LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

- DELIMBING STUDIES -

P.R.4 1978

N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

P.O. Box 147 Rotorua New Zealand

For information address the N.Z.Logging Industry Research Association (Inc.), P.O. Box 147, Rotorua, New Zealand.

- SUMMARY -

Conventional delimbing is highly labour intensive, and a significant cost element in some New Zealand operations. New methods and machines have been recently introduced into New Zealand, particularly for application in Ponderosa pine where labour problems occur and there have also been new developments overseas. LIRA's objective in initiating this project was thus to examine possibilities for reducing the costs and high labour involvement in the process of trimming trees.

(In this report the terms "delimbing" and "trimming" are used synonomously, the difference between them not being considered significant in this study.)

During 1977, LIRA accumulated data from various industry sources to establish the significance of trimming in cost and labour consumption. Known local developments in mechanised delimbing were observed and studied by industry and this information integrated with overseas data. To complement this, a log trim quality study at five major New Zealand mills was arranged and a brief look at alternative manual methods made. These aspects were then analysed by LIRA with respect to meeting the above objective.

The study concludes that the cost and labour consumption of trimming can be reduced in the harvesting of smaller trees such as the New Zealand stands of Ponderosa and Corsican clearfellings, and Radiata production thinnings. This is best achieved by mechanisation, however only specific machine concepts offer the potential to reduce

costs and these are characterised in the report. While current mills cannot readily accept a lower log trim standard, new mills being planned to handle pulp logs should consider this alternative. Where steeper country is involved or where mechanised trimming cannot be incorporated, alternative manual techniques for trimming smaller trees by chainsaw should be contemplated.

- ACKNOWLEDGEMENTS -

Information referred to within this report has been drawn from many sources both within New Zealand and overseas. In each case the source of information used is quoted and acknowledged. LIRA is particularly grateful to the Forest Research Institute, the Kaingaroa Logging Company, and Mr G.S.Brown, all of whom were involved in supplying considerable data towards the project.

- TABLE OF CONTENTS -

- LIST OF FIGURES -

- 1 -

INTRODUCTION

Trimming operations in New Zealand are currently highly labour intensive occupying as much as 50% of the bush cycle time, (felling and trimming with contingencies) in some operations.[1] It is also estimated to contribute up to 30% of total log extraction costs in some operations. The most common method used for trimming in New Zealand is the manually applied chainsaw and this operation is both arduous and conducive to accidents.

The use of different manual techniques for delimbing is prevalent in some overseas countries. Recent introductions of new methods and machines involved in delimbing and the subsequent acceptance of lower delimbing standards in some New Zealand operations indicates possible new approaches to trimming operations. This then presents the opportunity to improving effectiveness of our current trimming operations.

The objective of this study was thus to examine possibilities for reducing the costs and high labour involvement in the process of trimming trees.

1 "Thinning in New Zealand Radiata pine Plantations - Future Practices and Research Needs" by J.R.Tustin, C.J.Terlesk and T.Fraser.

- 2 -

MANUAL DELIMBING

More recent manual delimbing operations have utilised the chainsaw, the operation being carried out in the main at the felling face by fallers subsequent to felling operations. In some cases however a portion of the delimbing is done at the landing during final log preparation.

2.1 SIGNIFICANCE IN LABOUR CONSUMPTION:

Data extracted from a range of New Zealand studies that detailed trimming separately from felling and trimming is summarised in *Fig.1*. The limited amount of data available did not allow consideration of a variety of species. However, the information did provide a reasonable spread through a full range of tree sizes from 0.04 m^3 to 3.08 m^3 mean tree volumes, in the species pertinent to consideration.

This tabulated information is illustrated in *Fig.2* indicating more clearly the general variation of trim time with mean tree volume. For increasing tree sizes trim time per unit volume decreases rapidly, from approximately 16 minutes per m^3 to approximately 4 minutes per m^3 where it levels off for tree sizes greater than approximately 0.8 m^3. The significance of trimming with respect to labour consumption in the bush cycle of felling and trimming is indicated confirming earlier indications that trim time is a major element. Trim time varies from 30% to 60% of bush time over the range of data available.

Thus anything from one-third to two-thirds of a faller's labour is taken up by the process of trimming trees.

2.2 SIGNIFICANCE IN COST CONSUMPTION:

Log trimming with chainsaw can currently be costed out at:

8.9 cents per minute with saws smaller than 50cc. as used in small tree operations (mean tree sizes

CROP TYPE		MEAN TREE DBH (cms)	MEAN TREE HEIGHT (metres)	MEAN STEM VOL. (m^3)	FELL & TRIM TIME PER m^3 (Mins)	TRIM TIME PER m^3 (Mins)	SOURCE OF REFERENCE
Radiata	8 yr. Thinnings	14.6	13.2	0.04	68.57		(1)
Radiata	12 yr. Thinnings	22.0	15.5	0.15	28.00	10.92	(2)
Ponderose	41 yr. Clearfell (Untended)	21.9	15.5	0.16	28.20	13.30	(1)
Radiata		24.0 (Estim.)		0.28		6.32	(3)
Radiata	15 yr. Clearfell (Untended)	25.6	19.8	0.36	24.38	10.00	(4)
Radiata	17 yr. Clearfell (Tended)	36.0	28.3	0.86	7.13	3.44	(5)
Radiata		40.0 (Estim.)		1.12		3.09	(3)
Radiata		44.0 (Estim.)		1.82		2.40	(3)
Radiata	26 yr. Clearfell (Tended)	46.0	35.9	1.99		2.10	(6)
Radiata	29 yr. Clearfell (Tended)	47.2	40.0	1.90	4.00	1.76	(1)
Radiata	36 yr. Clearfell (Untended)	58.0		2.97	4.46	3.25	(7)
Radiata		60.0 (Estim.)		3.08		1.87	(3)

REFERENCE:

(1) *C.J.Terlesk, Personal Communication. (Unpublished)*

(2) *"Thinning P.Radiata - Southern Kaingaroa Forest" - by Fletcher & Terlesk - FRI Econ. of Silvi. Report No.88 (Unpublished)*

(3) *"Felling & Trimming Young Crop P.Radiata" - by R.L.Peterson - NZFS Management Services Report (Unpublished)*

(4) *"Production Study of a Clearfelling Operation in a 15 year old P.Radiata Crop at Matahina" - by O'Reilly & MacKintosh - FRI Econ. of Silvi. Report No. 61 (Unpublished)*

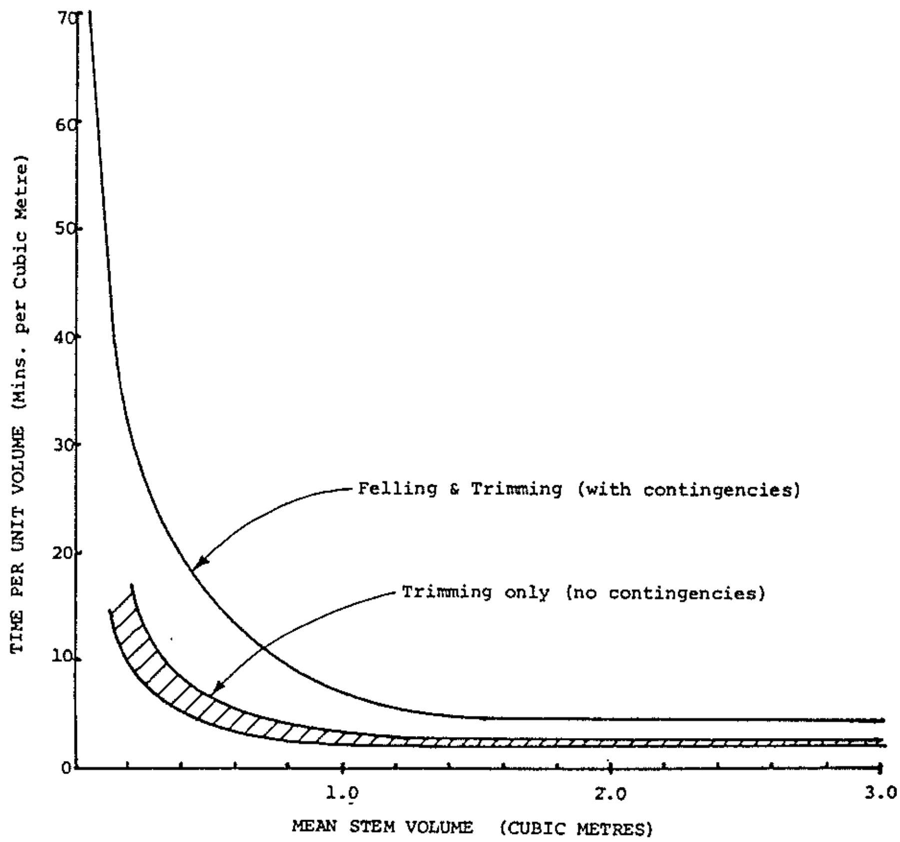
(5) *"Clearfelling Young Pinus Radiata" - by C.J.Terlesk - FRI Econ. of Silvi. Report No.58 (Unpublished)*

(6) *"Trimming Trial - Cpt.1099 Kaingaroa Forest" - by A.E.Russel - NZFS Management Services Report (Unpublished)*

(7) *"Profitability of Pinus Radiata Afforestation" - by Fenton, Granger, Sutton, Tustin - FRI Econ. of Silvi. Report No.111 (Unpublished)*

TABLE OF TIME CONSUMPTION IN TRIMMING

(Fig.1)



INFLUENCE OF STEM VOLUME ON PROCESS TIME

(Fig.2)

REFERENCE GROUPS OF OPERATION	"FELL & TRIM COSTS" AS PERCENT OF "LOGGING COSTS"
Tasman	39.3
NZFS (1)	31.3
NZFS (2)	24.9
NZFS (3)	25.0
NZFS (4)	23.1
NZFS (Waipa)	24.9
N.Z.Forest Products	26.7
H.E.Harvey	51.3
Carters (Riverhead)	30.5
Carters (Woodhill)	62.0

TABLE OF COST CONSUMPTION BY FELL & TRIM ELEMENT

(Fig.3)

up to 0.4 cu.m.).

