratefully acknowledge the cooperation and assistance of Dr. J. Dobie and Mr. D. Wright, Western Forest Products Laboratory, Environment Canada, Vancouver, B.C. for the mill study of shear damage. The following FERIC personnel were involved with the study and their assistance is also gratefully acknowledged: L.W. Johnson, B.D. Johnston, J. McDonald, and P.P. Tse.

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SUMMARY

FERIC studied two versions of the Earl's Industries Para-Shear Feller-Buncher. Under summer conditions the machine's productivity averaged 11.2 cunits (32 m^3) per productive machine hour, and in winter averaged 8.4 cunits (24 m^3) per productive machine hour. This difference in productivity was due to differences in tree size between the two study areas.

The ParaShear is a feller-buncher attachment for any tractor or excavator undercarriage. The machine studied had the felling head and boom mounted on a Terex 82-40 tractor undercarriage. The ParaShear name is derived from the saddle-formed surfaces of parabolic sections which the shear blades make when cutting trees. This cutting pattern was designed to minimize shear damage, and the tractor under-carriage was used to provide better mobility for the machine than that of excavator undercarriages.

The summer study showed an average time per tree of 79 cmin (1 cmin = 1 centiminute = 1/100 minute) with an average tree volume of 14.7 ft^3 (.42 m^3). For the winter study, average felling and bunching time per tree was 81 cmin, with an average tree volume of 11.4 ft^3 (.32 m^3). Stand and productivity factors are summarized below.

	Summer Study		Winter Study	
Average volume per tree, ft^3 (m^3)	14.7	(0.42)	11.4	(0.32)
Merchantable trees per acre (ha)	570	(1408)	571	(1411)
Unmerchantable trees per acre (ha)	309	(764)	53	(131)
Trees per productive machine hour (PMH)	76		74	
Productivity, ct (m^3) per PMH	11.2	(32)	8.4	(24)

Field assessments of shear damage were made on trees cut in summer and in winter. In both cases there was visible

damage to butt ends, with damage length averaging 7 in. (180 mm) in summer and 15 in. (380 mm) in winter. A mill study was also conducted, but only on summer felled trees of small sizes. This study showed that virtually no extra trimming was required after the 'cone-shaped' butts had been squared off.

Examination of the ergonomic characteristics of the operator's workplace showed that improvements were needed in the areas of mounting and alighting from the cab, noise levels in the cab, and operator visibility. The poor visibility was considered to be a contributing factor to the occurrence of shear damage.

In comparison to other feller-bunchers, e.g. Drott and Forano BJ-20, the ParaShear had slower cycle times and consequently lower productivity. Tests on machine performance showed that machine functions were slower due to undercarriage design and boom component speeds. In both studies, operators were inexperienced and contributed, together with machine design problems, to the slower times.

The ParaShear was designed to provide the industry with a feller-buncher with improved terrain capability and reduced butt damage. It is still in an early stage of development, however, and needs improvement in many details.

SOMMAIRE

FERIC a étudié deux modèles de l'abatteuse-empileuse Earl's ParaShear. Durant l'été, la machine a produit en moyenne 11.2 cunits (32 m^3) par heure effective de production; en hiver, 8.4 cunits (24 m^3). Cette différence est due à la dimension des arbres qui variait d'une aire d'échantillonnage à l'autre.

La ParaShear est un accessoire abatteur-empileur qui peut être installé sur la plupart des tracteurs chenillés ou sous-chassis d'excavateurs. La machine étudiée était équippée d'une tête abatteuse et d'une flèche assemblées sur un sous-chassis chenillé Terex 82-40. Le nom de ParaShear vient du fait qu'après la coupe d'un arbre les couteaux de la cisaille laissent une surface ondulée de forme parabolique. Ce genre de coupe fut développée pour minimiser le dommage causé au bois lors du cisaillage. Le sous-chassis Terex fut employé de préférence aux sous-chassis d'excavateurs à cause de sa plus grande stabilité.

L'étude effectuée en été a démontré qu'il fallait un temps d'abattage et d'empilage de 79 cmin par arbre (1 cmin = 1 centiminute = 1/100 minute) avec un volume moyen de 14.7 pi^3 (0.42 m^3) par arbre. Celle effectuée en hiver a indiqué pour les même opérations un temps de 81 cmin par arbre avec un volume moyen de 11.4 pi^3 (0.32 m^3) par arbre. Les caractéristiques des peuplements ainsi que les facteurs de productivité sont résumés dans le tableau suivant.

	étude en été	étude en hiver
Volume moyen par arbre, pi^3 (m^3)	14.7 (0.42)	11.4 (0.32)
Arbres marchands à l'acre (ha)	570 (1408)	571 (1411)
Arbres non-marchands à l'acre (ha)	309 (764)	53 (131)
Arbres par heure productive de la machine (HPM)	76	74
Productivité, ct (m^3) par HPM	11.2 (32)	8.4 (24)

Une évaluation a été faite des dommages causés aux arbres par la cisaille lors de l'abattage en été et en hiver. Dans les deux cas, le dommage causé aux billes de souche variait en moyenne de 7 po. (180 mm) en été à 15 po. (380 mm) en hiver. Les dommages furent évalués en usine sur des petits arbres provenants d'une coupe d'été. Cette étude a démontré qu'il était peu nécessaire d'ébouter d'avantage les arbres dont le bout en forme de cône avait été équarri.

Un examen des caractéristiques ergonomiques de la machine démontra que des modifications à l'entrée et à la sortie de la cabine s'avéraient nécessaires. L'intensité du son dans la cabine a été diminué et le champ de vision de l'opérateur amélioré. Une mauvaise visibilité contribuait aux dommages causés par la cisaille.

En comparaison avec d'autres abatteuses-empileuses, une Drott et une Forano BJ-20, la ParaShear enregistrait des temps de cycles d'opérations plus lents et conséquemment une productivité moindre. Des essais sur la performance de la machine démontrèrent que ses fonctions étaient plus lentes à cause de design du sous-chassis et des composantes de la flèche. Dans les deux études, l'inexpérience des opérateurs combinée avec les problèmes de design de la machine, occasionnaient des temps d'opération plus lents.

La ParaShear fut développée pour fournir à l'industrie une abatteuse-empileuse s'adaptant mieux aux conditions de terrain et limitant les dommages causés aux billes de souche. Elle est encore au tout début de son développement, toutefois, et doit être améliorée sous plusieurs rapports.

INTRODUCTION

The advantages of feller-bunchers are often offset by poor machine reliability and wood damage from the use of hydraulic shears--two problems which have been the subject of international studies for many years. Feller-bunchers were designed initially to improve daily felling production and assemble bunches for subsequent skidding. The first machines were modified excavators or earth-moving machines. The ParaShear concept was developed to minimize the wood damage by using a new cutting configuration in the shears. In order to increase machine mobility, the felling head and boom were mounted on a bulldozer undercarriage.

FERIC studied two versions of Earls Industries' ParaShear, the first under summer conditions at Beaverdell, B.C., in June 1976, and the second under winter conditions at Okanagan Falls, B.C., in February 1977. The results of the two studies are presented in this report.

MACHINE DESCRIPTION

The feller-buncher attachment was mounted on the back of a Terex 82-40 crawler tractor (see Figure 1). The engine power of the tractor is 275 hp (205 kW) at 2100 rpm. The standard winch was removed and the engine radiator moved from the back to the right side of the canopy. The operator's seat was exchanged for one which could swing 180° to allow the operator to face backward when felling trees. Controls for the boom and felling head were situated in the rear of the canopy. The controls for moving the machine were doubled so they could be reached by the operator when facing backward. The operator was protected from penetrating objects by grid guards (see also the Study of Ergonomics, page 27).

FIG. 1. First prototype of ParaShear during summer study.

The main components are: (1) Terex 82-40 tractor undercarriage; (2) knuckle boom; and (3) felling head.

The felling attachment used the standard tractor hydraulic system. The hydraulic oil reservoir was moved to the top of the canopy. A 6-spool hydraulic valve, mounted on the rear left side of the floor, was added for the felling attachment functions.

Of the two hydraulic pumps on the Terex tractor, one was connected to the boom swing and the other to the boom reach and shear functions.

The felling head is mounted on a knuckle-boom. Both boom members are rectangular tube construction with the cylinder hold brackets welded to the outside. This gives a very rigid design, both for bending and torsional stress. The joint bearings between the main boom and the stick are widely spread, giving low stresses for torsional loads. The two cylinders for the main boom, the two for the stick and the one for the tilt function are identical, the only variation being a 1 1/2-inch spacer to reduce the stroke on the main boom cylinders. All cylinders on the boom use the same spherical end bearings to avoid bending stress to the cylinders.

The two hydraulic cylinders limit the swing to $\pm 75^{\circ}$. The swing torque is 16,000 lb. ft. (21.7 kNm).

The felling head is attached to the end of the boom with a tilt and twist arrangement so that the head can be fully aligned to the tree when shearing to prevent bending stress in the tree. Such stress can cause severe damage to the butt, no matter what method is used for cutting. The total tilt range is 100° and the twist is $\pm 20^{\circ}$.

