FERIC

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

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Evaluation of the S.L.R.-2000 Dual Head Delimber Attachment

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M.P. Folkema is a graduate of Lakehead Univ. and a registered member of the Ont. Prof. For. Assoc.

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SUMMARY

The S.L.R.-2000 is a new sliding-boom delimber attachment that uses two sets of delimbing grapples (instead of the usual single set) to delimb two, or more trees at one time. This attachment, mounted on a modified 6-wheel Lokomo 928 carrier, was recently studied by FERIC. The Lokomo carrier was not evaluated since a variety of carriers can be used. Excavator-type carriers suitable for the S.L.R.-2000 attachment should ideally have a rated bucket capacity of 1.0 m^3 ($1\frac{1}{4}$ yd^3) because a relatively large capacity carrier is required to support the weight of the dual head, boom and multiple trees. Smaller carriers having a rated bucket capacity between .57 to 1.0 m^3 ($\frac{3}{4}$ to $1\frac{1}{4}$ yd^3) can also be used but must be equipped with a shorter boom (usually between 9 and 15 m in length) to obtain suitable stability.

The S.L.R.-2000 unit studied by FERIC had a boom length of 15.4 m and an effective delimbing stroke of 13.1 m. It had no stability problems. A "swing-aside" butt plate permitted all lengths of trees to be delimbed and topped. Both of the delimbing grapples and both of the topping knives could be operated individually or together, permitting trees of different lengths to be delimbed and topped at the same time.

FERIC's studies of the S.L.R.-2000 delimber were made in four different locations in northern Québec, using the same operator, an employee of S.L.R. Full trees piled at right angles to the road were delimbed. The study results are shown in Table S-1.

Table S-1: Production Summary

	STUDY I Alma, Qué.	STUDY II Chapais, Qué.	STUDY III Senneterre, Qué.	STUDY IV Lebel-sur-Quévillon, Qué.
Version studied	Mark I	Mark II	Mark II	Mark II
Date(s) of study	Sept. 9, 10, 1982	Nov. 12, 1982	Nov. 23, 24, 1982	Jan. 25, 26, 1983
Ambient temperature	10°C	-15°C	-10°C	-20°C
Study duration, hrs	4.38	3.53	5.72	5.01
Volume per tree, m^3 (ft^3)	0.183 (6.5)	0.138 (4.9)	0.083 (2.9)	0.111 (3.9)
Cycles per PMH	85	86	74	80
Trees per PMH	195	245	237	400
Production, m^3/PMH (ct/PMH)	36.0 (12.7)	34.0 (12.0)	19.4 (6.9)	44.4 (15.7)

When compared to several single-head delimbers previously studied by FERIC, the S.L.R.'s productivity was considerably higher. Users of the dual head, having operating conditions and equipment similar to those observed by FERIC, can expect a production increase ranging from 20 to 50%, with an average of about 25% to 30%, as compared to most single head units.

INTRODUCTION

The concept for the S.L.R.-2000 dual head delimber was developed by Pierre Gaudreault, mech. eng., of Les Équipement Forestiers S.L.R. Inc. of Alma, Qué. in late 1981. FERIC expressed interest in Gaudreault's dual head concept because a potential productivity increase, in comparison to single-head delimbers, seemed possible using the dual head concept. Some financial assistance was received by S.L.R. from the Fed. Dept. of Trade, Ind. & Commerce. A prototype unit, called the Mark I, was built in mid-1982 by P. Gaudreault, with assistance from G. Clouthier, also of S.L.R.

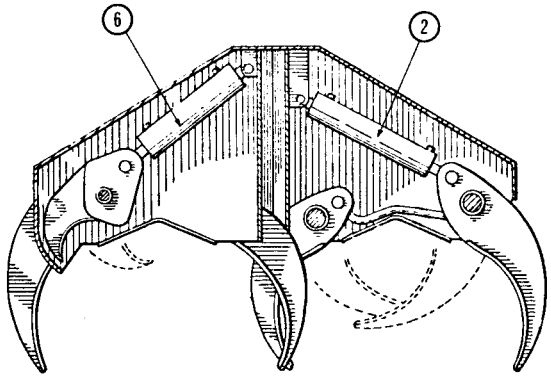
The Mark I prototype of the S.L.R.-2000 was mounted on a used 6-wheel Lokomo carrier, the same one used by S.L.R. for their single-head delimber. The S.L.R.-2000 has a standard boom length of 15.4 m and a delimbing stroke of 13.1 m. The "swing-aside" butt plate allowed all lengths of trees to be delimbed and topped. An illustration of the Mark I is provided in Fig. 1; a technical description plus comments on its operation are provided on page 3.

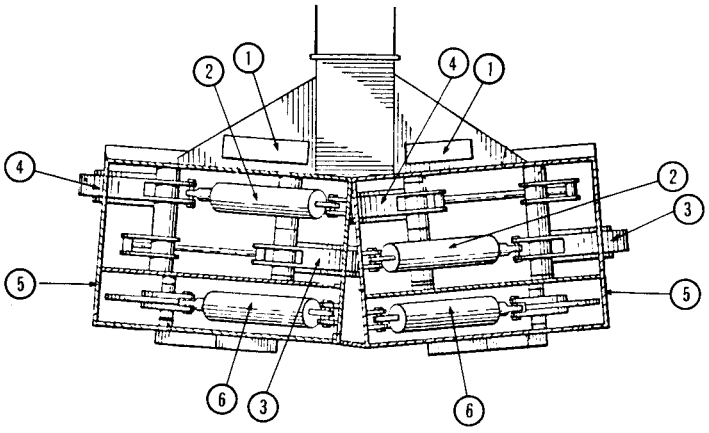
FERIC's first study of the S.L.R.-2000 was on the Mark I prototype operating near Alma, Québec in September, 1982. The results of that study have been included in this report, even though further improvements (some of which have helped to increase productivity) have been made on the S.L.R.-2000. In October 1982, the Mark II prototype was built; this version incorporated several significant improvements. During the period November 1982 to January 1983 the unit was demonstrated for 2-week periods on several logging operations in northern Québec. Additional FERIC studies were made during this period.

In January 1983, Les Industries Wajax Ltée of Montréal became the exclusive distributor for Canada (not including Québec) plus the north-eastern United States. Wajax Industries have informed FERIC that the S.L.R.-2000 can be purchased either with the Lokomo carrier (approx. cost Cdn. $250 000) or as an attachment for a suitable carrier of the buyer's choice. The approximate cost of the attachment installed will be Cdn. $78 000. Installation of the delimber units will be done by S.L.R. at Alma, Qué., with the warranty provided by Wajax Industries. S.L.R. also plans to modify some existing Rocket and Roger delimbers by installing a dual head package.

Technical specifications for the delimber are provided on page 3 and in Appendix A. A conversion table for converting from metric to Imperial units of measure is provided in Appendix B.