9.3 cents per minute with medium sized 50cc. to 100cc. saws as used in exotic clearfelling operations, (mean tree sizes above 0.4 cu.m.)

(These costs are based on labour at $4.50 per hour, smaller saws at $7.00 per day, larger saws at $9.00 per day.[1])

Using these cost rates per unit of time, and the trim times per unit volume as indicated in *Fig.2* , the cost of manual trimming per unit volume is thus of the order of:

TREE SIZE	*APPROX.TRIMMING COST*	*COST RANGE*
0.2 to 0.3 cu.m.	$1.00 per cu.m.	$0.62 to $1.43 per cu.m.
1.7 cu.m.	$0.30 per cu.m.	$0.23 to $0.80 per cu.m.

Using *Fig.2* as a basis for proportion, current bush costs are estimated as:

TREE SIZE	*APPROX.BUSH FELL & TRIM COST*	*COST RANGE*
0.2 to 0.3 cu.m.	$2.50 per cu.m.	$1.55 to $3.57 per cu.m.
1.7 cu.m.	$0.46 per cu.m.	$0.46 to $0.56 per cu.m.

In a 1972 survey[2], over a range of ten different groups of operations *(Fig.3)*, the bush fell and trim costs were shown to vary from 23.1% to 62.0% of logging costs. This wide range is undoubtedly influenced by the different log extraction methods used, but provides some indication of the cost significance of trimming. Combining these two figures with our *Fig.2* conclusion (that trimming time varies from 30% to 60% of bush fell and trim time), it seems reasonable to conclude that in some operations trimming forms up to 30% of log extraction costs. This, however, is the exception and in the two mean tree size areas considered (0.2 cu.m. to 0.3 cu.m. and 1.7 cu.m. mean tree sizes) trimming costs more commonly are approximately 15% of log extraction costs.

1 "Personal Communication" by C.J.Terlesk

2 "An Analysis of the Relative Significance of Various Cost Elements in Logging and Forestry" by B.D.McConchie. (Unpublished)

2.3 AREAS WITH POTENTIAL FOR REDUCED COST AND LABOUR:

Trimming cost per cu.m. in smaller trees (0.2 cu.m. to 0.3 cu.m.) is approximately four times (range 2.2 to 6.2 times) that in larger 1.7 cu.m. trees. Labour requirements in trimming smaller trees is also approximately four times that in the larger trees.

The tree size range 0.2 to 0.3 cu.m. covers crops typical of the New Zealand stands of Ponderosa and Contorta at clearfelling, and the early Radiata production thinnings of age 10 to 14 years. It is possibly also representative of what may be common Radiata tree sizes harvested for future energy crops, however these would probably not be delimbed prior to utilisation.

The major areas with potential to reduce costs and labour are thus in the smaller 0.2 to 0.3 cu.m. trees currently harvested. With manual trim costs in these sized tree crops currently at an average of $1.00 per cu.m. (compared to $0.30 per cu.m. in large 1.7 cu.m. trees), the maximum potential for cost reduction is of the order of $0.70 per cu.m. (range $0.40 to $1.20 per cu.m.) Manual labour requirements in trimming these sized trees is in the range of 0.10 to 0.25 man hours per cu.m.

2.4 MEANS OF REDUCING COST AND LABOUR:

There are three basic variables available for management manipulation in current trimming operations; the production rate, the hourly cost, and the trimming standard. Three readily available options that influence these three basic variables in trimming operations, and that may offer a means of reducing cost or labour are:

a. Suitable mechanisation of the process.

b. Reducing mill log trimming acceptance standards.

c. Changing manual chainsaw delimbing techniques.

- 3 -

MECHANISED DELIMBING

Over the past seven years but more particularly in the last two years there have been a number of New Zealand developments, trials and applications of mechanised delimbing operations. All of these have been applied to the smaller tree (0.2 to 0.3 cu.m. per stem) operations and particularly so in Ponderosa.

Since 1950 the mechanisation of delimbing has been reported overseas. A very rapid increase in development has occurred since 1960 with currently a wide range of equipment offering in terms of characteristics, cost and potential.

3.1 DEVELOPMENTS IN NEW ZEALAND TO DATE:

A total of 11 New Zealand delimbing machine concepts have been noted, some of which are plans only, some prototypes, and some units are in productive operation. The characteristics of these machines and their stages of development are shown in *Figs. 4 & 5,* with *Fig.4* showing the single stem delimbing machines, and *Fig.5* the multi-stem delimbing machines. They are briefly described as follows:

- The Can Car Processor is manufactured in Canada and two of these units were purchased by the Kaingaroa Logging Co. in 1970 for the delimbing and cutting-to-length of Ponderssa at roadside landing. It is a two-function machine which, although initially supplied on two axles as a self-propelled unit, has since been modified by K.L.C. and is now towed between sites. The machine is powered by its own engine and uses a knuckle-boom hydraulic crane to feed single stems butt first onto the delimbing bed and into a holding device (the bucking shear). Five over-lapping curved knives move along the stem to delimb a 2.4 metre length, then grip the stem to feed it further through the holding shear. The stem is held again and a further 2.4 metre length is delimbed. The machine is hydraulic and the unit is operated by one man who controls all functions from the raised cab. *(See Fig.6 for photo and basic specifications.)*

MACHINE DEVELOPER	MACHINE FUNCTIONS	STAGE OF DEVELOPMENT (At Jan. 1978)	BASE MACHINE	DELIMBING PRINCIPLE	FEED MECHANISM	MACHINE POSITION IN SYSTEM
Can-Car Processor	Delimb and Cut to length	Operational (Productive)	Can-Car Special Carrier	Overlapping Knives	Stepwise feed of Knife carriage by Hydr. ram	At Landing
Bolstad Delimber	Partial Delimb	Prototype (Operational)	Crawler Tractor (HD6 Allis)	Overlapping Knives	Continuous feed of knife carriage by winch rope	In Stand (prior to felling)
Pullar Processor	Delimb and Cut to length	Prototype (Uncomplete)	Used Truck	Overlapping Knives	Stepwise feed of knife carriage by Hydr. ram	At Landing
Hitachi Harvester	Fell, Delimb & Cut to Length	Drawing/Design (To be completed)	Hydraulic Excavator (Hitachi UHO4)	Overlapping Knives	Stepwise feed of either stem or delimbing head	At Felling Face
KLC 30RB Processor	Delimb and Cut to length	Drawing/Sketch (Uncomplete)	Rope-operated crane (30RB)	Overlapping Knives	Stepwise feed of knife carriage by winch rope	At Landing

SINGLE STEM N.Z. DELIMBING MACHINES AND DEVELOPMENTS

(Fig.4)

MACHINE DEVELOPER	MACHINE FUNCTIONS	STAGE OF DEVELOPMENT (At Jan.1978)	BASE MACHINE	DELIMBING PRINCIPLE	FEED MECHANISM	MACHINE POSITION IN SYSTEM
Panpac Chain Flail	Delimb	Operational (Productive)	Skidder Mounted (Clark 666)	Chain Flail	Continuous travel of flail along stems	On Cut-over
Cochrane Towed Chain Flail	Delimb	Was Operational (Replaced)	Skidder Towed (C8)	Chain Flail	Continuous travel of flail along stems	On Cut-over
Paewai Chain Flail	Delimb	Operational (Productive)	Skidder Mounted (C6)	Chain Flail	Continuous travel of flail along stems	On Cut-over
Jaw Type Delimber	Delimb	Prototype (Operational)	Skidder Operated	Fixed Knife Teeth	Continuous pull of stems through teeth	On Cut-over
Gate Delimber	Delimb	Prototype (Operational)	Nil	Fixed Knife Bars	Continuous push of stems through gate	On Cut-over
Cochrane Stationary Chain Flail	Delimb	Operational (Productive)	Crawler Tractor Operated (HD 11 Allis)	Chain Flail	Continuous pull of stems through flail	On Cut-over