Figure 2 illustrates the felling head, which consists of a frame with two tree-grapple arms and the shear at the

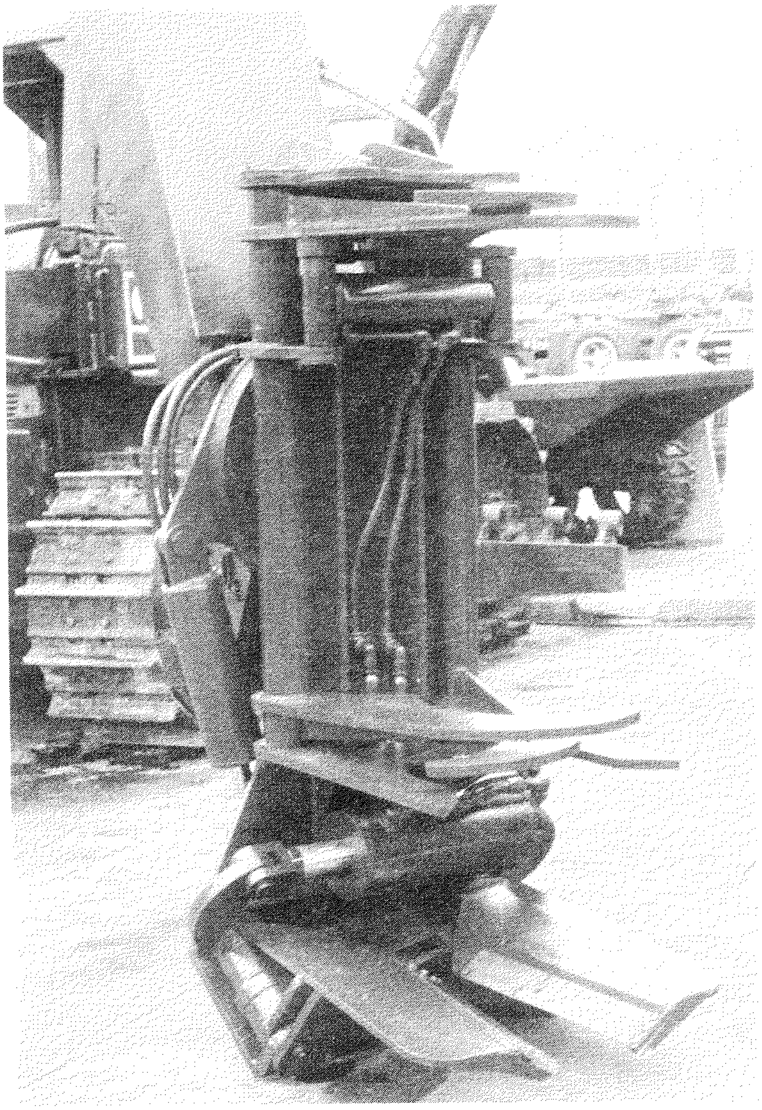


FIG. 2. Close-up view of felling head and shear blades.

bottom. The grapple arms are actuated by one hydraulic cylinder; they cannot adjust conically for different butt taper forms. The shear has two simple single-bevel blades on conical shaped mounts. The axes for these mounts are inclined downward at 40^{o} so that the cutting proceeds in an increasingly downward direction. The blades make a saddle-formed surface of parabolic sections, giving the machine its ParaShear name. The blades are actuated by a hydraulic cylinder mounted above them for protection. Movement of the blades is synchronized by lever arms. The felling head is designed for maximum 18-inch (460 mm) butt diameter. The theoretical minimum stump height is 8 inches (200 mm). The connected shear and grapple arm cylinders are parallel, manoeuvered by one spool valve.

The second prototype studied under winter conditions differed from the first by having a second cab mounted above the tractor canopy (see Figure 3), and a rack-and-pinion mechanism for the boom swing. This used only one cylinder and increased the swing to $\pm 83^{o}$ and the swing torque to around 20,000 lb.ft. (27 kNm). This cab contained the boom and felling head controls and a dual set of controls for the tractor undercarriage. More detailed specifications of the machine are presented in Appendix A.

STUDY OF MACHINE AND OPERATOR PERFORMANCE IN SUMMER

Study of the boom and felling head performance was made by methods described in Appendix B. The operator had operated the machine for only 10 days at the time of performance testing. The time to perform each individual function was measured and compared to theoretical time, calculated from hydraulic system data. The swing time was almost correct, while the times for the other functions were generally too long, indi-

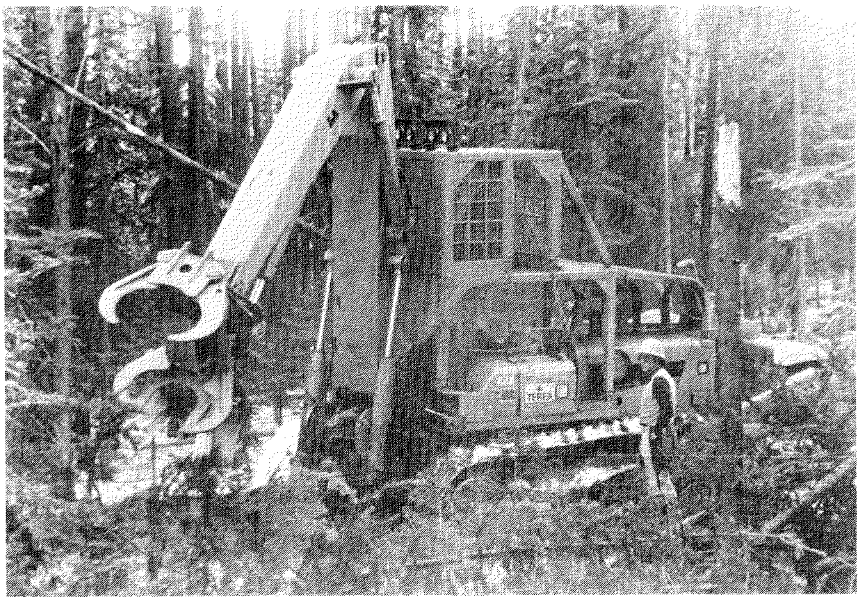


FIG. 3. Second prototype of ParaShear during winter study. Note the second cab on the roof of the tractor canopy.

cating an abnormal leakage in the big pump circuit. The theoretical boom speeds were adequate for this type of machine, as was the geometry of the boom. The performance of the operator was tested at "felling" poles placed in a given pattern shown in Appendix B. The average cycle time was 37 cmin, which may be compared with a cycle time between 18 to 26 cmin from tests of four different feller-bunchers in Sweden (see Berg, et al., 1974). However, relative inexperience of the ParaShear operator must be taken into account.

PRODUCTIVITY--SUMMER STUDY

The machine at Beaverdell was studied four days in early June, 1976. The operator was an experienced crawler tractor operator with about eight days of experience on the actual machine at the beginning of the study. The stand was spruce-pine on smooth ground with bearing capacity class 2 to 3. The stand characteristics are presented in Table 1.

Average felling and bunching time per tree was 78.9 cmin.* Average productivity, calculated from average time and volume per tree, was 11.2 cunits (32 m^3) per productive machine hour (PMH).

Felling cycle accounted for 62% of the total time per tree. The felling cycle was separated into three elements, swing empty, position and cut, and swing loaded, as shown below.

	cmin/tree	%
Swing empty	22.9	46
Position and cut	11.0	22
Swing loaded	15.9	32
Felling Cycle (total)	49.8	100

*1 cmin = 1 centiminute = 1/100 minute.

TABLE 1. Average Condition and Operating Factors - Summer Study.

Factor	Imperial Units			S.I. Units		
	Mean	S.D.	Range	Mean	S.D.	Range
Volume per tree, ft^3 (m^3)	14.7	10.8	7.6 - 62.4	0.42	0.31	0.22 - 1.77
Merchantable trees per acre (hectare)	570	114	360 - 800	1408	282	290 - 1977
Unmerchantable trees per acre (hectare)	309	129	109 - 472	764	319	269 - 1166
Saplings per acre (ha)	489	291	73 - 980	1208	719	180 - 2422
Slope in direction of travel, %	9	7.5	-10 - +25			
Side Slope, %	4	4.3	-10 - +10			
Stand volume, cunits/acre (m^3/ha)	83.3	30	50 - 146	583	210	350 - 1022

Total time per tree, including the felling cycle and all other functions, is summarized in Table 2.

TABLE 2. Summary of Times per Merchantable Tree - Summer Study.

Time Element	Time per tree, cmin		
	Mean	S.D.	Range
Moving in the stand	13.7	8.8	0 - 40
Felling cycle	49.8	18.2	15 - 175
Brushing time	11.6	5.1	3 - 26
Delay time	3.8	5.0	0 - 17
Total Time	78.9	22.5	33 - 204

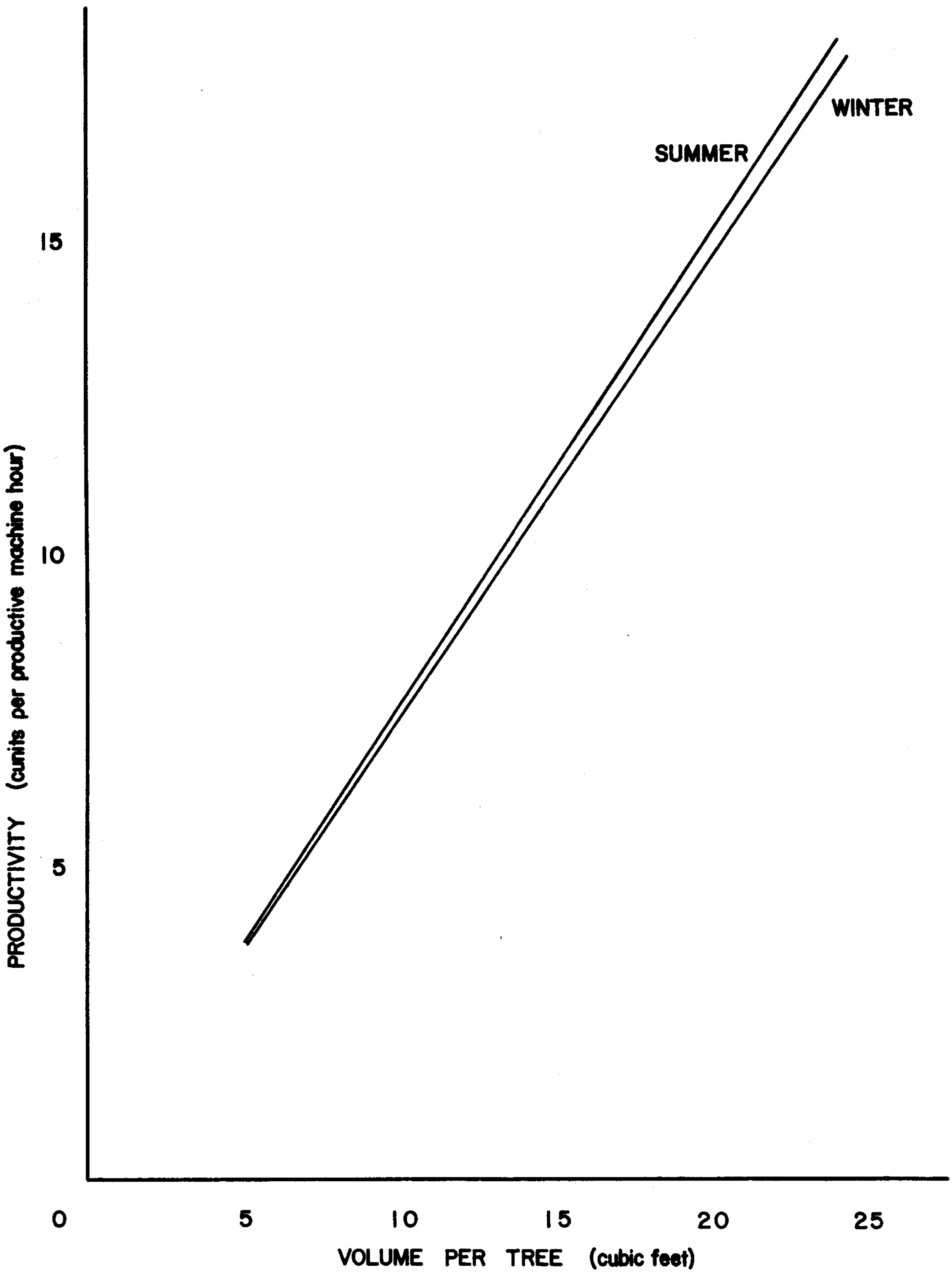
The elemental and total times per tree were not influenced by any of the measured stand and terrain characteristics. Productivity was influenced by volume per tree as shown in Figure 4.