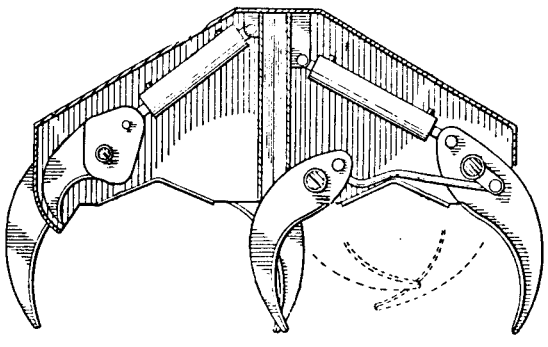
MARK I

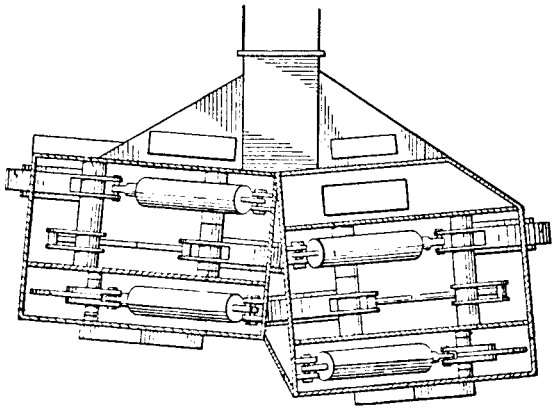


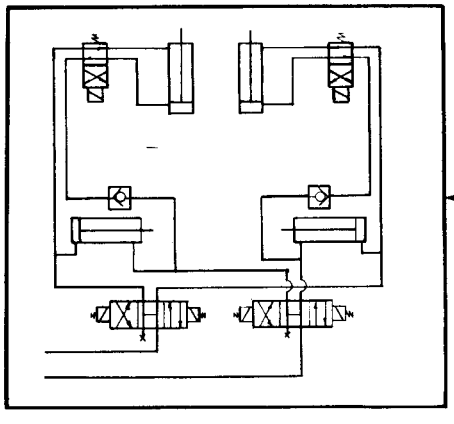


① Valves
② Grapple cylinder
③ R.H.S. grapple arm
④ L.H.S. grapple arm
⑤ Box section
⑥ Topping knife cylinder

MARK II







← HYDRAULIC SYSTEM ON THE MARK II DELIMBING HEAD

Figure 1. S.L.R.-2000, Mark I and Mark II prototypes.

TECHNICAL INFORMATION

Mark I:

This was the first prototype of the S.L.R. dual head delimber. An illustration is shown in Fig. 1.

The delimber head was constructed of two box-like structures mounted side-by-side. The left box was angled at 8^{o} to permit a tree in that grapple to be fed into the retainer arms. Each box contained a cylinder to activate two grapple arms which were mechanically linked to open and close together. A single cylinder was used to activate the topping knife. When fully opened the centre arms of both grapples met together in one point. The weight of the Mark I dual head was 690 kg, which included all the valves and hoses plus the hydraulic oil in the lines. The four cylinders used in the head were identical.

The delimber head was controlled by Dennison valves using an electrically-operated pilot pressure system. The maximum flow available to the head was 200 L/min, and the maximum flow to the (double) retainer arms was 135 L/min.

The delimbing knives had a "constant pressure" feature (approx. 500 p.s.i.) during Study I (see p. 4), which closed the knives according to tree taper as the tree was being delimbed. This "constant pressure" feature was based on the use of several limit switches. The electrical action of the limit switches was too fast, (sometimes 5 times per second), which resulted in a jerky action on the delimbing knives and tree stem damage. An electrical relay was tested for several weeks to slow down the jerky action on the hydraulics; but this was later removed. Soon after this the constant pressure feature was also removed for the following reasons:

1. The S.L.R. operator stated that after 2 or 3 weeks experience it was just as easy for him to manually control the (full pressure) delimbing knives.

2. The S.L.R.'s "constant pressure" system required several extra parts (value $1500) and was relatively complex. The additional maintenance problems that might be encountered would not necessarily offset the gain in productivity resulting from reduced operator workload.

After the "constant pressure" device was removed, the delimbing knives were always manually controlled (similar to most single-head delimbers).

Another feature on the Mark I (not present on the Mark II) was the limit switch that prevented the delimbing arms from opening until the topping knives where fully retracted. When unloading tree lengths, the operator normally opened both the delimbing knives and the retainer grapple simultaneously. However, as a result of debris in the topping knives or because the operator failed to wait for the knives to retract, the retainer arms would sometimes open, but the delimbing knives would stay closed. This resulted in poor butt indexing and some minor delays.

The butt plate on the Mark I could be swung aside to permit long trees to be delimbed. Since two limit switches plus mechanical stoppers were used there was a noticeable impact when the butt plate was opened and closed. This shock load resulted in premature bushing wear. Another problem was that the butt plate (which was normally held closed) would drop down when the oil pressure was reduced because other hydraulic functions were activated on the same circuit. This interfered with delimbing production to a small extent.

Mark II:

The Mark II prototype was built in October, 1982. Although its appearance was very similar to the Mark I, it incorporated several improvements over the earlier prototype. The Mark II used the same pins, bushings and cylinders as the Mark I. The butt plate was moved back 15 cm. Due primarily to the use of a smaller, lighter valve and less plating the head weight was reduced to 627 kg for the Mark II version. Additional information on the Mark II is provided below (see also Fig. 1):

1. The two box-like structures (each containing a grapple plus a topping knife) were offset relative to each other, permitting the arms of the left grapple (viewed from the operator's cab) to be interchanged in respect to their offset position to each other. This change helped to correct a problem of topping multiple trees, since in the Mark I head the trees tended not to be properly centred in the ^-section of the left grapple. It also helped to correct a problem when short (e.g. 3 to 6-m pieces) were picked up by the left grapple. These short pieces tended to twist in the left grapple of the Mark I head because of the offset arms of this grapple. It was therefore difficult to pull these short pieces into the retainer arms, resulting in production delays.

2. A considerably smaller, lighter main valve was used on the Mark II. This electrically-operated valve used an internal pilot pressure hydraulic system. The new valve was accompanied with a much more simple hose routing system as well.

3. The topping knives were re-designed with the knife bolted to each arm, rather than welded. This was done to facilitate repairs. A limit switch to prevent in/out boom movement while the topping knives were activated was also installed to protect the knives from operator error/abuse.

4. Servicing, particularly greasing, was greatly improved. On the Mark I, it required 15 to 20 minutes daily for the operator to grease the dual head (only), since he had to place the head in several different positions in order to reach all the grease nipples. Some greasing was done with the head resting on the ground, in both the open and closed grapple position; also some was done with the head raised off the ground (22 nipples in total). On the Mark II, the greasing can be done in 10 minutes.

5. The butt plate and its hydraulic system was re-designed. One problem with the Mark I had been that when oil pressure was used by other functions the oil pressure in the butt plate cylinder decreased and the butt plate could drop. On the Mark II, the butt plate is held in position by the constant pilot pressure system on the carrier. A button is used by the operator to open and close the butt plate; it requires 2 seconds for a cycle.

OPERATING SEQUENCE

Moving: The machine travels on the road, working from roadside piles (see Fig. 2).

Load Full Tree(s): The dual head is extended to the full tree pile. One or more trees are picked up about 3 m from their butt ends. The boom is retracted, drawing the trees to the retainer grapple which closes and holds them.

Delimb: The delimbing knives on the dual head then close and the boom is extended, thereby delimbing the trees. Trees up to 13.1 m merchantable length are delimbed in one stroke. For longer trees, the retainer grapple must be partly opened and the butt plate swung aside to permit the trees to be passed through. The remaining portions of the trees are then delimbed using a reciprocating action. Finally, the trees are topped (individually or together), moved in the reverse direction and placed on the pile to the right side of the machine.