MULTI-STEM N.Z. DELIMBING MACHINES AND DEVELOPMENTS

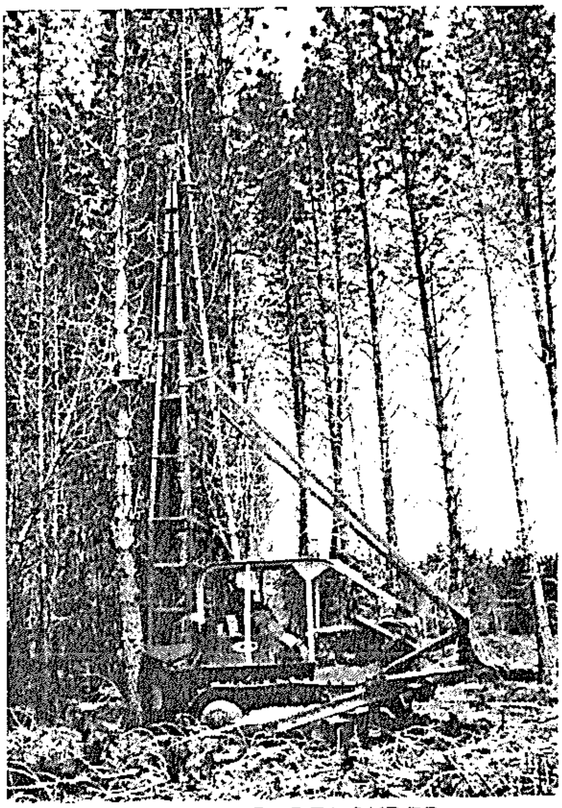
(Fig.5)

CAN CAR PROCESSOR

(Fig.6)

BASIC SPECIFICATIONS:

Power of Processor	48 kW
Max. stem diameter	40 cm delimbing (max.butt diam.56 cm)
Max. delimbing force	8600 Kg @ 0.6 m/s
Max. feeding speed	2.5 m/s @ 2000 Kg force
Approx. cost	$41,000 in 1970



BOLSTAD DELIMBER

(Fig.7)

BASIC SPECIFICATIONS:

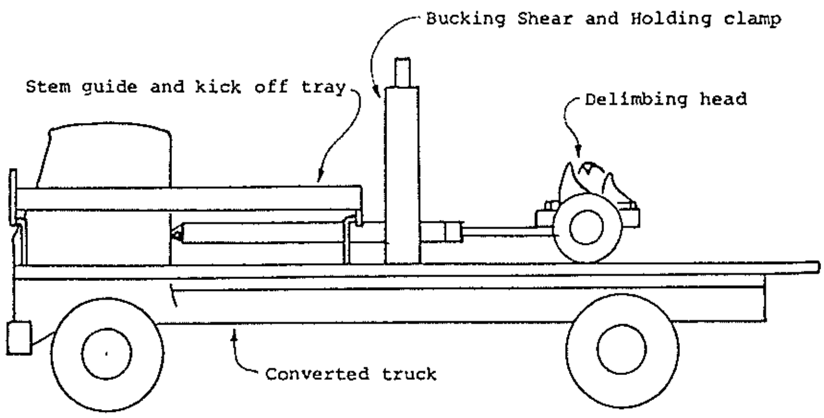
Power of Tractor	56 kW
Max. stem diameter	40 cm delimbing (max.butt diam.60 cm)
Max. delimbing force	13,500 Kg
Max. delimbing feed speed	0.7 m/s
Approx.cost - Tractor	$23,000 in 1974
- Delimber materials	$500 in 1976

The Bolstad delimber is a prototype attachment device aimed at delimbing the lower section of standing trees. It was built and operated in brief trials by Kaingaroa contractor S. Bolstad in 1977. The base machine is an HD6 Allis-Chalmers crawler tractor upon which is mounted a 7.5 metre high tower and up which a delimbing carriage is run. The delimbing head with twin wrap-around knives utilises an ingenious system of operation by the tractor winch rope being used to both close the knives around the tree and travel the carriage up the stem. In operation, the machine is positioned at the base of a tree and the delimbing run done. At the top of the 7 metre delimbing run the machine is moved away from the tree to be re-positioned and the delimbing carriage returns by natural fall. *(See Fig.7 for photo and basic specifications.)*

The Pullar machine was also a prototype in construction by contractor D. Pullar of Hawkes Bay, but was un-completed. The concept was a truck-mounted processing unit for delimbing and cutting to length of Corsican at a roadside landing. It was very similar in layout to the Can Car processor. The delimbing and processing equipment was hydraulically operated and mounted on the rear of an old 13-foot wheel-based truck. The delimbing head had five curved wrap-around knives and was mounted on a rubber-tyred bogie which was moved by a hydraulic ram. No provision existed for loading onto this unit, the operator envisaging using a rope-crane from part of his logging operation. Similarly, no means of slash removal had been developed. The hydraulic power came from a pump mounted on and driven from the front of the truck engine. *(See Fig.8 for sketch and basic specifications.)*

The Hitachi Harvester is currently under design and development by Cable-Price Corporation, it being design-ed to fell, delimb, buck and stack in a radiata thinn-ings operation. The machine base unit is a fully mobile Hitachi UH04 excavator with a special telescopic boom and processing head fitted. In operation, single trees are sheared at the stump, layed back onto the processing boom and delimbed intermittently by wrap-around knives mounted at two positions on the boom. This is achieved by progressive extention and retraction of the tele-scopic boom whilst feeding the stem down through the shear to cut to length if required. *(See Fig.9 for sketch and basic specifications.)*

The KLC 30RB-mounted processor was outlined in preliminary drawings done by Kaingaroa Logging Co. during 1976. The

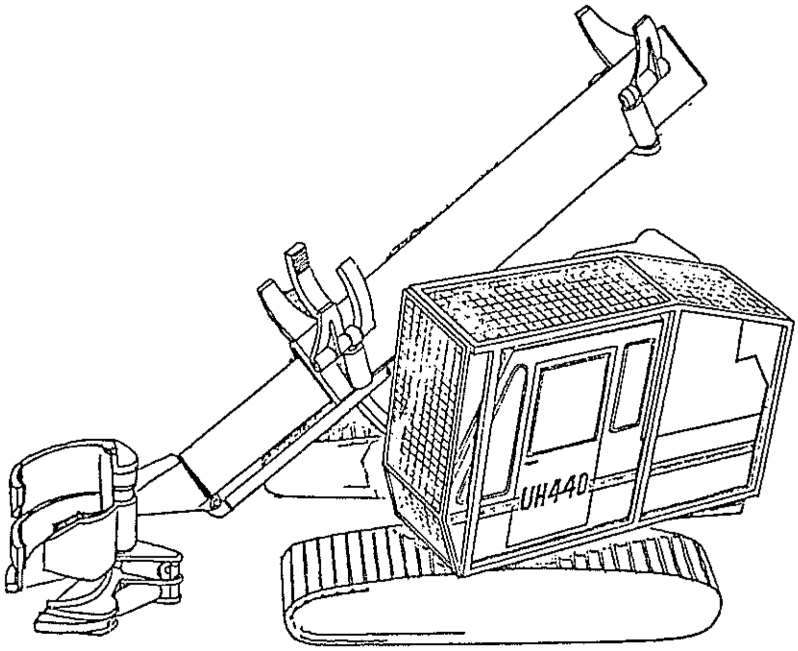


PULLAR DELIMBER

(Fig.8)

BASIC SPECIFICATIONS:

Power of truck	82 kW
Max. delimbing diameter	38 cm
Design delimbing force & speed	9000 Kg @ 0.3 m/s
Approx. Cost - Truck	$5,000 2nd-hand unit in 1976
- Delimber Materials	$1,500 in 1976



HITACHI HARVESTER

(Fig.9)

BASIS SPECIFICATIONS:

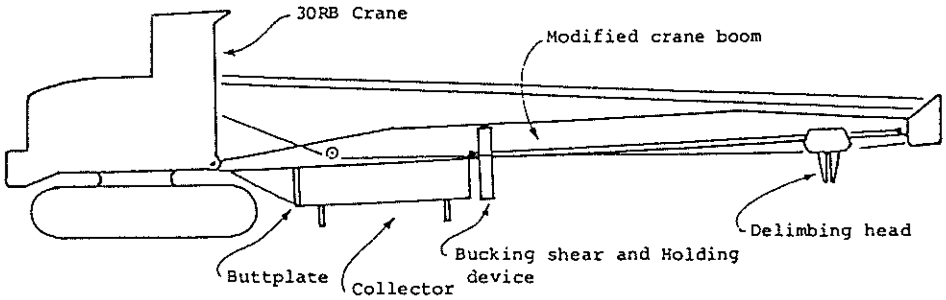
Power of Harvester	62 kW
Max. delimbing diameter	40 cm
Design delimbing force & speed	6500 Kg - 1m/s
Estimated Cost	$90,000 in 1978