Average stump height was 14.9 in. (380 mm) and average stump diameter 10 in. (250 mm). The stumps were shattered, and did not seem to harm the tires of the grapple skidder which was skidding the bunches.

Average distance for moving in the stand was 23 ft. (7 m) and the average time per move was 69 cmin. Average number of trees cut between moves was 5.3.

The average delay time was 54 cmin, and this was prorated to a per-tree basis and included in harvesting time per tree.

FIG. 4. PRODUCTIVITY COMPARISON BETWEEN SUMMER AND WINTER, SHOWING THE EFFECT OF TREE SIZE.



The graph is based on the average total time per tree for felling and bunching from the summer and winter studies, using 78.9 cmin and 81.3 cmin respectively.

The average number of trees per bunch was 7.2 The average bunch angle was 52° from the direction of travel.

No mechanical breakdowns occurred during the four study days.

PRODUCTIVITY--WINTER STUDY

A second test of the ParaShear operating under winter conditions was made in February 1977 (see Figure 5). The ground was frozen and covered with approximately 1 foot (300 mm) of snow. Felling of frozen trees was observed as a result of sub-zero temperatures just prior to the study period. Operating conditions in general were not representative of a "normal" winter, except for low temperatures and frozen wood. Table 3 gives details of conditions in the study area.

FIG. 5. ParaShear operating during winter study.

TABLE 3. Average Condition and Operating Factors - Winter Study.

Factor	Imperial Units			S.I. Units		
	Mean	S.D.	Range	Mean	S.D.	Range
Volume per tree, ft^3 (m^3)	11.4	5.5	5.8 - 28.7	0.32	0.16	0.16 - 0.81
Merchantable trees per acre (hectare)	571	155	327 - 834	1411	383	808 - 2061
Unmerchantable trees per acre (hectare)	53	43	0 - 145	131	106	0 - 358
Saplings per acre (ha)	499	157	290 - 800	1233	388	717 - 1977
Slope in direction of travel, %	+16	4.5	+11 - +29			
Stand volume, cunits/acre (m^3/ha)	65.1	17.8	29.2 - 89.8	455	125	204 - 628

Average felling and bunching time per tree was 81 cmin. Average productivity, calculated from average time and volume per tree, was 8.4 cunits (24 m^3) per productive machine hour.

Table 4 shows the elemental times and total time per tree. The felling cycle accounted for 66% of the total time, and consisted of the elements swing empty, position and shear, swing loaded and lower into bunch. These elements were separated during the timing of part of the sample, giving the following results:

	Mean Time cmin/tree	% of Felling Cycle
Swing empty	22.5	42%
Position and shear	9.2	17%
Swing loaded and lower	22.1	41%
Felling Cycle (total)	53.8	100%

TABLE 4. Summary of Times per Merchantable Tree - Winter Study.

Time Element	Time per Tree, cmin		
	Mean	S.D.	Range
Moving in the stand	14.5	3.6	8 - 21
Felling Cycle	53.8	13.0	28 - 104
Brushing Time	8.8	5.9	3 - 24
Delay Time	4.2	4.0	0 - 12
Total Time	81.3	18.1	45 - 140

Stand and terrain conditions, measured in the study area, had no effect on component and total times per tree. Productivity was influenced by volume per tree, as illustrated in Figure 4.

While the winter sample was smaller than the summer one, results showed little difference between average total times. Component times showed minor differences in felling cycle times and brushing times, which might be explained by operator differences and differences between study areas (see Figure 6). Winter performance might have differed more from summer if normal winter conditions, including deep snow, had been encountered. The conditions in early 1977 were more favourable than normal. Both operators observed during the studies had had limited experience with the ParaShear. Higher productivity was calculated for the summer study, resulting mainly from the larger average tree size in that area.

Table 5 shows a comparison of the ParaShear results for summer and winter studies with results from earlier studies of Drott and Forano BJ-20 feller-bunchers. Total time per tree for the ParaShear is greater than for the other two machines, and productivity, assuming a 15-ft^3 (0.42 m^3) tree, is close to half. The slower felling cycle and moving time for the ParaShear probably reflect operator inexperience. Differences in brushing and delay times reflect different stand conditions and different operators.

FIG. 6. COMPARISON OF COMPONENT TIMES FOR SUMMER AND WINTER STUDIES.

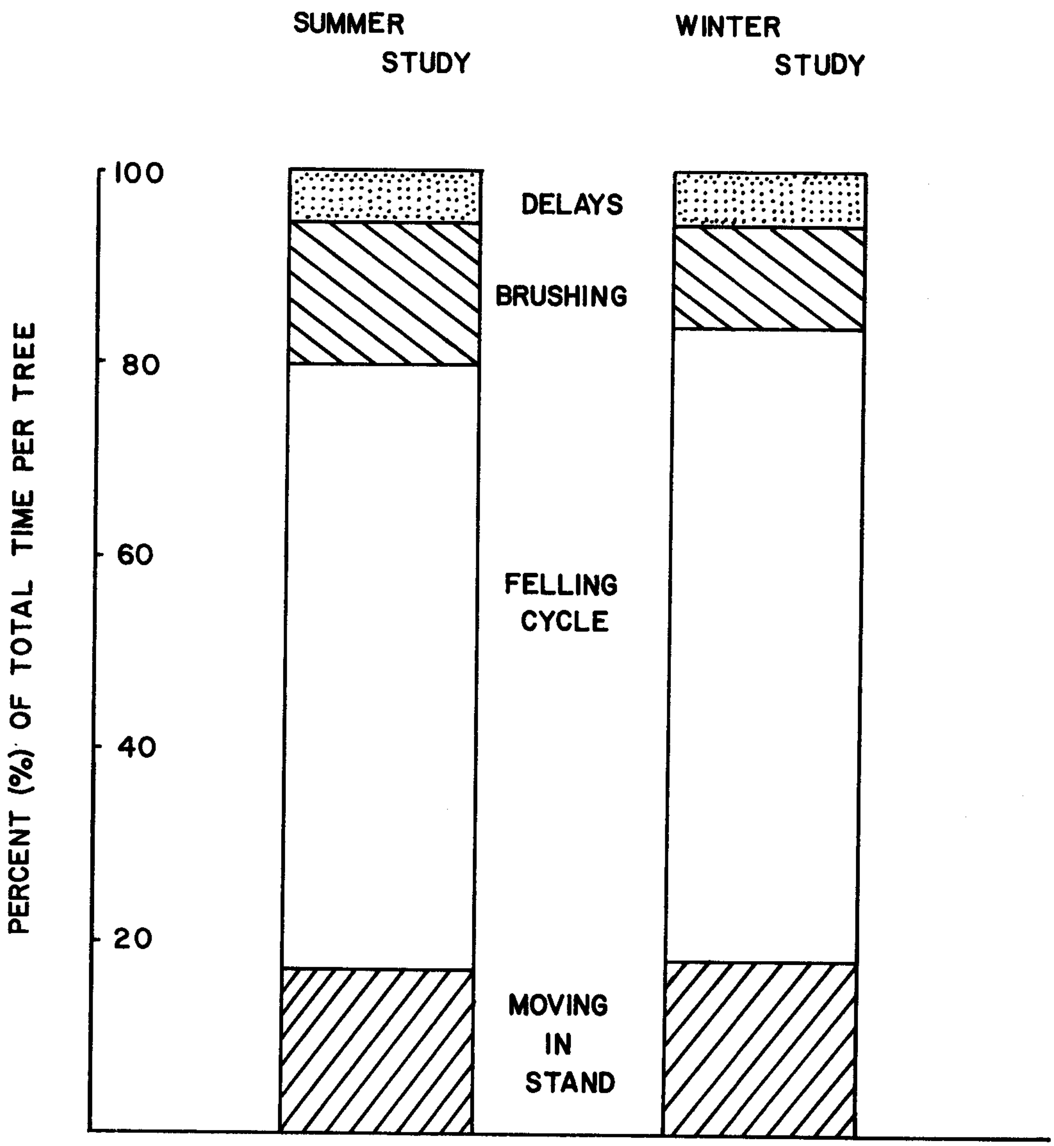


TABLE 5. Comparison of Feller-Bunchers based on Average Times per Tree (cmin).