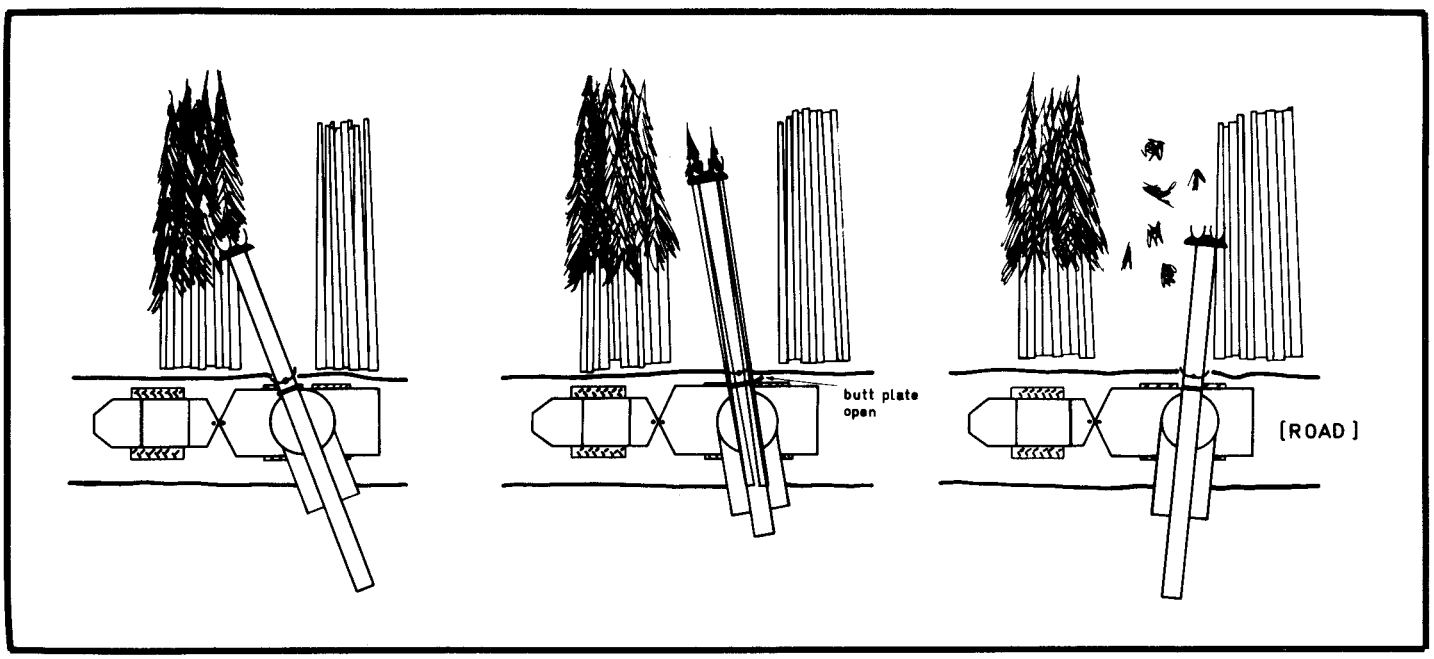


Figure 2. Operating sequence: S.L.R. dual head delimber attachment (mounted on modified Lokomo carrier).

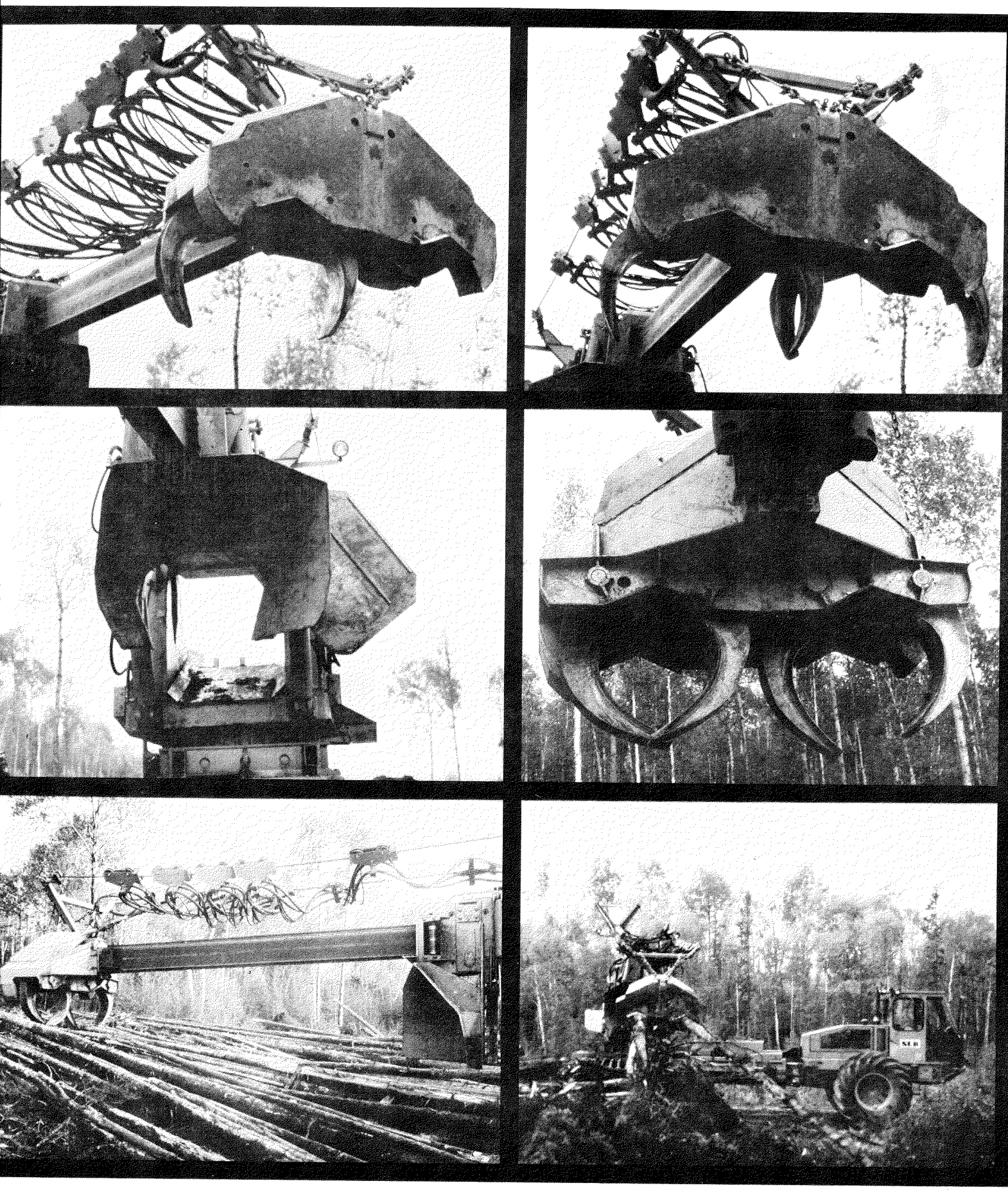


Figure 3. S.L.R.-2000 dual head delimber operating near Alma, Québec.