30RB crane processor attachment was aimed at performing all functions of the Can Car processor but using rope as a means of power transmission instead of hydraulics. Although not developed, the concept envisaged was to use a delimbing head suspended on sheaves which could travel along the boom underside to delimb a tree held beneath the boom. The delimbing head with wrap-around type knives also acted as a grapple and it was planned that this delimbing head/grapple would pick up trees by the butt, feed the trees into the shear and holding device and move back to the boom point delimbing as it goes. The delimbing head then clamps onto the stem and feeds it through the holding shear assembly to a required length and the stem is held by the holding device for a further delimbing run. The length can be sheared as required. *(See Fig.10 for sketch and basis specifications.)*

The Panpac Chain Flail delimber was made up from a Canadian-built Vulcan flail mounted on the front of a Clark Ranger 666 rubber-tyred skidder. The flail, which can be raised or lowered, is driven hydraulically and powered by an additional engine mounted on the rear of the skidder. The unit is being operated by Panpac in a totally mechanised harvesting system which includes a feller-buncher felling and bunching Ponderosa for the flail. Like other chain flail delimbers, a series of chains flail on a rotating drum and the machine is manoeuvred along pre-felled and bunched trees to delimb by repetitively flailing the branches with the chains. *(See Fig.11 for photo and basic specifications.)*

The Cochrane Towed Chain Flail delimber was a locally-manufactured trailer-mounted unit towed behind a Tree Farmer C8 rubber-tyred grapple skidder. It was used as part of a fully mechanised harvesting system in Kaingaroa for the delimbing of Ponderosa pre-bunched by a feller-buncher. The flail was driven hydraulically, power being supplied by its own engine. Trailer-mounted, it operated at a fixed height about ground level and operation was aimed at achieving all delimbing required. *(See Fig.12 for photo and basic specifications.)*

The Paewai Chain Flail delimber is also a locally manufactured flail but is mounted to the rear of a C6 skidder on a 4-point linkage system which allows hydraulic raising and lowering of the flail. The machine is being used to partially delimb Ponderosa pre-felled with a feller-buncher with final trimming done manually by two bush and one landing located trimmers. The flail unit is



KLC 30RB-MOUNTED PROCESSOR

(Fig.10)

BASIC SPECIFICATIONS:

Power of 30RB Crane	93 kW
Max. delimbing diameter	Unspecified
Delimbing force	6360 Kg
Delimbing speed	1 m/s
Estimated Cost	Not Stated

PANPAC CHAIN FLAIL DELIMBER

(Fig.11)

BASIC SPECIFICATIONS:

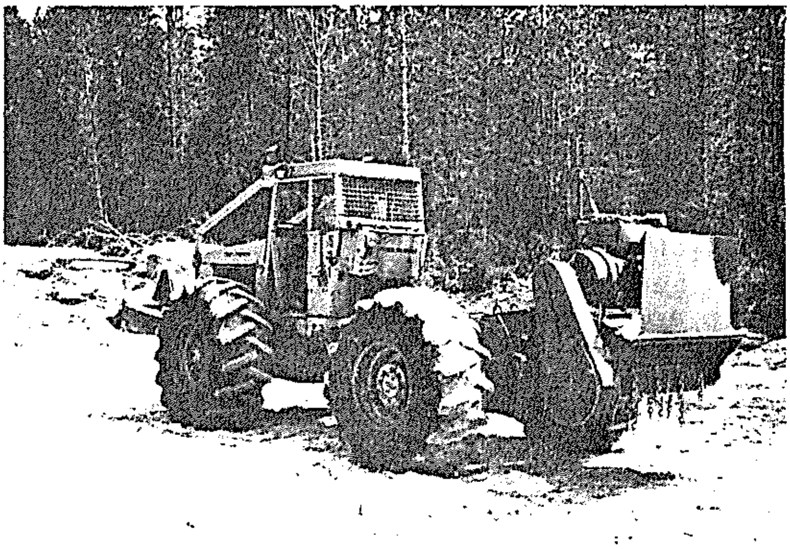
Power of Skidder	82 kW
Power of Auxiliary Engine for flail	56 kW
Flail Width	1.7 m.
Drum Speed	350 rpm
Approx. Cost	$10,000 for Vulcan Flail in 1976
	$10,000 to mount on the skidder in 1976
	$30,000 for used skidder in 1976

COCHRANE TOWED CHAIN FLAIL DELIMBER

(Fig.12)

BASIC SPECIFICATIONS:

Power of Skidder	130 kW
Power of towed flail	72 kW
Flail drum width	1.7 m.
Flail drum speed	350 rpm
Approx. cost	$13,000 towed flail $45,000 new skidder in 1975



PAEWAI CHAIN FLAIL DELIMBER

(Fig.13)

BASIC SPECIFICATIONS:

Power of Skidder	97 kW
Power of Flail engine	35 kW
Flail drum width	1.2 m.
Flail drum speed	rpm
Approx. cost	$8,000 for flail in 1976 $30,000 for used skidder in 1976

driven by its own integral air-cooled engine driving a triangular section drum which incorporates wear-pads on the three drum sides. *(See Fig.13 for photo and basis specifications.)*

The Multiple-tooth Jaw-type delimber is a prototype device aimed at multiple stem delimbing. Brief trials of this prototype were carried out by Panpac contractor Keremete in Ponderosa during 1977. The rig has two jaws built to accept a maximum of five stems, the bottom jaw of which rests on the ground and the top of which is raised or lowered by a skidder used to operate the rig. In operation, the rig is positioned on a skidder extraction track and the skidder with drag drops the trees on approach to the rig and positions on the exit side of the delimbing frame, at the same time bringing the drag rope into position through the opened jaws frame. The top jaw is lowered and the drag of trees is pulled through the jaws knocking off a portion of the limbs. Final trimming is done at a landing and slash clearing is done by the extraction skidder when returning for another drag. *(See Fig.14 for photo and basic specifications.)*

A Gate delimber was built by Panpac in prototype form for a brief trial in Ponderosa at Waimihia. The gate frame which is fixed to two standing trees left on the cut-over between the felling face and landing is used to delimb by the extraction skidder reversing and pushing a drag of trees through the frame during the extraction phase. *(See Fig.15 for sketch and basic specifications.)*

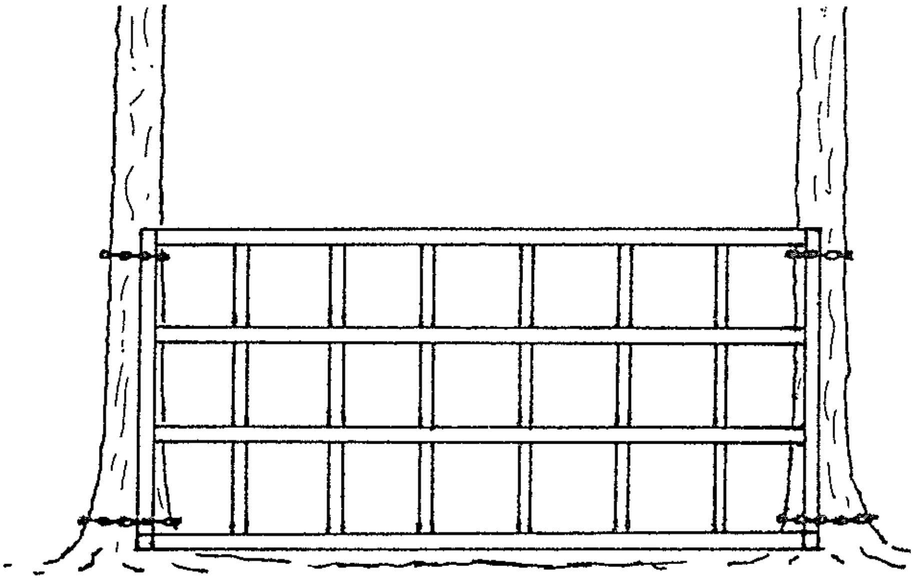
The Cochrane stationary chain flail delimber is a locally constructed machine currently undergoing initial trials in Ponderosa at Kaingaroa. The machine has a rotating chain flail drum supported by an overhanging cantilever construction mounted on a sledge base. The unit is positioned and powered through p.t.o. drive, by an Allis Chalmers HD11 tractor. Trees are pulled through under the rotating chain flail drum while supported on four jockey rollers on a common shaft, the height of which is adjusted hydraulically thus varying the distance between chain flail drum and stems. In operation the extraction skidder arrives at the flail with a drag of four trees held in a special spreading grapple. The skidder holds the four trees high enough off the ground and the chain flail is pushed in with the crawler tractor to straddle the trees. The crawler tractor operator starts the chain flail drum rotating and adjusts the height of the jockey rollers to suit. The trees are then dragged through the flail by the skidder. For the next drag of

MULTIPLE-TOOTHED JAW-TYPE DELIMBER

(Fig.14)

BASIC SPECIFICATIONS:

Power of Operating Skidder	65 kW
Max. tree diameter	50 cm
Feed Force & Speed	Determined by skidder with drag
Approx. cost	$300 for delimber materials
	$30,000 for operating skidder



GATE DELIMBER

(Fig.15)

BASIC SPECIFICATIONS:

Gate Size	4 m. x 2 m.
Approx. cost	$150 for materials

trees to be delimbed, the flail is moved along slightly with the crawler tractor thus disposing of the slash from the previous delimbing run. *(See Fig.16 for photo and basic specifications.)*

COCHRANE STATIONARY CHAIN FLAIL DELIMBER

(Fig.16)

BASIC SPECIFICATIONS:

Power of crawler tractor	130 kW
Chain Flail width	2.4 m.
Flailing drum speed	640 rpm
Approx. Cost	$10,000 for flail & spreading grapple in 1977 $40,000 for crawler tractor

3.2 TRIALS AND RESULTS WITH NEW ZEALAND MACHINES:

Detailed performance time studies have been done on only three of the eleven N.Z. delimbing machine concepts and the results of these are presented, along with comment on the construction and mode of operation of the remainder.