Time Element	ParaShear (summer)	ParaShear (winter)	Drott 35-YC[1]	Forano BJ-20[2]
Moving in the Stand	14	14	4	5
Felling Cycle	50	54	33	31
Brushing	11	9	2	4
Delays	4	4	2	3
Total Time, cmin	79	81	41	43
Hourly production when average tree volume is 15 ft^3 (0.42 m^3), cunits/PMH (m^3/PMH)	11.4 (32.3)	11.1 (31.4)	22.0 (62.3)	20.9 (59.2)

[1] Results from Powell, 1971. Study made under eastern Canadian conditions.

[2] Results from Powell, 1975. Study made under eastern Canadian conditions.

FIELD TESTS OF SHEAR DAMAGE--SUMMER FELLING

Field tests for shear damage were conducted on the landing using the method established by McLaughlan and Kusec (1975). The end of the log was first squared off by cutting the "V-shaped snipe" at the point where the shears began to cut. Then two-inch discs were bucked consecutively from the butt of the tree until shear cracks could no longer be detected visually. Each 2-inch (50 mm) disc was examined and the total lineal length of shear cracks recorded for that disc.

Four trees were selected for each 1-inch (25 mm) diameter class between 6 and 15 inches (150 and 380 mm) D.S.H. (diameter stump height) to obtain average shear damage for the class. The sample was confined to a 15-inch (380 mm) maximum stump diameter by the small average tree size of the stand.

Lodgepole pine (Pinus contorta Dougl.) was the predominant species but some spruce, balsam and larch was scattered throughout.

Larch was not included in the sample for damage assessment because it represented a minor percentage of total stand volume and because most of the larch trees in the area were too large for the shear to cut. There was also a good deal of butt rot and wind shake in the larch which tended to accentuate shear damage beyond normal proportions.

Length of damage averaged 7 inches (170 mm), and ranged from 2 to 28 inches (50 to 700 mm). Table 6 summarizes the average number of inches bucked off the end of each diameter class to find wood having no visible damage. If 4 inches (100 mm) are bucked off the end of each log, 40% of the damaged stems would have been eliminated and by bucking 8 inches (200 mm) off, 82½% of the stems would be free of visible damage.

Indications are that once visible damage has been bucked off, the log will likely be damage-free, i.e., no further damage will show up in the lumber after it goes through the dry kiln. But further studies must be done before this can be stated factually.

Results clearly indicated that of the 40 trees sampled, 10 trees were damage-free after the first 2-inch (50 mm) cut. This suggests that the ParaShear can produce shatter-free wood and any further studies must include examination of operator technique to isolate procedures which help reduce shear damage.

TABLE 6. Average Length of Damage--Summer Felling.

Stump Diameter Class	Average length bucked off trimmed butt to eliminate damage. (inches)	(mm)
6	2.5	63
7	4.5	115
8	4.5	115
9	7	180
10	10	250
11	6	150
12	9	230
13	11.5	290
14	9.5	240
15	3.5	90
Average for sample	6.8	173
Total length	272	6900
No. of sample trees	40	

FIELD TESTS OF SHEAR DAMAGE--WINTER FELLING

Shear damage to the butt ends of full trees was also assessed during the winter study. A sample of 40 trees from the machine's production during the study covered a range of butt diameters from 8 to 16 inches (200 to 400 mm). Figure 7 shows a typical winter stump and illustrates the characteristic shape of the ParaShear cut.

Length of damage averaged 15 in. (380 mm), and ranged from 1 to 42 in. (25 to 1100 mm). The length of damage was measured after the "V-shaped snipe" had been trimmed off (see Figures 8 and 9). The volume trimmed from the trees in order to remove all visible damage averaged 1 ft^3 (.03 m^3) per tree, and using the average tree size for the sample, represented a loss of 5.5% by volume. Table 7 shows the average damage length for each 1-inch (25 mm) diameter class. Also shown in the table are comparative results for a standard QM single-blade tree snipper, which was operating in the same general area as the ParaShear. Average length of damage with the snipper was 21 in. (530 mm), with a range from 8 to 48 in. (200 to 1200 mm). The amount of butt trimming measured for the single-blade shear was consistently greater than that for the ParaShear.

Damage to frozen trees in winter cutting was worse than in summer cutting. For results comparable to those in the summer sample 10 inches (250 mm) of trim would be necessary for 40% damage-free butts, and 25 inches (610 mm) of trim for 85.7% damage-free butts.

During the winter study, the operator frequently had to lean out of the cab to see where to position the felling head. This visibility problem, affecting the positioning of the

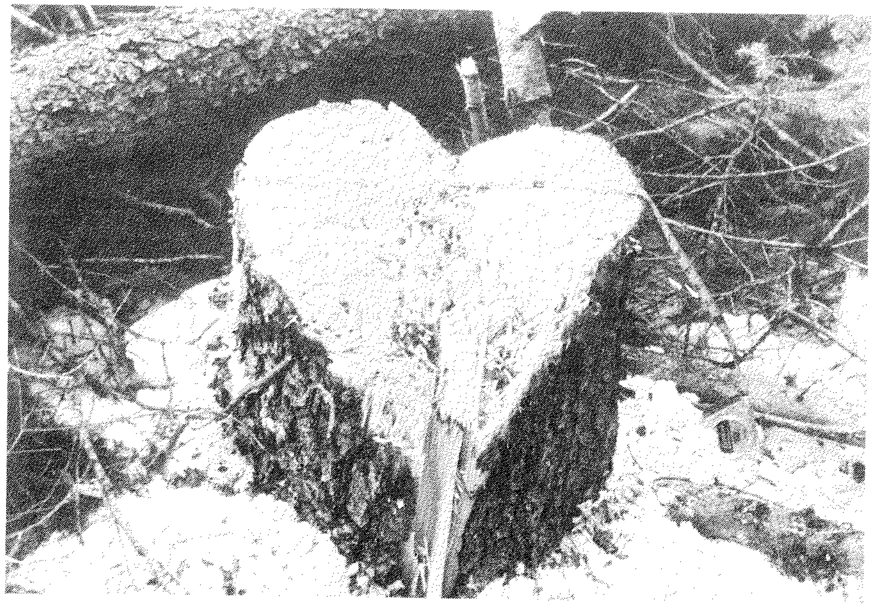


FIG. 7. Characteristic shape of stumps after ParaShear felling of frozen trees. This stump, cut in winter, is not as smashed up or shattered as stumps cut in summer.

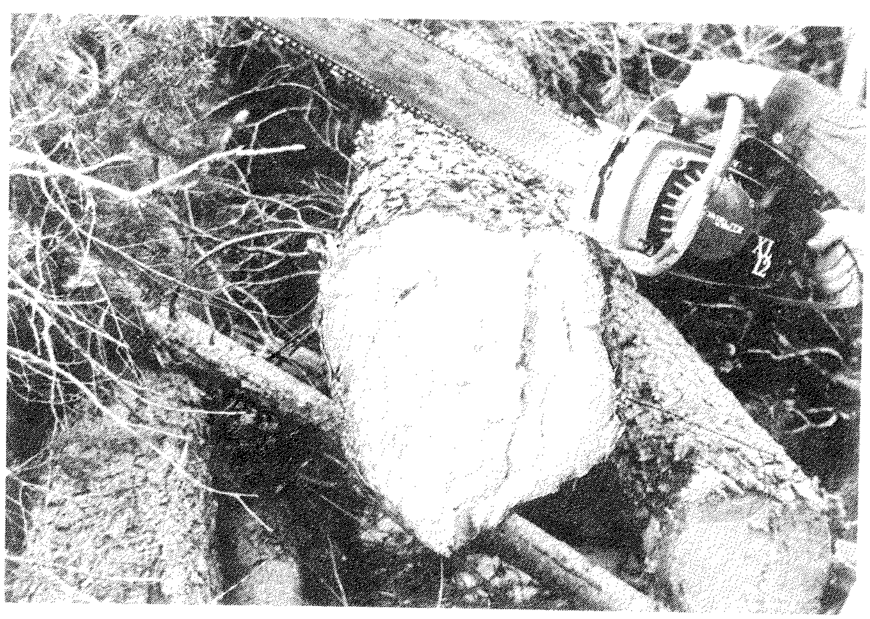


FIG. 8. ParaShear cut trees from winter study. Note the "V-shaped snipe" on the butt end and the visible shear cracks.

FIG. 9. Field testing of shear damage in frozen wood. The arrow shows splitting visible after "V-shaped snipe" has been trimmed off the butt.

TABLE 7. Average Length of Damage--Winter Felling (from trimmed butt).

Diameter Class inches	mm	ParaShear inches	mm	Snipper inches	mm
8	203	4.8	122	11.0	220
9	229	7.5	191	14.0	356
10	254	15.2	386	22.4	570
11	280	17.3	430	21.3	540
12	305	15.5	394	21.0	534
13	330	21.8	554	30.0	762
14	356	22.1	560	26.7	678
15	381	9.5	242	18.0	457
Average for sample		14.9	378	21.3	541
Total length		595	15150	468	11900
No. of sample trees		40		22	

shear against the tree, resulted in additional shear damage. Such damage was obvious in many of the sample trees because they had been partially crushed by the shear blade arms rather than cleanly sheared by the blades.

The "V-shaped" butt ends of trees cut by the ParaShear have resulted in complaints from some millyards, particularly those using automatic scanning devices for measuring log lengths. If ParaShear felled wood is run through a sawmill in separate batches, the scaling can be adjusted to allow for the extra trim necessary to remove the conical butt. If some ParaShear felled wood is mixed with chainsaw felled wood going through the mill however, the "V-shaped" butt end will be included in the log length. Extra trimming will then be necessary to remove this part and logs will also be trimmed down to the next smaller length, resulting in additional waste.

MILL STUDY OF SHEAR DAMAGE[1]

A sample of 59 trees cut from the same stand as that upon which Table 6 was based during the summer was processed through the mill and assessed for shear damage by the Western Forest Products Laboratory. The sample trees were divided into two size classes, 4.0 to 7.9 in. D.B.H. (101 to 200 mm) and 8.0 to 11.9 in. D.B.H. (201 to 300 mm). The conical butt end made by the ParaShear was squared off in the mill yard before the logs were converted into lumber.