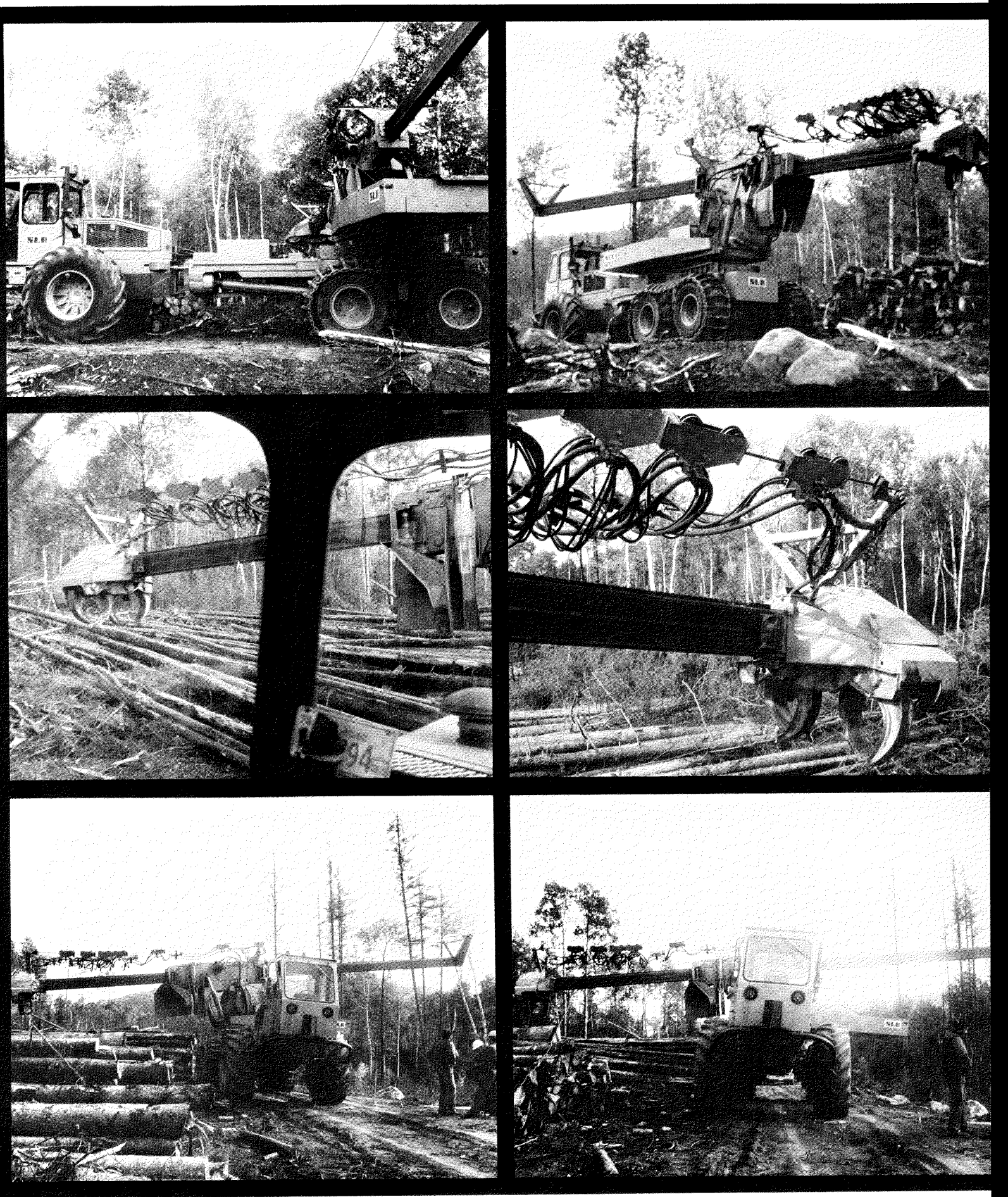


Figure 4. S.L.R.-2000 dual head delimber operating near Alma, Québec.

STUDY SITES

STUDY I: FERIC's first study of the S.L.R.-2000 delimber was on the Mark I prototype in September, 1982 on the operations of Abitibi-Price Inc., 50 km south of Alma, Qué. The operator, an S.L.R. employee, had 3 weeks experience with the dual head, plus 3 months experience on the S.L.R. single-head delimber. Information on operating conditions and production results are shown in Table 1.

In October 1982, the Mark II prototype was built. This unit incorporated many improvements over the Mark I. During the period Nov. 1982 to Jan. 1983 the unit was demonstrated, usually for a 2-3 week period, at several locations in northern Québec. The same S.L.R. operator was studied at each location. At each location, full trees had been skidded to roadside using cable skidders.

STUDY II: This study was conducted on Nov. 12, 1982 on the operations of Barrette Inc., 50 km south of Chapais, Qué. The temperature averaged $-15^{o}C$ and there was 0.4 m of snow. These (early) winter conditions facilitated delimbing.

STUDY III: FERIC's third study was made on Nov. 23 & 24, 1982 on a road right-of-way cut located 25 km west of Senneterre, Qué., on the operations of Normick-Perron Inc. The tree size was small, averaging only 0.083 m^3 (2.9 ft^3). The jack pine (30% of the total) was sorted by placing these trees at a 45^{o} angle on top of the tree-length pile. This sorting procedure decreased the potential productivity by 6.85%. Ambient temperatures when full tree skidding occurred (2 or 3 days prior to delimbing) were above $0^{o}C$. As a result the trees had retained most of their limbs. The temperature during FERIC's study was about $-10^{o}C$.

STUDY IV: This study was made on January 25 & 26, 1983 on the operation of Barrette-Saucier Ltée, about 40 km west of Lebel-sur-Quévillon, Qué. The delimbing conditions were typical for mid-winter; the trees were fully frozen and 80-90% of the branches had been broken off during felling and skidding. The trees were small and uniform in length permitting joint topping, usually at a 6-cm diameter (to permit maximum chip recovery).

Table 1. Operating Conditions and Study Results.