The Can Car processor was studied by KLC during 1974, with the machine processing Ponderosa with mean stem volume ranging from 0.27 cu.m. to 0.33 cu.m. The study showed a performance of 50 trees per productive machine hour when producing to Tasman's mill standard of delimbing. Target eight hour shift production on this basis, with contingencies, was approximately 80 cu.m. The delimbing mechanism produces good quality delimbing and has given little trouble in use. One of the main maintenance problems has been with the hydraulic equipment, particularly in the knuckle-boom crane and delimber carriage travel ram. During the study the trees were brought to the processor by a grapple skidder and the processed logs and slash were removed by a front end loader.

Observations of the Bolstad prototype delimber by LIRA during a brief trial delimbing standing Ponderosa of approximately 25 cm dbh and 14 m in height, indicated a potential output of 90 partially delimbed trees per productive machine hour. The amount of delimbing achieved was 65% of that normally done in trimming to 7 cm SED. The prototype trials showed that this was a feasible method with potential to partially delimb trees before felling, return slash trimmings to the forest floor and to crush undergrowth for easier felling. Some significant features of this unit are:

- It is an attachment device
- Initial cost is low
- Delimbing operations can proceed independently of felling
- Slash is returned to the forest floor
- Rope operation is simple and probably less cumbersome than hydraulics.

Although the Pullar prototype delimber was uncompleted, there were a number of aspects worthy of mention in terms of construction. The delimbing knife bogie travel, using unguided bogie wheels and a semi-supported hydraulic travel ram, would yield considerable maintenance problems and is considered unsuitable. The use of a bogie on rails with a winch and rope for carriage travel would seem more suited to low cost and simplicity in prototype development. Another area requiring refinement is the method of getting trees into the delimbing head at a desirable rate, and also a system of slash removal from around the machine. A production estimate is not made for this uncompleted prototype.

The Hitachi Harvester, although still in the planning stage, is being designed to process 50 stems per hour (felled, delimbed, cut to length) in trees of maximum size 40 cm butt diameter, and one tonne (1 cu.m. stem volume) maximum tree weight. A standard Hitachi excavator is planned as the base for this harvester. It should be noted that the larger model Hitachi feller-bunchers currently in use in N.Z. have coped with forest operating conditions relatively well. The processing attachment however is completely new.

The KLC 30RB based processor concept, although only reaching the initial drawing stage, was aimed at a possible means of replacing the Can Car processors. Performance rate envisaged was thus similar to the Can Car processors, and it was anticipated that the use of rope operation instead of hydraulics would alleviate maintenance problems existing with hydraulics in the processors.

F.R.I. studies in 1976 indicated that Panpac's chain flail could keep up with a feller-buncher which produced 110 trees per productive machine hour. Mean stem volume during this study was 0.20 cu.m. and mean dbh was 19 cm. Shift production with contingencies for the system on a 9.5 hour shift day was 154 cu.m. and the trees were delimbed to a standard acceptable to the Whirinaki Pulp Mill. Chain wear is a major factor in flail operation. Panpac's flail was initially fitted with standard shape chain links costing from $11.50 to $14.00 per metre, and these gave a useful life of from 25 to 50 hours depending on operating conditions. More recently they have been using round link chain costing $21.50 per metre, this giving a useful life of from 100 to 125 hours, and improving delimbing quality by 25%.

Cochrane's towed flail production as measured by KLC's work study team was 80 stems per productive machine hour in pre-bunched Ponderosa with a mean stem volume of 0.22 cu.m. and a mean dbh of 25 cm. Target eight-hour shift production in this operation was only 120 cu.m. as difficulty was experienced in meeting the delimbing standard set by the Tasman Pulp Mill. An attempt was being made to meet this delimbing standard (which was higher than the Whirinaki Mill Standard) by spending a greater time on each flail pass, however this caused further quality complications, due to dirt being pounded into the stems flailed. This flail was fitted with standard chain links costing $13.80/m. and chain life was approximately 40 hours.

No measured data was available on the Paewai flail. Observations and discussions indicated however that the concept of light flailing to remove the bulk of limbs only, in conjunction with three manual trimmers works well. The trimming operation keeps up with a

Clark 45 FB feller-buncher capable of felling 94 trees per hour in 0.38 cu.m. stem volume Ponderosa, and a delimbing quality is achieved that is acceptable to the Tasman Mill. Standard chain is used on this flail and a chain life of 300 hours is reported, which is considered due to the slow drum speed and the aiming for light flailing only.

A brief trial with the Jaw-type delimber, delimbing drags of two, three and four trees of Ponderosa, indicated that head pulling was more suitable than butt pulling. During butt pulling branches tended to force the jaws open. Actual delimbing quality was surprisingly good *(see Fig.14)*, with the smaller the number of stems per drag, the better the delimbing quality due to less interference between stems. The speed of dragging stems through is also important, the slower the better the delimbing quality. Shape of the teeth and attention to knife sectional shape could improve effectiveness. The upper jaw weight, or downward force needs to be increased particularly so where three or more stems are being delimbed, or where drag speed is high. Costwise, this delimbing rig seems to have potential even if an older skidder or a small agricultural type tractor is used to operate the delimbing rig. A number of structural and operational modifications need to be made, however these would not add significantly to cost and it should be feasible to build an operational rig for under $2,500. The machine required to operate it requires either a winch or a hydraulic power supply, and this machine with operator could be used to clear slash build-up between drags.

In a brief trial with the Gate delimber, the skidder grapple tended to prevent the trees from splaying apart to enable an adequate delimbing job to be done. Costwise, this concept has potential for partial delimbing, particularly where a logging operation is required to work in the appropriate stands such as Ponderosa for a very short period only. Further trials of this unit are planned.

The Cochrane stationary chain flail delimber, currently undergoing initial trial operation, is aimed primarily at flailing stems clear of the ground, thus overcoming the dirt problem arising with the Cochrane towed chain flail. This new machine is flexible enough in terms of flailing depth, and speed of drag through the flail to provide good control on delimbing quality. Points to note in the application of this machine are:

- It will be important to keep trees up to the delimber so that the machine is actually delimbing for the bulk of its operational time. This may require two or even three skidders feeding it.

- Compared to a mobile chain flail system, this operation requires additional equipment thus creating a higher capital involvement.

3.3 OVERSEAS EQUIPMENT TRENDS:

Early introductions (from the 1950s) of mechanised equipment for delimbing trees were developed in an attempt to reduce costs, increase man/day productivity and produce better forest products. A Canadian report[1] studies all known delimbing machines for the period 1950-1970 and outlined aspects of 76 different prototype and commercial machines mechanising delimbing. Of these 42 were delimb only machines and by far the most popular delimbing principle used (approx. half) was the stripping concept with wrap-around knives, other principles including milling heads, rotating knife rings, flails and saws.

A 1970 Swedish Technical Survey by Skogsarbeten[2] of 30 different delimbing devices on the market concluded that the most common limbing tool is the wrap-around knife or knife belt with feeding at that stage most commonly done stepwise. They envisaged that the use of rotary type knives would decrease and that the use of feed rollers for feeding would increase. The survey indicated that:

Maximum stem diameters varied from 33 cm to 76 cm with 51 cm to 64 cm being most common.

Feed forces with wrap-around knives or belts varied from 2000 kg to 9000 kg, the most common values being from 3000 to 5000 kg.

Maximum branch diameter capacity varied from 5 cm to 13 cm , the most common being from 7.5 cm to 10 cm

Machine costs varied from $50,000 to $150,000 for complete units and $17,500 to $43,750 for attachment devices.

The majority of layouts were on standard units that had been considerably modified and were thus not readily re-converted.

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1 "Annotated Bibliography on Delimbing of Trees" by J.D.Dunfield. A Canadian Forest Service, Forest Management Institute Report.

2 "Limbing Devices - Technical Data" by Dag Myhrman. A Skosarbeten Report.

> Rubber-tyred machines accounted for approximately two-thirds of those considered.

This report provides an excellent coverage of layout and specifications of these 30 machines.