Log input, lumber outturn and lumber trim volumes were calculated for each 4-inch (100 mm) D.B.H. class.

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[1]This section summarizes the findings of the report "ParaShear shatter damage study" by Wright, D.M., Restricted Report, Western Forest Products Laboratory, Environment Canada, Vancouver.

Lumber recovery information was applied to total tree volume, thereby providing a lumber recovery factor and percent trim loss per tree.

Table 8 shows that the very small diameter trees had no shatter damage and in the larger diameter trees only 3.2 percent of the pieces of lumber required trimming.

Table 9 shows that the percent volume loss due to shatter is only .33 percent of lumber yields from butt logs and that the reduction in lumber recovery factor is minimal.

Lumber volume loss per tree is approximately a quarter of one percent for the larger sample trees (see Table 10).

The results from the two samples studied indicate that shatter damage in unfrozen lodgepole pine felled using a ParaShear is insignificant.

Losses could be greater in frozen and larger trees as suggested by the field test results, but a mill study on frozen wood was not made.

TABLE 8. Percent of Lumber Pieces Trimmed.

D.B.H. in. (mm)	Total Pieces	Percent Trimmed
4.0 - 7.9 (101 - 200)	117	-
8.0 - 11.9 (201 - 300)	93	3.2
Total:	210	1.4

TABLE 9. Lumber Recovery and Percent Trim Loss in Butt Logs

D.B.H. in. (mm)	Total Lumber Volume (bd.ft.)	Trimmed Volume (bd.ft.)	Percent Trim Loss	Total Log Volume cu.ft. (m^3)	L.R.F.* Untrimmed	L.R.F. Trimmed
4.0 - 7.9 (101 - 200)	903.4	-	-	125.1 (3.5)	7.22	7.22
8.0 - 11.9 (201 - 300)	904.7	6.0	0.66	112.5 (3.2)	8.04	7.99
Total:	1808.1	6.0	0.33	237.6 (6.7)	7.61	7.58

TABLE 10. Lumber Recovery and Percent Trim Loss per Tree

D.B.H. in. (mm)	Total Tree Volume 4" Top ft^3 (m^3)	Total Lumber Volume Untrimmed	Total Lumber Volume Trimmed	L.R.F. Untrimmed	L.R.F. Trimmed	Percent Trim Loss
4.0 - 7.9 (101 - 200)	236.4 (6.7)	1706.8	1706.8	7.22	7.22	-
8.0 - 11.9 (201 - 300)	298.3 (8.4)	2246.0	2240.0	7.53	7.51	.27
Total:	534.7 (15.1)	3952.8	3946.8	7.39	7.38	.14

*L.R.F.: Lumber Recovery Factor, bd.ft. lumber tally per cu.ft. log scale.

EXPECTED COSTS

The machine costs presented below show a realistic range of costs that may be expected with the ParaShear. The costs are calculated on the purchase price of a used crawler undercarriage with a new feller-buncher attachment. The purchase price of $130,000 is based on a price of $65,000 for a second-hand 1970 Caterpillar D8 tractor* (with canopy and blade, but no winch, and 50% usable undercarriage life), and $65,000 for the new boom and felling-head attachment. The purchase of a ParaShear using a new crawler undercarriage and feller-buncher attachment would be approximately $215,000, f.o.b. Vancouver. Because of uncertainties in the cost calculation arising from estimates of some variables, a range of costs is given instead of a single estimate.

The total cost ($/cunit) is calculated from the following equation:

$$\$/\text{cunit} = \left[\left[\frac{I-R}{L}\left(1+\frac{i(N+1)}{2}\right) + \frac{iRN}{L} + M + W\right]\frac{100}{U} + F\right]\frac{1}{P}$$

where:

Known Values

I	=	purchase price: $130,000 f.o.b. Vancouver
F	=	fuel (including hydraulic fluid): $3.50/PMH
W	=	operator's wage: $12/SMH (including fringe benefits)
N	=	depreciation period: 4 years
i	=	interest and insurance factor: 0.13

Estimated Values (based on western Canadian conditions)

	favourable	unfavourable
R = residual value, $	13,000	13,000
L = economic life of machine, SMH	10,000	8,000

---

*Price supplied by Finning Tractor & Equipment Co.Ltd., Vancouver.

	favourable	unfavourable
U = utilization percent	80%	60%
M = maintenance cost (100% and 150% of fixed costs), \$/SMH	16.18	30.35
P = productivity (based on tree volumes of 20 ft^3 and 10 ft^3), cunits/PMH	15.6	7.8
(m^3/PMH)	(44.2)	(22.1)

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

	favourable	unfavourable
Total cost, \$/PMH	58.95	107.80
Total cost, \$/cunit	3.78	13.82
(\$/m^3)	(1.33)	(4.88)

The calculation shows that the ParaShear could achieve reasonable costs for felling and bunching, if the machine operates at a high level of utilization in favourable stand conditions. A residual value of 10% of purchase price was used in the calculation because the machine was based on a second-hand tractor undercarriage. If a new machine were purchased, there would be a higher residual value reflecting the potential to convert the machine, if not successful, back into a bulldozer.

STUDY OF ERGONOMICS

The study of ergonomics was made during the summer test and was based on the Swedish Ergonomic Checklist, published by the Logging Research Foundation (Aminoff *et al.*, 1974). The inspection was based on the reference data given in the checklist and the operator's comments were also considered (see Appendix C). For the most part, the ergonomic characteristics are for the tractor undercarriage used and not the feller-buncher attachment.

Mounting and alighting was considered to be poor. Because no special steps were provided and handles only on one side the operator risked slipping on the A-frame and track. Bailing out quickly was difficult, as the gear shift stand was positioned in the middle of the entrance opening.

Working position was fairly good, although some controls were placed out of the recommended areas.

Operator's seat was difficult to adjust and was not inclined backwards. Upholstery was vinyl, which is cold in winter time and hot in summer. The seat was sprung and damped, but the efficiency of the suspension was unknown.

Operator's cab was roomy, but it was not enclosed and there was no guard against objects penetrating from lower rear. Once, during the study, a snag entered the cab while the machine was backing. Hydraulic valves, because of their location, might leak oil inside the cab.

Controls: actuating forces were close to reference data. Main boom manoeuvre lever should be to the right as on most excavators and cranes.

Instruments cannot be seen by operator when facing backwards. A warning light or sound for low oil pressures, etc. should therefore be provided.

Visibility was poor when felling due to the wide boom. See vision diagram, Appendix C.

Lighting was not tested, but was believed not to fulfil the reference data.

Working climate was not tested.

Noise level was estimated to be high. Operator should wear hearing protectors.

Vibration was not tested, but should be the same as for a crawler tractor.

Exhaust emission was not tested.

Maintenance can generally be made without too much trouble, but a ladder or platform had to be used to lubricate the boom.

CONCLUSION

The ParaShear was designed for felling and bunching one tree at a time, and had slower cycle times and lower productivity than other similar models such as the Drott and Forano BJ-20. The slower cycle times are due to the undercarriage design and the boom component speeds, and also to the inexperience of the two operators observed. In its present configuration, the ParaShear shows potential only under better conditions, with a high proportion of trees close to the upper size limit for the shear. If the felling head were mounted on other carriers, it seems probable that cycle times and productivity would improve. The ParaShear's crawler undercarriage does however give the machine the ability to work steeper slopes and rougher terrain than the Drott. It may also be used for skid-road and landing construction, while in the feller-buncher configuration.

The cost examples presented here reflect the initial cost of a used undercarriage, with a new boom and felling head. It is feasible to use a new crawler undercarriage with the boom and felling head, but at a much higher initial cost. With a new undercarriage the machine could be converted back to a bulldozer, if no longer required as a feller-buncher, and could realize a much better residual value as compared with that of the Drott or Forano machines. It is also feasible to use a fully depreciated crawler tractor undercarriage, where the initial cost would be only that of the feller-buncher attachment and modifications to the undercarriage.

The cutting action of the shear was designed to eliminate shatter in the butt by directing cutting forces into the stump and by cutting at an angle to the grain in the tree. Field assessments of shear damage, both in summer and winter, showed that there is still damage occurring. The length of shear damage was less than that of other feller-bunchers, but was not eliminated, even in summer. Winter results showed splitting to be twice as long as it was under summer conditions. Much of the winter damage appeared to be the result of faulty positioning of the felling head. This induced stress in the trees prior to shearing, and was a direct result of the operator's inexperience in positioning the felling head.

From the ergonomic standpoint, the machine with tractor undercarriage needs further attention in several problem areas. These include mounting and alighting from the cab, noise levels in the cab, and the operator's visibility. The use of a different undercarriage would change the assessment and could provide a more favourable environment for the operator.

Many of the problems observed with the ParaShear were the same as those encountered with other new machines during their introductory stages. The inexperience of the operator is one area where improvement will result as he becomes more skilled and familiar with the machine. Other areas, such as hydraulic problems and poor visibility, are dependent upon changes and modifications by the manufacturer before improvement can be realized. Some of the problems resulted from the use of a used tractor-undercarriage for the machine, in an attempt to minimize the capital outlay and at the same time, use a more rugged undercarriage with better terrain capabilities. The machine was also introduced at a time when there was low economic activity in the forest industry, which undoubtedly influenced the locations and extent of its trials.

The forest industry needs a feller buncher with good mobility and a rugged, easily-maintained cutting head which produces a minimum of butt damage to the trees. The Para-Shear was designed to provide these features.

In summation, the study showed that the machine has a place in a mechanized logging operation, but is still at an early stage of development, needing improvement in many details. The felling head on its own would be a promising alternative attachment for other feller-buncher machines.