	STUDY I at Abitibi-Price Inc. Alma, Qué. Mark I prototype		STUDY II at Barrette-Chapais Ltée Chapais, Qué. Mark II prototype		STUDY III at Normick Perron Inc. Senneterre, Qué. Mark II prototype		STUDY IV at Barrette-Saucier Ltée Lebel-sur-Quévillon, Qué. Mark II prototype	
Date(s) of study	Sept. 9 & 10, 1982		Nov. 12, 1982		Nov. 23 & 24, 1982		Jan. 25 & 26, 1983	
Ambient temperature	10°C		-15°C		-10°C		-20°C	
Operator-experience on S.L.R.-2000	3 weeks[1]		2 months[1]		2½ months[1]		4 months[1]	
Operator - class	good		excellent		excellent		excellent	
Volume per tree, m^3 (ft^3)	0.183	(6.5)	0.138	(4.9)	0.083	(2.9)	0.111	(3.9)
Species, approx. %	black spruce 60% white spruce 15% balsam fir 25%		jack pine 100% - -		black spruce 70% jack pine 30% -		black spruce 100% - -	
Branchiness class[2]	1-45% 2-45% 3-10%		1-100% 2-0% 3-0%		1-80% 2-20% 3-0%		1-100% 2-0% 3-0%	
Study duration, hours[3] (= PMH)	4.38 hrs		3.53 hrs		5.72 hrs		5.01 hrs	
No. of delimbing cycles	375		301		424		401	
No. of trees delimbed	856		863		1353		2007	
No. of trees delimbed per cycle	16 @ 1 tree 264 @ 2 trees 70 @ 3 trees 18 @ 4 trees 6 @ 5 trees		5 @ 1 tree 124 @ 2 trees 107 @ 3 trees 40 @ 4 trees 22 @ 5 trees	3 @ 6 trees	3 @ 1 tree 164 @ 2 trees 112 @ 3 trees 81 @ 4 trees 37 @ 5 trees	17 @ 6 trees 7 @ 7 trees 1 @ 8 trees 2 @ 9 trees	6 @ 1 tree 54 @ 2 trees 59 @ 3 trees 73 @ 4 trees 43 @ 5 trees	66 @ 6 trees 42 @ 7 trees 33 @ 8 trees 13 @ 9 trees 12 @ 10 trees
No. of trees per cycle, average	2.28		2.87		3.19		5.01	
Volume per cycle, m^3 (ft^3)	0.42	(14.8)	0.39	(14.0)	0.26	(9.3)	0.55	(19.6)
	cmin[4]	% of time per cycle	cmin	% of time per cycle	cmin	% of time per cycle	cmin	% of time per cycle
Load full tree(s)	32.3	46	29.3	42	34.1	42	31.7	42
Delimb	17.6	25	17.4	24	23.8	29	20.4	27
Reverse tree(s) to unload	10.5	15	9.6	14	13.3	17	8.7	12
Moving time	4.2	6	2.6	4	1.1	1	2.3	3
Delays	5.6	8	11.5	16	8.6	11	11.9	16
	70.2	100	70.4	100	80.9	100	75.0	100
Cycles per PMH[5]	85		86		74		80	
Trees per PMH	195		245		237[6]		400	
Production per PMH, m^3/PMH (ct/PMH)	36.0	(12.7)	34.0	(12.0)	19.4	(6.9)	44.4	(15.7)

[1] plus 3 mo. experience on S.L.R. delimber with single head.

[2] Branchiness class, % = $\frac{\text{Merchantable length with live branches}}{\text{Total merchantable length}}$

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

[3] This includes operational delays, mechanical breakdowns and personal delays less than 15 minutes. Delays greater than 15 minutes were not considered as part of productive time (PMH) and were therefore excluded.

[4] cmin = centiminute = 1/100 minute.

[5] PMH = Productive Machine Hour.

[6] Sorting of all jack pine (by placing the tree lengths at a 45° angle on top of the pile) was required on this operation. FERIC calculations indicate that productivity would increase by 6.85% (from 237 to 253 trees/PMH) if no sorting was required.

RESULTS & DISCUSSION

Table 1 summarizes the working conditions and study results. It should be noted that the Study I was based on the use of the Mark I prototype and that improvements were incorporated into the Mark II that helped to increase its productivity. For this reason, some comparisons in this section do not include Study I results. The discussion on productivity is mainly based on the trees per PMH to simplify the comparisons. All the trees delimbed in Study II (.14 m^3), III (.08 m^3) and IV (.11 m^3) were relatively small in diameter.

Productivity

Table 1 indicates that the number of delimbing cycles per PMH was relatively constant for the four studies; it varied between 74 and 86. The number of delimbing cycles per PMH was lowest for Study III (74) and Study IV (80) because the operator tried to maximize the number of trees for each cycle. This required extra time but increased overall productivity. NOTE: The number of delimbing cycles per PMH for the S.L.R.-2000 is compared to several "single-stem" delimbers on p. 18.

Table 1 also indicates that the operator seldom delimbed only one tree per cycle. The average number of trees per cycle varied between 2.28 and 5.01. The percentage of "one-tree" cycles was highest (4%) in Study I, where the largest tree size occurred. The high percentage of "multi-tree" cycles for the S.L.R.-2000 indicates that the delimber can (within the range of conditions observed) consistently function as a "multi-stem" delimber.

FERIC expected a problem with piling after topping trees of different lengths because the top of the shorter tree would no longer be supported. During the studies this proved to be only a minor problem. In many cases, the grip of the stationary grapple continued to hold the (small) tree in position. In other cases a brief delay (included in "piling" time in Table 1) resulted while the operator reversed the boom to re-grab the smaller tree.

The number of trees delimbed per PMH was higher for each successive FERIC study (Study I: 195, Study II: 245, Study III: 237 (253 if no sorting was required), Study IV: 400. Several factors, including seasonal operating conditions, tree size and operator experience contributed to the variation in productivity. These factors are discussed below:

1. Winter Conditions - Frozen wood conditions facilitate delimbing because the branches become brittle and easy to remove. During felling and skidding many branches are normally broken off, which also facilitates delimbing.

   Frozen wood conditions had no effect on Study I and only a moderate effect on Study III ($-10^{o}C$), because of warm temperatures (above $0^{o}C$) during the 2 or 3 days prior to delimbing, when felling and skidding occurred. For Study II ($-15^{o}C$) the frozen wood effect was more significant. Most of the branches had been broken off these trees during the extraction process.

   For Study IV ($-20^{o}C$) the frozen wood effect was highly significant, because of typical mid-winter weather conditions. The high productivity (400 trees/PMH) reflects the fact that 85-90% of the branches had broken off previously, plus the minimal effort required to sever the remaining branches. The small size and uniform length of these trees also contributed to the high level of productivity because it permitted the S.L.R.-2000 operator to jointly top (on a fairly consistent basis) up to 4 trees in each grapple, or 8 trees per cycle. This high production level would not be possible in summer conditions because the limbs between the trees would not be removed, which would result in unacceptable delimbing quality.

2. Tree Size - Good quality delimbing (in unfrozen conditions) for medium-sized trees normally requires that one tree be delimbed per grapple. However, two small trees of similar length can often be delimbed in one grapple with acceptable results. This principle also applies to the S.L.R.-2000, which has two grapples.

3. Operator Experience - The same operator, an S.L.R. employee, was observed by FERIC at the four study locations. His proficiency level and productivity increased as he gained experience on the machine. For this reason he was classed as a "good" operator in Study I and as an "excellent" operator in subsequent studies (see Table 1).

The combined effects of operating conditions, tree size and operator experience can be demonstrated by comparing Study IV to the other studies. Study IV was conducted in late January, when temperatures had been consistently cold. That study showed the highest values for both trees per PMH and volume per PMH, in spite of the small tree size.

Delimbing Quality & Topping

The delimbing quality was rated as very good, similar to that of single-head delimbers (Denis, Roger) working in the same areas. The only exception was in Study I, where the Mark I prototype was observed. At Study I the delimbing quality was sub-standard - because of the "early" prototype stage of this head (see p. 3 for details). These problems were not evident on the Mark II version.

The retainer grapple on the S.L.R. dual head has a 91 cm holding capacity. Its two arm design permits a much better grasp on multiple trees than for the single arm type used on some single-head delimbers. The problem of trees being pulled out of the retainer grapple sometimes occurred during Study I, but seldom occurred during the other studies. When delimbing two or more large trees (e.g. over 30 cm butt diam) it was observed by S.L.R. (not during FERIC's studies) that tree pullout was a problem. Several changes were made by S.L.R. to correct this problem. The changes (made after Study IV) solved the problem, according to S.L.R.:

1. A hydraulic accumulator was installed on the pressure line control for the retainer grapple to keep constant pressure on the retainer arms. Thus, if a tree shifted position within the grapple during delimbing the retainer arms would tighten automatically.