During 1971 the prospects of mechanising limbing in the Northern Interior of B.C., Canada, were studied and reported[1]. The report, which covers specifically this Canadian region where most stems ranged from 30 cm. to 45 cm. dbh and branches 2.5 cm. to 5 cm. diameter, concluded that for mechanised limbing to cost less than manual limbing maximum machine investment for 28 cu.m./hr per day production is $30,000. It further outlines that to achieve significant cost savings a production rate of 180 to 250 trees per hour is required, and suggests that only multi-stem delimbers should be considered. The types of machines considered suitable for development were the multi-stem processing machines using impact shearing devices and the landing was considered the logical place for operating these mechanised delimbers.

The American Pulpwood Association categorised over 100 delimbing devices for the period 1960-1973[2] looking specifically at the following aspects of machine delimbing:-

- Where delimbing occurs
- Tree and tool relationships
- Tools action on tree
- Tree position during delimbing
- Single or multi-stage delimbing
- Single stem or multi-stem
- Product length
- Direction of the delimbing on tree stem.

They subsequently drew up a sketch of a machine using the most commonly applied principles and this is shown in *Fig.17*. This report, whilst not covering the specifications of the machines considered, does describe or classify the different aspects of each machine.

A further Technical Survey[3] of 16 more limbing machines was reported by Skogsarbeten in 1975, all machines being on the market. It confirmed their previous report that the most common delimbing device is the wrap-around or knife-belt and that roller feed was becoming increasingly popular. In this survey:

> Maximum tree diameters varied from 25 cm to 67 cm but were usually around 50 cm.

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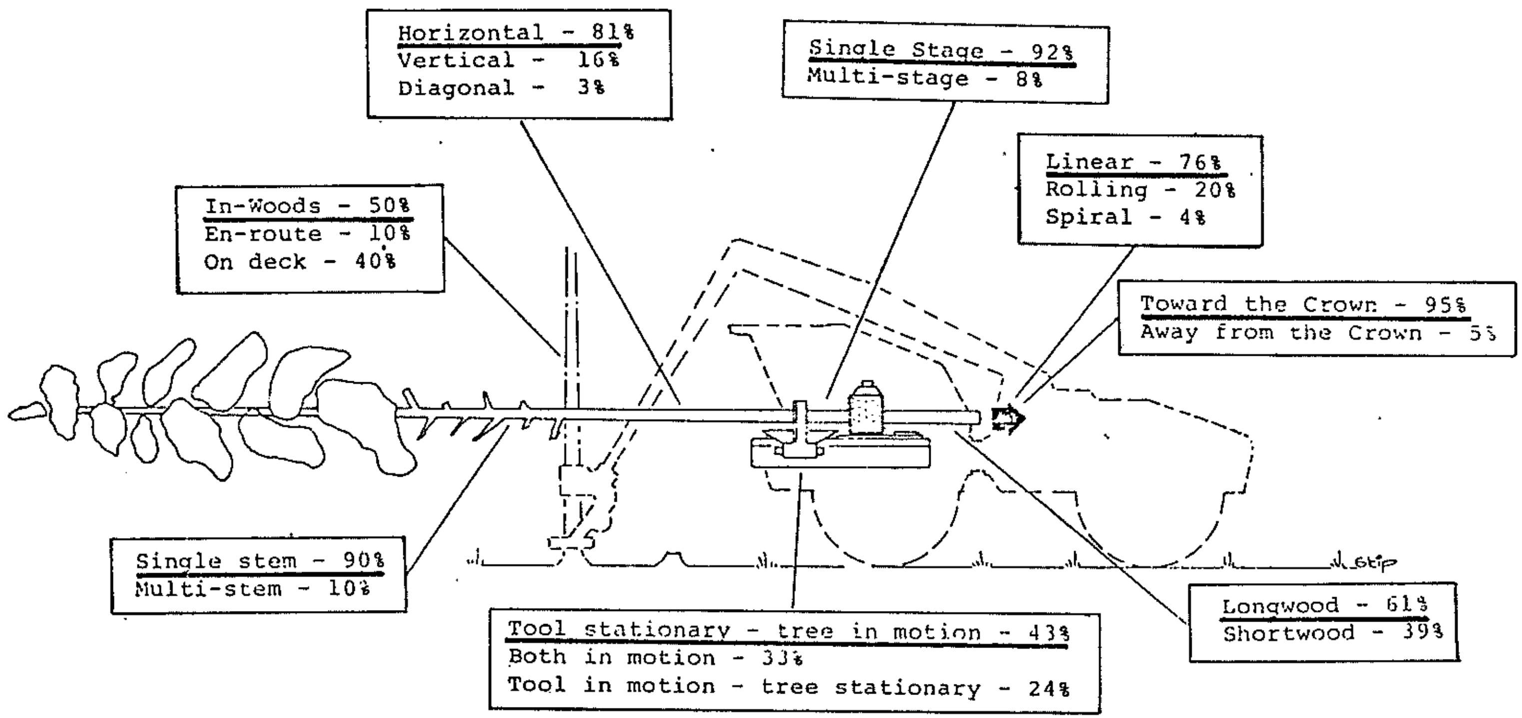
[1] "An Investigation into the Prospects for Development of Mechanized Limbing Machinery for Woods Operations in the Northern Interior area of British Columbia" by J.H.Boyd. An Unpublished Report.

[2] "Categorization of Delimbing Devices" by G.I.Carlson & J.E. Blonsky. An American Pulpwood Association Project Report.

[3] "Limbing Machines 1974 - Technical Data II" by Dag Myhrman. A Skogsarbeten Report.



A.P.A. CONCEPTION OF MOST COMMONLY APPLIED WORK PRINCIPLES FOR FOREST TREE DELIMBING.

(Fig.17)

Feeding force varied between 2000 kg and 6000 kg but usually between 3000 kg and 5000 kg.

Feed speed varied between one and three metres per second, usually around two metres per second.

Over three-quarters of the machines considered were rubber-tyred units.

Illustrations and basic specifications of these machines are provided in that report.

In 1976 FERIC of Canada reported on the chain flail delimber[1] as it met three basic Canadian requirements:

- Multi-stem delimbing
- High productivity capacity
- Low capital investment.

They outlined that despite problems (mainly chain wear) the flail was reducing limbing costs and detailed the following as obtained from 11 different flail operations. *(It should be noted that in many cases they operated on frozen or partially frozen wood where impact branch removal is easy and effective)*

Maximum tree diameters varied from 51 cm to 122 cm (mostly about 64 cm to 76 cm)

Average limb diameters varied from 2.5 cm to 5 cm

Flail drum speeds varied from 350-650 rpm (mostly about 485 rpm)

Chain lengths varied from 23 cm to 36 cm averaging at 30 cm

Flail units with skidders costed from $40,000 to $55,000.

Chain life varied from 15-45 hours (costing from $300-$400 per set)

Production rates of up to 280 cu.m. per hour were achievable but more common from 50 to 150 cu.m. per hour and delimbing costs were stated as between $0.25 and $0.50 per cu.m.

Chain flail limbing, they said, was desirably carried out at one place if the flail was to be kept working steadily.

Further work was reported by Skogsarbeten[2] in 1976 aimed at identifying the most effective limbing components for mounting on logging machines currently under development. It concluded that the most economical limbing solution is that where fixed knives are employed in combination with roller feeding. Further, that limbing should be carried out in the stand.

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1 "What is Happening to the Chain Flail Limber?" by L.W.Johnson. A FERIC Report.

2 "Mechanised Delimbing" by B.Nilsson. A Skogsarbeten Report.

A special Canadian report[1] in 1977 provided an indication for different machines, of typical performance figures in terms of minimum achievement, industry average, industry achievable and ultimate performance. For all equipment, *Fig.18 TABLE I* shows the performance assumptions used for four levels of achievement, the industry average performance being indicated in *Fig.18 TABLE II* for delimbing machines, processors and harvesters.

The report concluded that any of the presently available machine concepts had the potential to produce wood at costs equal to or better than manual systems. What is required are good concepts with effective application.

Further reports studied and listed in *Fig.19* look at specific delimbing machines showing information on size, cost and performance.

It is difficult to draw conclusions as to the specific direction of overseas equipment trends. However, certain aspects stand out as follows:

1. Machines that delimb are mainly being developed where tree sizes are relatively small. They most commonly can handle diameters up to 64 cm, and stem volumes up to 0.25 cu.m.

2. Machine layouts vary considerably with two main directions -
   (a) The single stem delimbing device using wrap-around knives and high speed feed rollers. This type of machine usually performs another function such as fell or cut-to-length and most popularly operates on the cutover thus returning slash to the forest floor. Extensively modified rubber-tyred carrier machines are most popular thus the machines tend to be expensive ($100,000 to $250,000 complete). Production rates of the order of 10-25 cu.m. per hour are achieved (50-100 trees per hour) and delimbing quality by these machines is rated good.
   (b) The multi-stem delimbing machines using impact or fixed devices to knock branches off. The machine is not combined to perform other functions and usually operates at a fixed point in the system thus tending to concentrate slash. There is a preference again for use in conjunction with rubber-tyred equipment, the delimbing devices themselves being attachments of lower initial cost (up to $25,000 for

[1] "A Method for Comparing Logging Systems and Machine Concepts" by J.H.Boyd & W.P.Novak. A FERIC Special Report.