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APPENDIX A

MACHINE SPECIFICATIONS

TEREX 82-40 CRAWLER TRACTOR

General dimensions	in.	mm
Overall length	196.6	5000
Overall width	104.5	2650
Ground clearance	19.5	495
Gauge	78	1985
Track length on ground	124	3150
Track width	24	610
Ground contact area	5960 in^2	3.85 m^2

Engine

Make: TEREX Detroit Diesel, 2 cycle		
Model: 8V 71-N		
Net power at 2100 RPM	275 HP	205 kW
No. of cylinders	8	
Displacement	568 in^3	9.3 ℓ
Fuel tank	112 gal	510 ℓ

Transmission

Make: Allison
Type: Torque Converter with 3 speeds forward and reverse power shift

Speed:					
Forward -	2.1	3.7	6.1	MPH
	3.4	5.9	9.8	km/h
Reverse -	2.4	4.3	7.1	MPH
	3.8	6.9	11.4	km/h

Hydraulic System

Pump capacity at 2100 RPM - 69 and 30 GPM (Imp)
314 and 136 ℓ/min

Pressure relief valve setting - 2100 and 1700 psi
14.5 and 11.7 MPa

Tank volume - 35 gal   159 ℓ

Electrical system: 24V

FELLER-BUNCHER ATTACHMENT

Boom

Reach, maximum	25 ft	(7.6 m)
minimum	12.5 ft	(3.8 m)
maximum below ground	7.0 ft	(2.1 m)
Swing angle	±75°	
Gross lift moment	373,300 lb.ft.	(510 kNm)
Net lift capacity in felling head	7,500 lb	(3400 kg)
Swing torque	16,000 lb.ft.	(21.7 kNm)
Swing speed	15° per sec	
Weight	15,000 lb	(6650 kg)

Shear

Max. shear capacity	18 in.	(46 cm)
Blade thickness	0.75 in.	(19 mm)
Tilt angle	100°	
Twist angle	±20°	
Weight	4,500 lb.	(1800 kg)

Total Machine Weight	92,000 lb.	(42000 kg)
Ground Pressure	15.4 psi	(106 kPa)

Manufacturer's specifications are subject to change without notice.

APPENDIX B

STUDY OF MACHINE AND OPERATOR PERFORMANCE

MACHINE PERFORMANCE

The base machine should be put on a flat surface. The engine should be run at normal working speed. Each function of the boom is to be timed three times at least. The time recorded should be for the full stroke of the function, or for continuous runnings etc. for 180° movement. All times are given in centi-minutes (cmin).

Machine make and type: Earl's ParaShear 18 on TEREX 82-40.
Boom make and type:

Machine No.: 1 Operator: Joe Kirschner Date: June 6/76

Locality: W. Beaverdell Sig. DWM

Engine speed at study: 1500 rpm

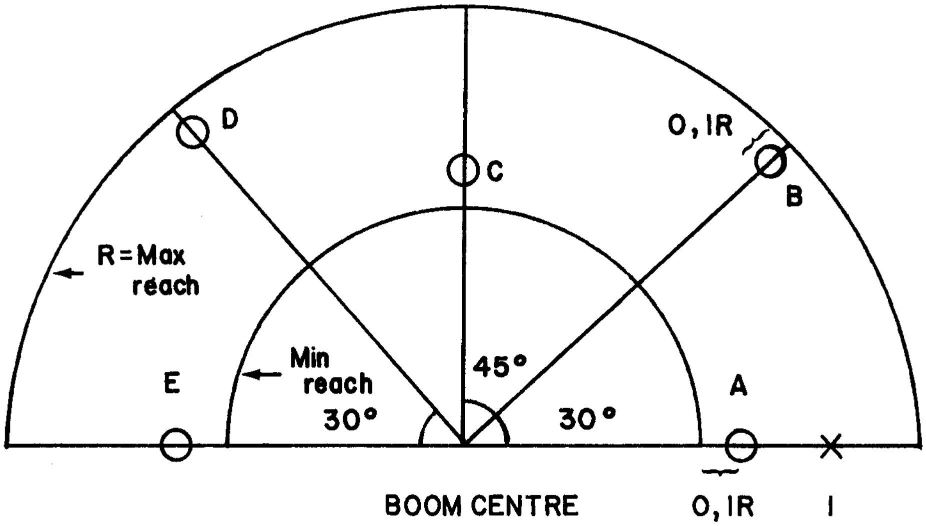
Function	Part function	Test Number 1	2	3	4	5	Avg.	Recommended time	Difference %	Notes
Swing	left	14	14	14			14.0	13.5	-4	150°
	right	13	13	14			13.3	13.5	+1	
Main boom	up	18	17	18			17.7	12.6	-40	26" cylinder stroke
	down	6	4	4			4.7	-		
Outer boom	up	22	22	22			22.0	18.2	-21	
	down	9	10	9			9.3	-		
Tilt	forward	9	8	8			8.3	6.8	-22	
	backward	10	10	10			10.0	9.1	-10	
Twist	left	5	5	5			5.0	3.25	-54	
	right	5	4	5			4.7	3.25	-44	
Grapple arms	close									
	open									
Cutting device	close	6	6	6			6.0	4.9	-22	Incl. grapple arms
	open	7	7	7			7.0	6.1	-15	

Recommended times are calculated from hydraulic system data and adjusted to engine speed at study.

Comments: The test indicates an abnormal leakage in the big pump circuit. The slow action of the twist movement is probably also due to the small diameter oil hoses used for that function.

Operator Performance

The machine is put on a flat surface about 30 by 50 feet. Five sticks, about 2 in. diameter and 8 feet long, are put in front of the machine according to the figure below. If boom movement is less than 180°, position of sticks A and E is altered accordingly.



Study starts with felling head at 1. The sticks are grabbed in alphabetic order and put at 1. Each cycle is timed. The study is repeated four times. The operator uses engine speed to his choice.

Machine make and type: Earl's ParaShear 18" on TEREX 8240
Boom make and type: Earl's
Machine No: 1 Operator: Joe Kirschner Date: June 1/76
Locality: W. Beaverdell Sign: DWM

Stick	A	B	C	D	E	SUM	AVG	Notes
Test No	cmin	cmin	cmin	cmin	cmin	cmin	cmin	
1	31	33	43	48	40	195	39	
2	38	35	40	42	33	188	38	
3	32	34	41	45	36	188	38	
4	25	30	38	42	31	166	33	
SUM	126	172	167	177	140		148	
AVG	32	43	42	44	35		37	

APPENDIX C

ERGONOMIC CHECKLIST
for
transport and materials handling machinery

Staffan Aminoff
Jan-Erik Hansson
Bo Pettersson

INSPECTION FORM

Machine type . Earl's ParaShear No. 1 ....

Model .. On TEREX 8240 ....

Place ... W. Beaverdell ....

Date .... June 3, 1976 ....

Inspected by ..... D.W. Myhrman ....

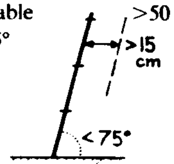
Before the inspection is started, the following points should be checked:

- Field of application of the machine.
- On what type of ground will the machine operate?
- The relative duration of the various work elements (driving, loading, unloading, processing, etc.).
- How often must the operator climb in and out of the cab?
- How long is the machine utilized per shift?
- Is the machine to be used in darkness?

1. Mounting and alighting

Reference data

Height to first step, cm		Gap between steps, cm	
Comfortable	<35	Comfortable	20 – 30
Uncomfortable	35 – 50	Uncomfortable	30 – 40
Very uncomfortable	>50	Very uncomfortable	>40
Angle of steps <75°		Width of step	>30
		Size of door	>62×160
		Depth of step (foot-room)	>15



Points to assess

		Yes	No
1.1	Can work be done without risk of slipping (material, design and location of steps, etc.)?	☐	☒
1.2	Can work be done without other accident risks (sharp edges, pointed corners, etc.)	☒	☐
1.3	Is it possible to bale out quickly (roof hatch, location of doors, etc.)?	☐	☒
1.4	Is there a sufficient number of emergency exits?	☒	☐
1.5	Is it possible to mount and alight without undue discomfort (gap between steps, the design, location and functioning of handles, doors, steps, etc.)?	☐	☒
1.6	Other points ____________	☐	☐

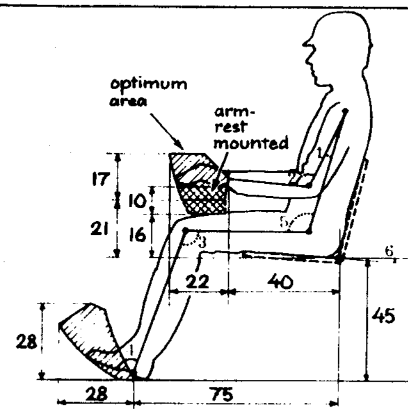
Remarks: Height to first step (A-frame) 75 cm (30"); Height to second step (track) 115 cm (45"); Height to floor 148 cm (58"); No anti-slip device furnished on steps; Risk of slipping into space between A-frame and track frame and between tracks and machine frame with possible damage to foot or leg; No handle on left side. Very narrow passage at gear shift stand.

2. Working position

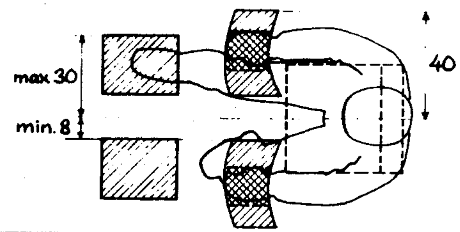
Reference data

Angles:

1 10 – 15°
2 105 – 115°
3 105 – 120°
4 90 – 100°
5 approx. 100°
6 3 – 7°



Bear in mind that the working place should be comfortable for large and small operators.



Points to assess

		Driving Yes	Driving No	Stationary work Yes	Stationary work No
2.1	Are the pedals and controls conveniently located?	☒	☐	☐	☒
2.2	Can work be done without twisted and awkward postures?	☒	☐	☒	☐
2.3	Is the working position generally comfortable?	☒	☐	☒	☐
2.4	Other points	☐	☐	☐	☐

Remarks: In position for stationary work the steering ~~levers are too low,~~ it is difficult to reach the gear shift lever and the decelerator is for the left foot. The control levers for the boom are too far away from the operator.