2. Triangle-shaped inward-facing teeth were welded onto the arms of the retainer grapple. NOTE - Although not observed by FERIC, this can cause wood damage, particularly in non-frozen wood.

According to S.L.R., one cause of "pullout" has not been eliminated. This occurs when large trees (over 30 cm butt diam.) with jagged or unevenly-cut butts are held in the retainer grapple. Changes in felling practice may be necessary to correct this problem.

On the Mark II, repeated topping attempts by the operator were sometimes observed when 3, 4 or even 5 trees that were held in a grapple. This was not surprising because that number of tops requires considerable space and the knife stroke is limited; also there is a high force requirement when topping 3 to 5 trees. S.L.R. reported that some topping knives had bent or twisted. In spite of several attempts by S.L.R. to overcome the multi-tree topping problem, it has not been completely resolved at the time of writing. One helpful feature on the Mark II is a locking arrangement for the boom that prevents its in/out travel while the topping knives are activated.

Large Tree vs. Small Tree Capability

FERIC's studies of the Mark I version indicated that there was a substantial increase in productivity when using the dual head (as compared to single-head delimbers) when delimbing small (.08 to .14 m^3) trees. The question that can be asked is "Is the dual head concept valid for larger trees?".

Soon after Study IV, the S.L.R.-2000 was demonstrated for several weeks at Dubreuilville, Ont., where the average tree size was much larger than in northern Québec. The production of the S.L.R.-2000 was, according to Dubreuil Bros., considerably higher than for a Denis/Drott 40 delimber working nearby, mainly due to the multi-tree capability of the S.L.R. The S.L.R. was usually limited to two trees with a maximum d.b.h. of 75 cm because of the limited size of the retainer grapple. For example, two trees, one 35 cm d.b.h., the other 40 cm d.b.h. could be delimbed together. NOTE: The Lokomo 928 provided a very stable carrier for the delimber unit, mainly due to the large counterweight on the turntable. Most excavator carriers would have less tree lift capability at the same boom extension.

The opening on each of the delimbing grapples on the S.L.R. was 82 cm, similar to the grapple opening on most other single head delimbers.

Butt Indexing

The butt indexing with the Mark II version was generally good, similar to most single-head sliding-boom delimbers. The butt indexing for the Mark I prototype was not as good mainly because the retainer grapple and delimber grapples sometimes did not open simultaneously (see p. 4).

Controls & Operator Technique

The operator controls for the dual head in the Lokomo cab were well designed, and were only slightly more complex than for single head delimbers. The S.L.R.-2000 was operated with two joysticks to operate the turntable, boom, delimbing grapples, butt plate and the retainer grapple. The topping knives were operated by a (foot controlled) floor button. All these controls were basically similar to those for single-head sliding-boom delimbers (e.g. Roger, Harricana, Denis) with the possible exception of the "swing-aside" butt plate (which is not available on all single-head units) and the floor button for the topping knives (which is usually a thumb control button on the single-head units). The main difference of the S.L.R. is the 3-position foot pedal, which the operator uses to select the right, left or both grapples and topping knives.

The operator does not need to keep his foot on this pedal; it stays in position once placed. The S.L.R.'s additional control(s) means that a longer training period will likely be required before an operator becomes fully proficient. Operator fatigue will likely be similar to single-head delimbers (provided the foot controls do not contribute to fatigue) since the lower number of cycles per PMH compensates for the larger number of delimbing grapple manipulations.

The sliding-boom action which goes "across" the operator's field of vision is unique to the Lokomo 6-wheel carrier. An advantage of this design is that the operator can see the trees being delimbed more clearly (see Fig. 4) which can be useful for selecting the proper diameter for topping. To date however, single-head delimbers have usually been placed beside the cab on a turntable, mounted on a tracked or wheeled base unit. The advantage of their design is that the boom slides in a "back/forth" movement directly away from and back to the operator making the boom movements easier to learn.

The S.L.R.-2000 is constructed of more parts as compared to single-head delimbers. Also, the valves and their electric/hydraulic controls are more complex than for single-head delimbers. As a result, field mechanics may require additional training.

Improvements in the operating technique of the S.L.R. operator were observed as the studies progressed. In Study I, the operator placed more emphasis on maximizing boom speed than the number of trees per grapple. In study III and IV, it was observed that the operator picked up full trees with the right grapple first and then the left; this made loading faster. Earlier, he had done the reverse.

Carriers

Since a variety of carriers are suitable for the S.L.R.-2000 attachment, the Lokomo 928 carrier was not evaluated. It is noteworthy that the Lokomo provided a very stable carrier for the delimber unit, mainly because of the large counterweight on the turntable. At full boom extension, the Lokomo/S.L.R.-2000 had excellent lifting capacity, much higher than most excavator units that have been observed by FERIC.

Excavator-type carriers suitable for the S.L.R.-2000 attachment can be equipped with booms ranging from 9.1 to 15.2 m, or longer. To obtain adequate stability, S.L.R. recommends that excavator carriers with a rated bucket capacity ranging from .57 to 1.0 m^3 ($\frac{3}{4}$ to $1\frac{1}{4}$ yd^3) should be equipped with booms ranging from 9.1 to 15.2 m. Carriers with rated bucket capacity greater than 1.0 m^3 can be equipped with booms longer than 15.2, if this is considered necessary. For carriers using booms shorter than 15 m, some reduction in the productivity can be expected because of the shorter delimbing stroke.

The S.L.R.-2000 is similar in some respects to the Rocket single-head delimber (of which about 50 have been sold) since for both delimbers the head weighs 627 kg; also both delimbers use a boom of similar dimensions (30 x 20 cm - .95 cm thickness) and length (15.2 m is standard).

Wajax Industries currently have plans to use a Caterpillar 225 tracked carrier as a base unit. A lower-priced, 4-wheel Pettibone unit equipped with a turntable is also available.

Table 2. Production Results for Several "Single-Stem" Delimbers.

	SINGLE HEAD S.L.R.[1] Lokomo 6-wheel carrier		TANGUAY EC-200 Cat 225-D5L undercar.		DENIS[1] Hitachi UOH7 carrier	
DESCRIPTIVE						
Location	Val d'Or, Qué.		Lebel-sur-Quévillon, Qué.		Val d'Or, Qué.	
Date	Sept. 12, 1981		April 1982		Sept. 11, 1981	
Operator - experience	2 months		6 months		1 month	
- class	good		excellent		good	
Volume per tree, m^3 (ft^3)	0.12	(4.2)	0.16	(5.8)	0.14	(5.0)
Species, approx., %	black spruce 100%		black spruce 100%		jack pine 100% (with few limbs)	
Study duration, hrs[2] (or PMH)	2.21 hrs		10.50 hrs		.88 hrs	
Number of trees delimbed per cycle, % of total cycles						
1 tree	63		55		66	
2 trees	27		29		24	
3, 4 or 5 trees	10		16		10	
SUMMARY OF CYCLE TIME	cmin[3]	% of time per cycle	cmin	% of time per cycle	cmin	% of time per cycle
Load full tree(s)	29.1	46	26.0	50	16.1	40
Delimb	29.7	47	10.6	21	20.9	52
Reverse tree(s) to unload			8.7	17		
Moving time	1.2	2	2.1	4	.8	2
Delays	3.2	5	4.4	8	2.4	6
Total	63.2	100%	51.8	100%	40.2	100%
PRODUCTION						
Cycles per PMH[4]	95		116		131	
Trees per PMH	147		191		196	
Trees per cycle	1.55		1.64		1.49	
Production per PMH, m^3/PMH (ct/PMH)	17.5	(6.2)	31.3	(11.1)	27.7	(9.8)

[1] FERIC data - not previously published.
[2] This includes operational delays, mechanical breakdowns and personal delays less than 15 minutes. Delays greater than 15 minutes were not considered as part of productive time (PMH) and were therefore excluded.
[3] cmin = centiminute = 1/100 minute.
[4] PMH = Productive Machine Hour.