FACTOR	STANDARD 1 "ULTIMATE" PERFORMANCE	STANDARD 2 "INDUSTRY ACHIEVABLE" PERFORMANCE	STANDARD 3 "INDUSTRY AVERAGE" PERFORMANCE	STANDARD 4 "MINIMUM ACHIEVEMENT" PERFORMANCE
Scheduled machine days per year	365	315	225	175
Scheduled hours per working day	24	24	18	16
Aver.utilisation of scheduled machine time	1.0	.80	.75	.60
Aver. operator efficiency during productive time	1.0	.85	.70	.60
Aver. repair parts and labour cost, $ per PMH per $1000 of original price	.05 (100% - 20,000hr)	.08 (100% - 12,500hr)	.100 (100% - 10,000hr)	.150 (100% - 6667 hr)

TABLE I: ASSUMPTIONS OF PERFORMANCE AT FOUR LEVELS OF ACHIEVEMENT

MACHINE TYPE	MACHINE DESCRIPTION	PURCHASE PRICE CAN ($)	TREES PER P.M.H.	PRODUCTIVITY M^3/PMH	MACHINE COST PER P.M.H. CAN ($)
Limbing Machines	Flail limbing machine	55,000	333	39.2	25.60
	Bunch limbing machine	66,000	240	28.0	26.20
	Single stem limber (roadside)	145,000	162	19.0	41.20
	Single stem limber (stump)	145,000	100	11.8	41.20
Processors (limb,top, buck,pile)	Processor (roadside)	220,000	206	24.4	57.30
	Processor (stump)	185,000	130	15.4	48.60
Shortwood Harvesters	Harvester Forwarder	230,000	61	7.3	58.0
	Harvester Forwarder	173,000	35	4.2	47.40
Tree Length Harvesters	Small Harvester (bunches)	91,000	74	8.7	30.80
	Harvester head on boom (no bunch)	120,000	74	8.7	36.20
	Harvester head bunching	104,000	72	8.4	33.90
	Harvester semi-auto (no bunch)	199,000	100	11.8	52.30
	Harvester bunching	200,000	88	10.4	52.20
	Harvester head on boom (bunching)	120,000	63	7.6	36.80
	Harvester assembles	120,000	54	6.4	36.60

TABLE II: INDUSTRY AVERAGE PERFORMANCE OF MACHINES (1977)

(Fig.18)

MACHINE	REFERENCE & DATE		MACHINE COST (Approx.$NZ)	MAX.STEM DIAM. (cms)	TRIAL-MEAN STEM VOL. (m^3)	TRIAL PERFORMANCE (Trees/Hr.)	TRIAL PRODUCTION (m^3/Hr.)
Bronemo Delimber	(1)	1972	$23,000 (attachment)	48	0.22		24.7
Morard	(2)	1973	$15,000 (attachment)		0.17		39.3
Sifer SS103	(3)	1975		30	0.15	90	13.15
Chain Flail	(4)	1976	$18,000 (attachment)				48.0
Stripper	(5)	1976	$9,500 (attachment)	23	0.06	60	3.6
Timberjack TJ30	(6)	1977	$100,000 (complete)	30		25	5.0
John Deere 743	(7)	1977	$150,000 (complete)	46	0.21	100	21.0
Grill Delimber	(8)	1977			0.25		2.0
Cleverhole Delimber	(8)	1977			0.12	75	8.5

REFERENCE:
(1) "The Bronemo Delimber", by D.Myhrman & J.Sondell. A Skogsarbeten Report.
(2) "Evaluation of Morard Limber", by E.Heidersdorf. A PPRIC Logging Research Report.
(3) "Mini Processor tackles Thinnings", a World Wood Journal Article, Nov. 1976.
(4) "The Flail Delimber", by D.Evans. A Canadian Forest Industries Journal Article, Feb. 1976.
(5) "Selective Thinning...with Stripper II Delimbing Machine" by J.Clausen. A Danish Institute of Forest Technology Report.
(6) "TJ30 - Another Step Forward", a Northern Logger and Timber Processor Journal Article, July 1977.
(7) "The John Deeres are Coming", by R.Letkeman. A Canadian Forest Industries Journal Article, April 1977.
(8) "Logging Systems in South East Queensland", by C.A.Lembke. An Australian Forest Industries Journal Article, Oct. 1977.

TABLE OF OTHER DELIMBING MACHINES

(Fig.19)

attachment) and the rubber-tyred machines being standard logging items (costing up to $40,000). Production rates with multi-stem delimbing units are higher and of the order of 50 to 150 cu.m. per hour (100 to 200 trees/hr.), however delimbing quality is not as good.

3.4 GENERAL PERFORMANCE AND COST PICTURE OF MACHINE APPLICATION:

Considering the N.Z. developments to date, and overseas developments in mechanised delimbing, the following evolves.

Generally the picture with N.Z. developments, to mechanise delimbing, is similar to that overseas *(Note last paragraph Section 3.3)* with the exception that the N.Z. single stem delimbing devices have exclusively used a moving knife carriage to delimb a stationary stem. The overseas trend has been towards using feed rollers to move a stem through fixed knives. This is probably due to our lag in following overseas trends generally, noting that initial overseas developments use the moving knife carriage principle and that it is still used in some new overseas machines.

In order to gauge the likely production and costs of typical machine types, the table in *Fig.20* shows the results from the analyses shown in Appendix Section I. It assumes such machines are applied to N.Z. crops with trees in the 0.2 cu.m. to 0.3 cu.m. stem size range.

The conclusion drawn is that:

1. Generally all popular forms of mechanised trimming have a lower labour consumption rate than that using the manual chainsaw method.
2. Only certain types of delimbing machine concepts offer the possibility of having a lower cost consumption than the manual chainsaw method, these being:
   (a) Multi-stem delimbing units. The attachment type units operating off standard unmodified logging machines have best potential.
   (b) Single stem delimbing units that are low cost a achments to low cost standard unmodified logging machines.
   (c) Single stem feller delimbers have a marginal potential to reduce cost but can do so only under favourable conditions and competent management.

MACHINE DESCRIPTION	SINGLE STEM DELIMBER		MULTI-STEM DELIMBER		FELLER-DELIMBER
	Attachment	Complete	Attachment	Complete	Complete
Machine Example	Bolstad Delimber	Can Car Processor	Multiple Tooth Jaw Delimber	Panpac Chain Flail	John Deere 743 Harvester
Initial Cost (Estimated)	$30,000	$100,000	$30,000	$60,000	$150,000
Allowed Machine Life	5 yrs	7 yrs	5 yrs	5 yrs	7 yrs
Scheduled Daily Hours	8 hrs	8 hrs	8 hrs	8 hrs	10 hrs
Utilisation	75%	75%	75%	75%	75%
Calculated Operating Cost *(see Appendix I)*	$17.39/hr	$34.58/hr	$17.39/hr	$28.78/hr	$40.30/hr
Probable Production Rate	$18m^3$/hr	$15m^3$/hr	$25m^3$/hr	$30m^3$/hr	$20m^3$/hr
Production Cost	$0.96/$m^3$	$2.30/$m^3$	$0.69/$m^3$	$0.96/$m^3$	$2.01/$m^3$
Labour Consumption Rate *(man-hrs/m^3)*	0.056	0.066	0.040	0.033	0.050

TABLE OF MACHINE PRODUCTION AND OPERATING COST ESTIMATES

(Fig.20)

3.5 DELIMBING MACHINES WITH MOST POTENTIAL IN NEW ZEALAND:

Section 2.3 of this report outlines that the major trimming area with potential to reduce costs and labour in N.Z. lies in the small 0.2 cu.m. to 0.3 cu.m. tree crops. Crops such as Ponderosa, Contorta at clearfelling and Radiata at production thinnings fit this category. The volume of wood cut annually in N.Z. that falls into this size category is comparatively small, hence the number of delimbing machines N.Z. forest operations could support is similarly small. In addition to this, the clearfelling crops such as Ponderosa which come from suitably flat forest areas will most probably be completely cut within ten years and replaced by Radiata. The major application for delimbing machines is thus a short term one.

For these reasons and keeping in mind the objective of this study (to reduce costs and high labour involvement), the delimbing machine characteristics considered to have most potential in N.Z. are as follows:

- multi-stem delimbing device
- attachment type unit capable of local construction
- use in conjunction with standard logging equipment
- low capital cost unit.

These characteristics should give the lowest delimbing costs, the highest production rates and involve equipment more readily available and easier to maintain and later dispose of in N.Z. Delimbing quality will not be high and it is recommended that machines of this nature be used in conjunction with a small amount of final manual trimming to maintain quality.

Typical examples of current machines that fit this category (which are mentioned in this report) include:

- Chain flails
- Jaws stripper-type units
- Grill delimbers
- Gate delimbers.