3. Operator's seat

Reference data

Seat

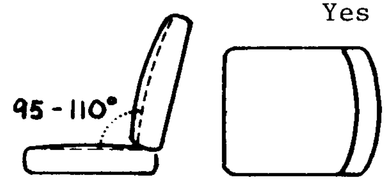
Width >44 cm	44
Length to reference point 37 – 43 cm	37
Backward inclination 3 – 7° (adjustable)	0
Height above floor 45 cm	55
Height adjustment range ± 5 cm	3
Length adjustment range ± 8 cm	8
Cushion thickness 25 – 50 mm, fairly firm and vibration absorbent	Yes

Backrest

Width 40 – 50 cm	35
Height 40 – 50 cm	33
Seat-backrest angle adjustable between 95 and 110°	No

Shape:

Slightly convex to the front vertically Yes



Slightly concave to the front horizontally

Points to assess

		Yes	No
3.1	Is the seat properly secured?	☒	☐
3.2	Are the design and inclination of the seat and backrest satisfactory?	☐	☒
3.3	Is the upholstery of the seat and backrest satisfactory (friction, ventilation, etc.)?	☐	☒
3.4	Is the seat well sprung and insulated from shock?	☒	☐
3.5	Has the seat a sufficient adjustment range for both height and length?	☐	☒
3.6	Is the seat easily adjustable?	☐	☒
3.7	Other points: ______	☐	☐

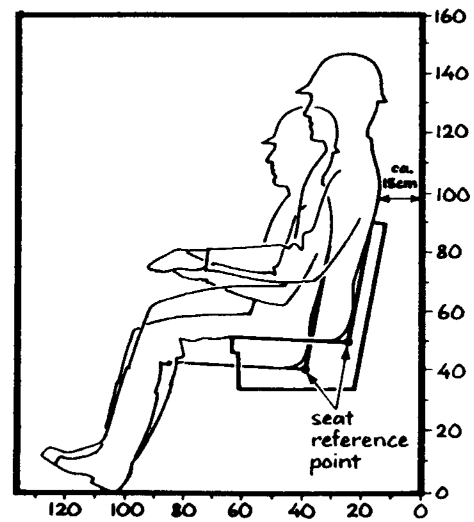
Remarks: Seat does not incline backwards; Seat upholstery is unventilated vinyl; Adjusting seat height requires spanner; Seat dimensions are not fully within the reference data.

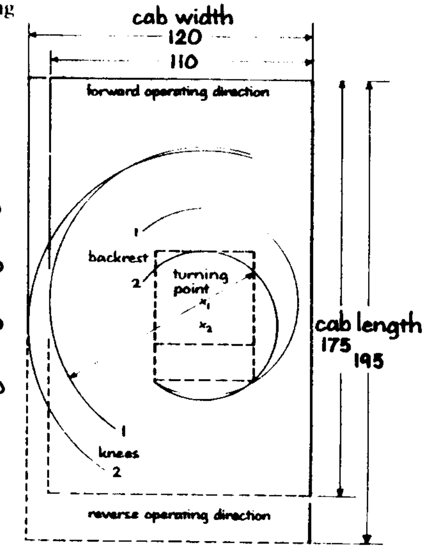
4. Operator's cab

Reference data

Leg and knee-room when seat revolving:
Slewing radius (seat in centre position) >65 cm.

	One operating direction	Two operating directions
Cab width	> 90 cm	>110 cm
Height	>160 cm	>160 cm
Length	>135 cm	>175 cm





Example of the importance of the location of the turning point of the seat in cabs on machines operating in two directions. Two alternative locations of the turning point (x_1 and x_2) are compared.

Points to assess

		Yes	No
4.1	Is the cab large enough?	☒	☐
4.2	Is the cab free from protrusions which may injure the operator?	☒	☐
4.3	Is the cab easy to clean?	☐	☒
4.4	Other points: ______	☐	☐

Remarks: Cab not enclosed; No guard for objects penetrating from lower rear; Floor is not flat; Hydraulic valves inside might leak oil.

5. Controls

Reference data

	Actuating force for control, N	
	optimum	**maximum**
Hand-operated	5 – 20	230 steering wheel 140 lever, operating direction forward – reverse 60 lever, operating direction sideways
Leg-operated	45 – 90	250 brake, clutch
Foot-operated	20 – 45	

Points to assess

	Steering wheel Yes	Steering wheel No	Pedals Yes	Pedals No	Hand controls Yes	Hand controls No
5.1 Are frequently used controls located within easy reach (see point 2)?	☒	☒	☒	☐	☒ 1)	☐
	Front	back				
5.2 Is the actuating force below the maximum specified?	☒	☐	☒	☐	☒	☐
5.3 Does the actuating force correspond to the optimum reference data?	☐	☒	☐	☐	☐	☒
5.4 Is the range of movement within the optimum working area?	☐	☐	☒	☐	☐	☒
5.5 Are the controls suited to their functions?			☐	☐	☒	☐
5.6 Is the operation of the control logical and are there a suitable number of operations per control?			☐	☒	☐	☒
5.7 Is the design, grouping and coding of the controls such that a good grip is obtained and that confusion or involuntary actuation of the controls can be avoided?			☐	☒	☐	☒
5.8 Other points ______			☐	☐	☐	☐

Remarks: Boom control levels are 20-30 N (4.4-6.6 lb); steering levers are 50 N (11 lb); Boom manoeuvre lever should be to the right; Controls not coded.

1) Except gear shift.

6. Instruments

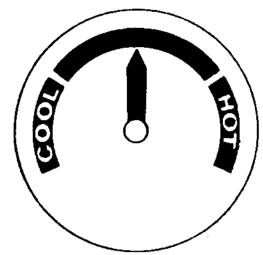
Reference data

The type of instrument should be suitably adapted to the receiving conditions:
Acoustic signals – short, warning signal
Light signals – indicating one of two conditions, e.g. empty – not empty
Dials – most usual for other cases.

Location of instruments – should enable easy surveillance.

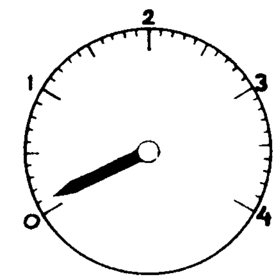
Design of dials

No unnecessary information



Light figures against dark background – if they are to be read under various lighting conditions

The scale should be graduated clockwise and be divided in 2 or 5 divisions or multiples thereof.



Points to assess

	Yes	No
6.1 Are all necessary instruments/signals provided?	☒	☐
6.2 Are all the instruments/signals provided necessary?	☒	☐
6.3 Is critical information communicated in such a way that it is noticed?	☐	☒
6.4 Are the instruments of suitable type?	☒	☐
6.5 Are the instruments well located?	☒	☐
6.6 Are the instruments clearly legible (illumination, size, dial scales, colours, etc.)?	☐	☒
6.7 Other points: ______	☐	☐

Remarks: No warning light or sound for low oil pressure etc. when operator faced backwards; Instruments have black figures on white background.

7. Visibility

Reference data

In driving:	A clear view of the ground all round the machine starting at a maximum of 5 m from the operator
In operation when machine is stationary:	A clear view of the ground within the working area of the loading equipment (e.g. boom). Unrestricted visibility within the vertical operating area of the loading equipment (forwards, sideways, up and down).

Points to assess

		Driving		Stationary operation	
		Yes	No	Yes	No
7.1	Does the operator have a generally good view of the ground?	☐	☒	☐	☒
7.2	Does the operator have sufficient upward visibility?	☒	☐	☐	☒
7.3	Is the machine free of components which obstruct visibility (exhaust pipes, safety grille, equipment, etc.)?	☐	☒	☐	☒
7.4	Is it possible to see through windows without the occurrence of confusing reflections?	☐	☐	☐	☐
7.5	Is the machine fitted with windscreen wipers and windscreen washers in proper working order when these are required?	Yes ☐	No ☐		
7.6	Other points: ____________________	☐	☐		

Remarks: Operator cannot see the top of the tree to be felled. Grading blade, boom and felling head restrict the visibility. See vision diagram, figure 10.

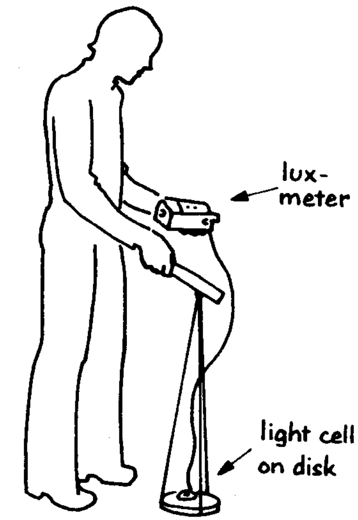
8. Lighting

Reference data applicable to stationary work

Illuminance in operating area

Satisfactory	>30 lux
Unsatisfactory	15 – 30 lux
Highly unsatisfactory	<15 lux

N.B. To measure illuminance, the light cell should be placed on a horizontal disk just above the ground.



Points to assess

		Driving		Stationary operation	
		Yes	No	Yes	No
8.1	Is the illuminance satisfactory?	☐	☐	☐	☐
8.2	Is the illuminated area sufficiently large?	☐	☐	☐	☐
8.3	Is the distribution of light in the field of vision satisfactory (dazzle, etc.)?	☐	☐	☐	☐
8.4	Is maintenance of the lighting equipment straightforward (replacing bulbs, glass, etc.)?			☐	☐
8.5	Other points: ____________________	☐	☐	☐	☐

Remarks: No test made. The machine has two lamps ahead and four backwards, mounted on the ROPS, and two lamps on the boom. There are no lamps sideways. Illumination is probably not satisfactory.