S.L.R.-2000 VS "SINGLE-STEM" DELIMBERS

Previously [1], mechanical delimbers have been divided into two broad categories: "single-stem" and "multi-stem". Single-stem delimbers were defined as "delimbers that normally delimb only one medium-size tree at a time". It was acknowledged that some single-stem delimbers can occasionally delimb two or more trees at once. However, this was usually possible only with small trees having similar size and length characteristics, which allow joint topping. Using the above definition the three delimbers presented in Table 2 (single-head S.L.R., Tanguay EC-200 and Denis) should be considered as "single-stem" delimbers. The S.L.R.-2000 dual head delimber, due to its individual grappling and topping capability can be classed as a "multi-stem" delimber.

FERIC's study of the single-head S.L.R. (see Table 2) was done on one of the first two delimbers produced by S.L.R., prior to their development of the dual head concept. The cycles/PMH for the single-head S.L.R. (95) was lower than for the Tanguay EC-200 (116) or for the Denis (131). The difference between these three delimbers was not considered significant by FERIC. Why? The S.L.R. operator was timed near the end of his shift; thus a fatigue factor was likely; the operator (not an S.L.R. employee) was not fully proficient. It should also be noted that the number of cycles per PMH for the Denis (131) would likely have been less (perhaps by 10-15) if the duration of that study had been longer. In each of the three studies (of single-stem delimbers) at least 95% of the trees were delimbed in one motion (without requiring "step" delimbing); they were very similar in this respect.

Each of the three "single-stem" delimber studies (see Table 2) were done in northern Québec in unfrozen, but relatively favourable delimbing conditions (e.g. very few large diameter limbs; few crooked or forked trees; most trees were of Branchiness Class 1 or 2). All the S.L.R.-2000 studies (see Table 1) were also made in northern Québec but in a variety of unfrozen and frozen wood conditions. Because of the factors listed above, FERIC presumes that the production results for the single-stem delimbers would not have been significantly higher if conditions had been similar to those stated for the S.L.R.-2000 in Table 1.

It is noteworthy that the number of delimbing cycles per PMH for the S.L.R.-2000 (85, 86, 74 and 80) is significantly lower than for the single-head S.L.R. (95), the Tanguay (116) and the Denis (131) delimbers (see Table 1 and 2). This is because the S.L.R.-2000 requires additional time to pick up several trees. Also, delimbing, individual topping of different lengths and unloading require more time per cycle for the S.L.R.-2000.

Favourable delimbing conditions were observed at all the study locations described in Table 1 and 2. Also, in each study, the operators tried to maximize the effective number of trees per cycle. As a result, the productivity of the three single-stem delimbers in Table 2 can be compared to the S.L.R.-2000 results presented in Table 1:

1. Assuming an average of 110 cycles/PMH for the three-single stem delimbers in Table 2 (see comment on the short study period for the Denis in par. 2, p. 18), plus an average trees/cycle of 1.56 (actual was 1.55, 1.64 and 1.49 - see Table 2), the productivity is 172 trees/PMH.

2. A valid comparison to 1. (above) requires that the "high" production results of the S.L.R.-2000 from Study IV be deleted. Using Study I, II and III data from Table 1, we obtain an average of 82 cycles/PMH with an average of 2.78 trees/cycle (actual was 2.28, 2.87 and 3.19 - see Table 1). The resulting productivity was 228 trees/PMH.

Based on the above comparison, the cycles/PMH for the S.L.R.-2000 was 27.3% lower than the single-stem delimbers. However, due to increased trees/PMH, the productivity of the S.L.R.-2000 was 30.6% higher. Actual results will vary, depending on conditions, from 20% to 50%.

NOTE: The above comparison is general in nature and does not attempt (in the interest of simplicity) to take all possible factors into account. For example, the effect of tree size has been ignored. Further examination by the reader of the two sets of data will indicate that even if the comparison is based only on volume per PMH, that the productivity of the S.L.R.-2000 will still be higher than the single stem units, in spite of the smaller tree size for the S.L.R. Conversely, it can be argued that the Study I results (based on the Mark I S.L.R. prototype) should be deleted since significant improvements effecting the productivity were made on the Mark II unit. If only Study II and III S.L.R. results are used as a basis for comparison, the increase in trees per PMH for the S.L.R. is 40.1%.

CONCLUSIONS

The S.L.R.-2000 dual head is a new concept for multi-stem delimbing that can provide a significant increase in productivity, as compared to single-head units. For conditions within the range of those observed by FERIC (see Table 1) the increase in productivity (trees/PMH) will likely range from 20% to as high as 50%, with an average of about 25% to 30%. When using the dual head the number of cycles per PMH decreased by about 25% (as compared to single-head delimbers) because additional time was required to pick-up, delimb, top and unload several trees, as compared to one at a time. The large increase in the number of trees delimbed per cycle resulted in the overall production gain.

During FERIC's studies, the S.L.R. operator rarely delimbed only one tree per cycle; the highest percentage of "single-tree" cycles was 4%, observed in Study I where the largest tree size, 0.183 m^3, occurred. Because of the independent delimbing/topping capability of the dual head, the S.L.R.-2000 was considered an effective "multi-stem" delimber.

The weight of the S.L.R. boom and dual head is similar to the Rocket single head delimber (boom and single head). More than 50 Rocket delimbers are currently in use. The additional weight of extra trees on the S.L.R. may, however, require a shorter boom, as compared to the Rocket unit.

The S.L.R.-2000 is constructed of more parts than most single-head delimbers; also the S.L.R.'s valves and electric/hydraulic controls are more complex as compared to those on single-head delimbers. Since increased complexity on logging machines often results in higher repair levels it is important that field mechanics obtain adequate training.

The initial cost of the S.L.R.-2000 will be higher than for single-head attachments. However, significant fuel savings can be realized because of an increase in the number of trees processed per cycle and a decrease in the number of cycles per hour. The same logic can be applied to the friction caused by moving parts (on the delimber itself and on the turntable). Less cycles means less wear on these components; therefore they should last longer provided the load is the same as on single-head delimbers.

Although FERIC's studies did not cover a full range of operating conditions, the results were encouraging. It is expected that if a production increase of 25-30% per PMH can be obtained by using the S.L.R.-2000, that this will easily compensate for the higher cost of purchase and the somewhat higher maintenance cost. FERIC considers the dual head to be a useful concept that offers considerable potential for a reduction in delimbing costs.

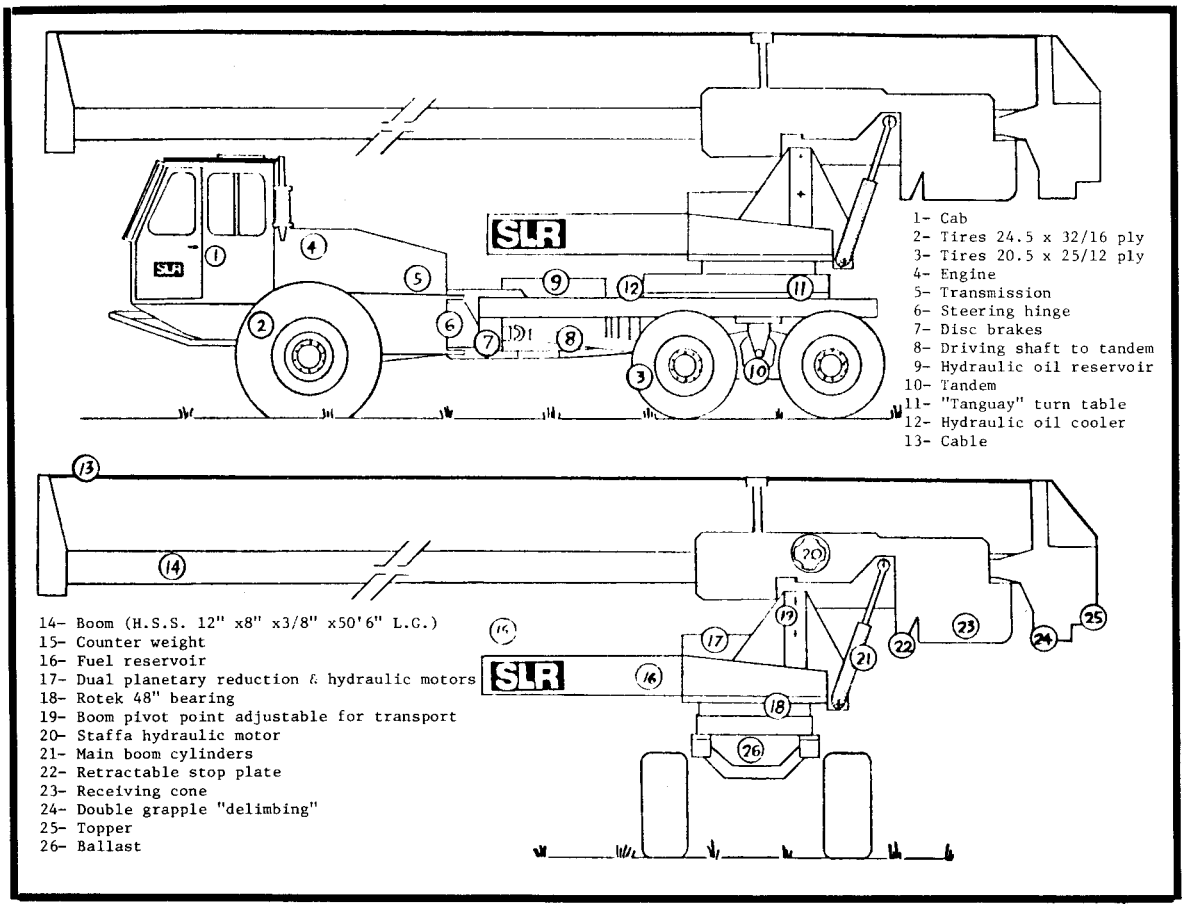
REFERENCES

1. Folkema, M.P. Delimbing: Problems and Prospects, FERIC, Spec. Rep. No. SR-4, 1979.

2. Folkema, M.P. Evaluation of the Tanguay EC-200 Delimber, FERIC, Tech. Note No. TN-63, 1982.

APPENDIX A

TECHNICAL SPECIFICATIONS



LOKOMO 925 MODIFIED FOR S.L.R. – 2000

MOTOR

- Deutz BF6L913 turbo charged, 6 cylinder, air cooled diesel.
- Output: 119 kw (162 BHP) 2400 RPM SAE.
- Max. torque 490 Nm (362 ft lb) 1,620 RPM.

TRANSMISSION

- Allison "Power-shift" TTB 2421-1

SPEED

- High forward approx. - 23 km hr.
- Low forward approx. - 6 km hr.
- Reverse approx. - 9 km hr.

AXLES (6 wheels drive)

- Front: oscillating, automatic differential lock
- Rear: 4 wheel drive, 2 separate tandem housings with individual shafts

TIRES

- Front: 2 - 24.5 x 32/16 ply
- Rear: 4 - 20.5 x 25/16 ply
- 366 kgs (800 lbs) calcium water per tire.
- Tandem chain.

STEERING

- Articulated frame steering with two steering cylinders.
- "Orbitol valve on the steering wheel".
- Steering range 40°.

BRAKES

- Two disc brakes on the tandem shafts.
- Hydraulic brake on the transmission
- Parking brake on transmission output.

HYDRAULIC SYSTEM

- Hydraulic circuit.
- Two pumps mounted in tandem one of 170 liters min. (45 G.P.M.) 2 200 RPM and one of 114 liters min. (30 G.P.M.) 2,200 R.P.M. working pressure 155 bar (2,250 psi) using both circuits in series.
- Steering circuit of the vehicule and piloting of the hydraulic levers: 42 liters min. (11 G.P.M.) 2,200 RPM.
- Working pressure: steering 155 bar (2,250 psi), piloting 20 bar (300 psi).
- Cartridge filters on returns to the reservoir.
- Oil cooling system with high output fan 24 volts and thermic switch.
- Flexible hoses built to operate under pressure higher than 275 bar (4,000 psi).
- Hydraulic reservoir capacity: 565 liters (150 gal.), feeds the pumps by gravity; oil and temperature gauge visible from the operator's cab.

ELECTRICAL SYSTEM

- 24 volts, continuous.
- 2 batteries - 12 volts - 128 amp.
- Alternator 28 volts - 50 amp.

FUEL TANK CAPACITY

- 585 liters (155 gal.) feed the pump by gravity.

ROTATION

- Rotates 360° on a "Rotek" system, 1,220 MM. (48 inch) diam. with turret support engineered by "Tanguay Industries" used on the TT-14030 loader.
- Dual planetary gear reducers mounted by two "Commercial Shearing" hydraulic motors in parallel.

OPERATOR'S CAB

- Safety cab, thermal and sound insulated.
- Two side doors with locking system.
- Adjustable seat with numerous positions. Security belt.
- Heater.
- Security gates.
- Complete dashboard.
- Easy access to the cab.

LIGHTS

- Two front lights for the road.
- Four lights when working, two in parallel on the delimber boom and two fixed on the cab secure a perfect lighting on the job site.
- Four indicator lights for security on counter weight.

S.L.R. – 2000 DELIMBER

BOOM

- Length 50'6" (H.S.S. 12" x8" x 3/8")

OSCILLATION MOTOR

- "Staffa" 75 G.P.M. 2,500 psi nominal.

CHAIN

- #120 double.

CYLINDERS FOR ACCESSORIES

- Heavy duty with cushion device

STOPPING PLATE

- Permanent.
- Optional: retractable to process quite any length.

HOSES (Head of the delimber)

- Extra flexible hoses, 4 steel threads rolled (XT-3) (Caterpillar product).

APPENDIX B

CONVERSION TABLE

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