9. Working climate

Reference data	Maximum value:
– Temperature 18–22°C*	32°C 27° SWBGT**
– Air velocity 0.1–0.3 m/s	0.4 m/s

Points to assess

		Yes	No
9.1	Is the climate good during summer?	☐	☐
9.2	Is the climate good during winter?	☐	☐
9.3	Is the operator protected from draught?	☐	☐
9.4	Does the interior cooler (if any) operate satisfactorily (adjustibility, reliability and air circulation)?	☐	☐
9.5	Does the defroster work properly (no mist or ice on windows)?	☐	☐
9.6	Other points: ______________________	☐	☐

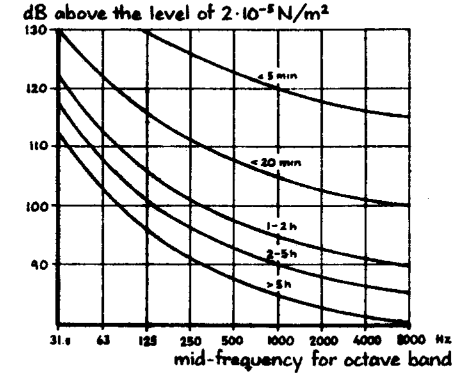
Remarks: No test made. The open cab is heated by the engine radiator. There is no cooling device for summer operation and heat from engine and the hydraulic valves enter the cab. The reference data can probably not always be maintained.

* Applies to continual work in the cab.
** See paragraph 9 on page 6.

10. Noise

Reference data

Maximum permissible exposure (mean level) to noise during typical working day (in accordance with SEN 59 01 11).



If the sound level measured exceeds 85 dB(A) a frequency analysis of the noise should be conducted.
From a comfort and communication standpoint the noise should be considerably lower than 85 dB(A).

Points to assess

		Yes	No
10.1	Can the operator work without danger of injury to hearing if ear muffs are not used?	☐	☒
10.2	Can the operator work without irritating noise if ear muffs are not used?	☐	☒
10.3	Other points: ______________________	☐	☐

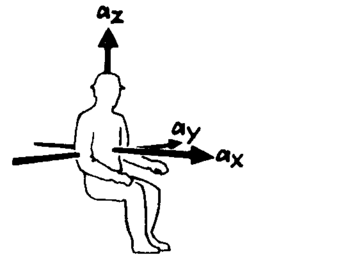
Remarks: No test made, but noise level is high.

11. Vibration

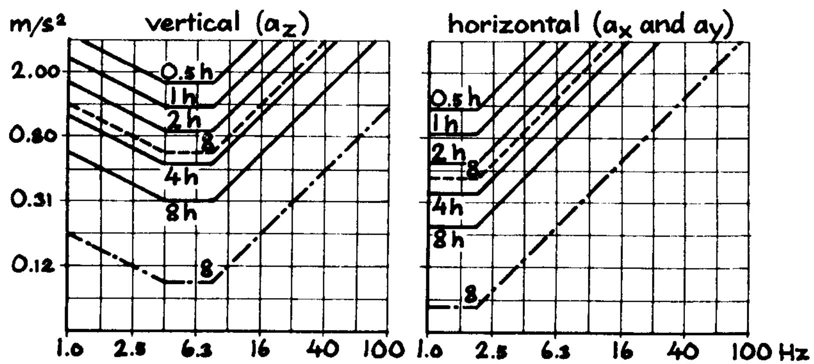
Reference data

Reference data in accordance with ISO 2631 – 1974.

Limit curves for fatigue and reduced work capacity caused by continuous exposure to vibration. The danger limit levels can be obtained by moving the curves up 1 1/2 squares. In the same way, the limit curves for reduced comfort can be obtained by moving the curves down 2 1/2 squares.



ax, ay, az = acceleration in different directions



Points to assess

		Yes	No
11.1	Is the design of the machine favourable from a vibration viewpoint?	☐	☐
11.2	Can the operator work without danger of injury from vibration?	☐	☐
11.3	Can the operator work without being exposed to vibrations which are fatiguing and which reduce his work capacity?	☐	☐
11.4	Can the operator work without being exposed to vibration which may affect his comfort?	☐	☐
11.5	Other points: ______________________	☐	☐

Remarks: No test made.

12. Exhaust emission

Reference data, safety limits

Carbon monoxide = 35 ppm (time-weighted mean 8 – hour value)

Formaldehyde = 2 ppm (ceiling value*)

Nitrogen dioxide = 5 ppm (ceiling value*)

Points to assess

		Yes	No
12.1	Do measurements show the gas concentration to be below the reference level?	☐	☐
12.2	Is the cab free from odour of diesel exhaust?	☐	☐
12.3	Is the cab free from odour of oil or petrol?	☐	☒
12.4	Other points: ______________________	☐	☐

Remarks: No test made.

* ceiling value = maximum time-weighted mean concentration during a 15 – min period.

13. Maintenance

Points to assess

		Yes	No
13.1	Can work be carried out without the danger of slipping?	☐	☐
13.2	Can work be done without heavy lifting or other physically exerting operations?	☒	☐
13.3	Does the design of the machine allow routine maintenance work to be carried out in a comfortable working position?	☐	☐
13.4	Can the work be carried out without the operator becoming unnecessarily dirty?	☒	☐
13.5	Are the lubrication and service points designed and located so that they are readily found?	☒	☐
13.6	Are suitable storage facilities provided for maintenance equipment?	☐	☒
13.7	Other points: ______	☐	☐

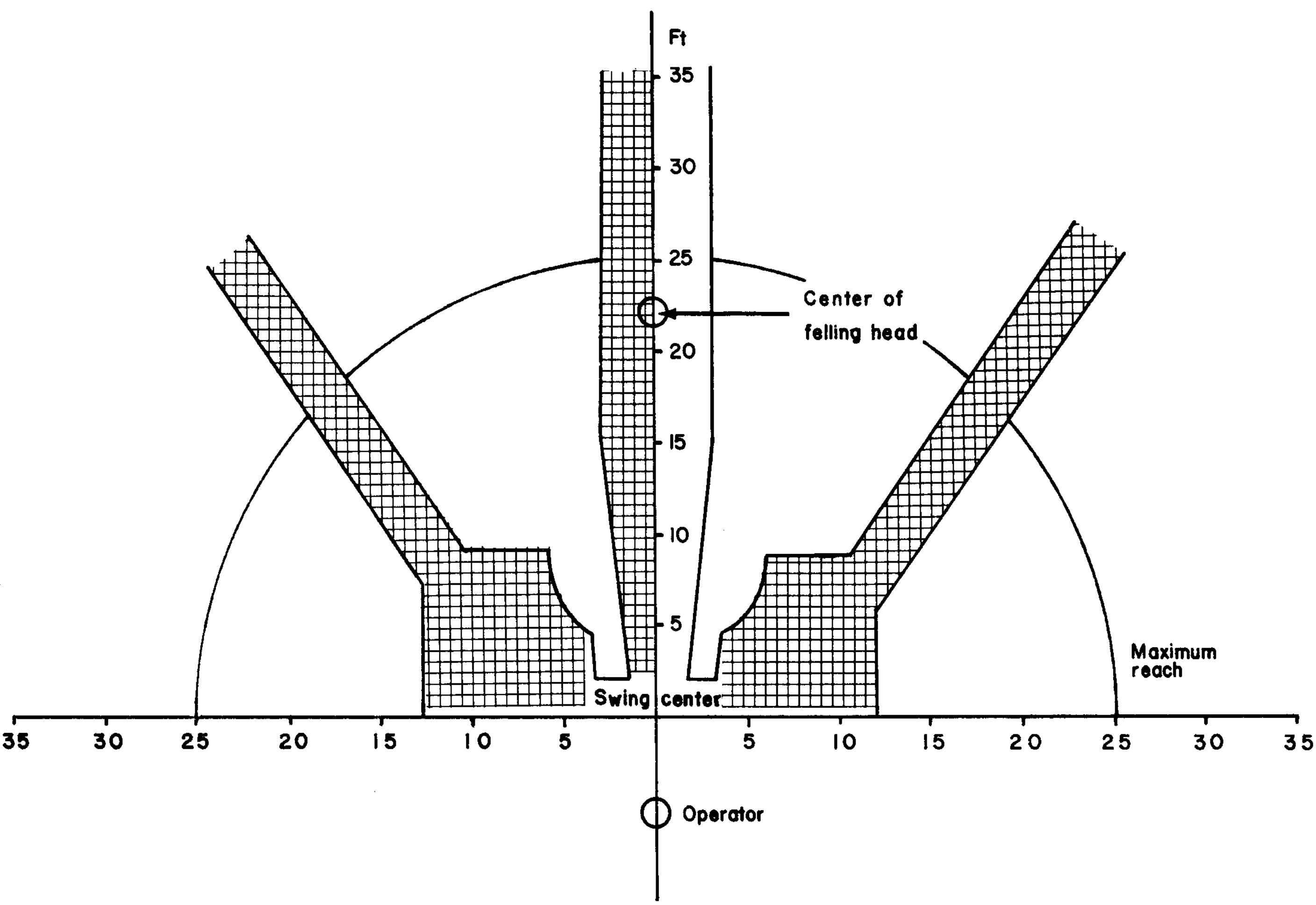
Remarks: To lubricate boom a ladder or platform has to be used.

Overall impression

The checklist contains a large number of points, each of which should be individually assessed. The items are not usually of equal importance. In the final assessment, therefore, the various points should be judged in the light of their ergonomic importance, consideration being given to where, when, how and how often the machine is to be utilized.

Point to assess	Machine design					Ergonomic importance of point to assess		
	1 Very poor	2 Fairly poor	3 Indiff-erent	4 Fairly good	5 Very good	Less im-portant	Import-ant	Very import-ant
1. Mounting and alighting	X					X		
2. Working position				X				X
3. Operator's seat			X					X
4. Cab		X						X
5. Controls			X					X
6. Instruments			X				X	
7. Visibility Driving			X					X
Stationary		X						X
8. Lighting		X					X	
9. Working climate		X						X
10. Noise	X							X
11. Vibration			X					X
12. Exhaust emission			X				X	
13. Maintenance				X			X	

FIG. 10. VISION DIAGRAM.



Shaded areas indicate blind spots in operator's visibility.

Vision is somewhat restricted by protection grid.