- 4 -

MILL ACCEPTANCE STANDARDS

Up until a few years ago trimming had been done by axe, cutting parallel with the tree axis from the butt end upwards. Trimming now is almost entirely by chainsaw with which it is often easier and quicker to cut at right angles to the branch leaving a short projecting stub. Workers in mill and bush have tended to become specialists and strangers to each other, particularly in the more recently developed large saw-mills and pulpmills, with the men in the bush working to instructions and not personal awareness of mill conditions. The man trimming with a chainsaw in the bush is not now favourable placed to use his own judgement as to how well he should do his job and is dependent commonly on indirect information and on instructions. A lowering of trimming standard has been accepted by the industry with this change from axe to chainsaw trimming. Can a further lowering of trimming standard be accepted?

The possibility of reducing log trim acceptance standards in New Zealand was investigated during 1977 by a consultant G.S.Brown working to the LIRA brief, "to compare a variety of current mill log acceptance standards having regard to specific restraints imposed by wood-room machinery, with the manpower and costs in meeting these standards", and "to identify the aspects of milling that would be significantly affected by any relaxation in current trim standards". The study was confined to five major mills of the Central North Island area, each with a scale of operations as indicated in the table below:

Annual Saw and Pulp Log Intake to Mill Yard in Thousands of m^3					
USE OF LOGS	MILL				
	N.Z.F.P.	Panpac	Tasman	Waipa	Fletchers
Sawlogs	370	130	453	354	225
Groundwood logs	-	-	443	-	-
Disc Refiner logs	-	170	277	-	-
Chemical Pulp logs	1101	-	827	-	-
TOTALS:	1471	300	2000	354	225

(Fig.21)

4.1 DELIMBING FOR SAWLOGS:

Written log specifications in use by the firms above were obtained. Only one of these mentioned the quality of delimbing at all and then only to say that all branches must be trimmed flush with the stem. The reason for ommission as outlined by all Sawmill Managers, technicians and saw operators interviewed, was that only one specification is acceptable - flush trimming. This is so well known in the industry that it goes without saying and there is no need to reaffirm it in a specification for use in the bush. Further, milling personnel generally considered that compared with other things, efficient delimbing is only of minor importance, noting that it could be of major importance were it not the subject of constant check, supervision and control. More actual mill damage and downtime is in fact caused by nodal swellings, bumps, bends, draw-out, splits, partial breaks, fluting and taper, all of which can cause delays in handling and tend to produce short thick oddly-shaped pieces of wood. In recent years the difficulties the large modern sawmills have experienced with badly shaped logs have been aggravated by the desirability of supplying a favourable log export market, and even more by increasing pressure for more complete harvesting.

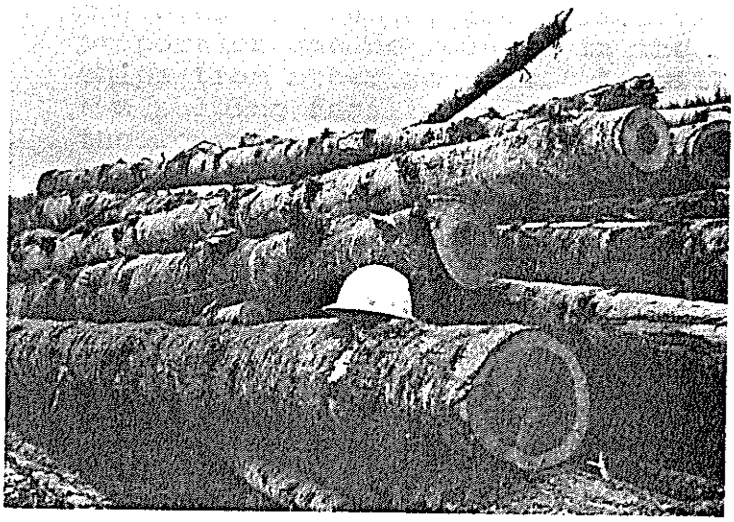
There is in practice a considerabe difference between what is described in written log specifications, and the range of types of log that reaches the mill, in most factors including branch trimming. The standards of delimbing actually achieved in practice are illustrated in *Figures 22 & 23*.

The general impression gained is that on logs without noticeable nodal swellings, branch pegs*of up to about 5 cm diameter and 5 cm length in logs up to about 30 cm small end diameter, and branch pegs of up to twice these dimensions in the largest logs, would not cause delays in most mills. Logs with branch pegs of similar size associated with nodal swelling would be likely to cause trouble, but because of the swelling rather than because of the peg itself. The proportion of logs not flush delimbed affects the situation. One odd bad log among many clean logs would not cause trouble. Most machines in a large sawmill have a little time in hand and an occasional short delay with a difficult log does not starve the next machines in line and is therefore not of great importance.

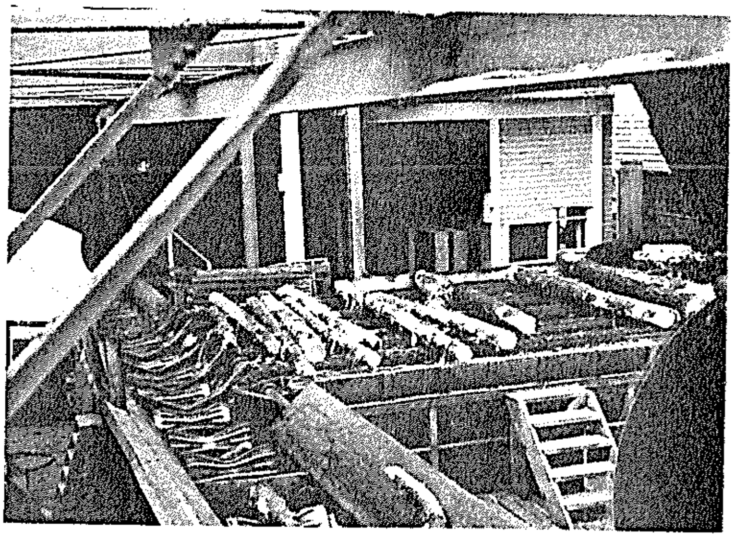
Large modern exotic (or Conifer) sawmills are designed for largely automatic handling, very rapidly, of flush trimmed straight logs of moderate taper. Their production

(In this report the terms "branch stubs" and "branch pegs" are used synonymously.)*

Radiata pine logs for sawing - well delimbed.
(FIG.22)



Douglas fir sawlogs - a barely acceptable delimbing standard.
(FIG.23)



Log transfer from roll case to chain deck - an example of a situation where large pegs interrupt log flow.
(FIG.24)

is adversely affected by logs that are bent, severely tapered, forked or have marked nodal swellings or are unduly short. The fact that branch pegs do not greatly affect production is due to the fact that large pegs in practice are uncommon. Branch pegs can cause delays or breakdowns at the following points:

1. On any break point in the bull chain feeding logs into the mill, (e.g. at the cross-cut saw or where kickers are installed to divert logs from the chain). Pegs can hook into the sides of the trough.
2. In the ring debarker pegs and especially log branches left on logs can jam the operation of the tool arms. Long branch pieces falling among the bark into the bark disposal shutes can cause arching of the waste and clog up the system.
3. At mills with their own pulping facilities, (at Tasman, N.Z.F.P., and Panpac) if a few logs get through the ring debarkers incompletely debarked, the proportion of bark that gets into chips from the slabs is not of great importance because the proportion can be reduced in the later mix with chips from other sources. At mills without their own pulping facilities however (such as Waipa), the lowering of the efficiency of the debarker by branch pegs on the logs can have a serious economic effect by raising the bark percentage of slab chips to a level at which they become unsaleable.
4. On the band head rig, half broken pegs may give before the saw and spring back then foul the band on the return of the carriage causing the band to leave its wheels. Small cut off pieces can also fly dangerously.
5. On the band head rig, branch pegs and nodal swellings have to be removed by a pass of the carriage before the face cut proper is made. An unprofitable pass reduces production.
6. The pieces so cut off tend to be short and to fall between the rollers on the take-off side. Because the projections are usually associated with awkward shape, they can be dangerous for the downturner to handle.
7. Branch pegs interfere with the passage of flitches through a horizontal band saw and can hold up production.
8. Branch pieces falling below the band head rig into the sawdust disposal shute can cause arching of the sawdust sufficient to clog the system.
9. Slabs carrying pegs if they happen to fall flat side up, can fail to travel lengthwise along a roll case, or they may jump erratically dangering the mill operators.

10. Pegs on logs and slabs travelling sideways can cause the logs or slabs to get out of parallel and so cause pile ups.
11. If an attempt is made to pass a flitch with pegs through a band resaw, a peg may hook into the top cross piece of the roller frame and so jam the saw.
12. In the frame gangsaws, pegs can knock out the sideblocks.
13. In a double arbour gang circular saw, pegs can and do cause real trouble by jamming between the blades. Similar trouble is caused by lumps sawn off nodal swellings.

The view at four of the major mills appears to be that it is so difficult to alter the design of a large mill in full production that it is impractical, and that therefore the standard of delimbing must be adjusted to suit the existing mill. The other mill indicated that an economic standard of delimbing should be aimed at, but perfection should not be expected and the mill machinery should be designed to cope with the imperfections.

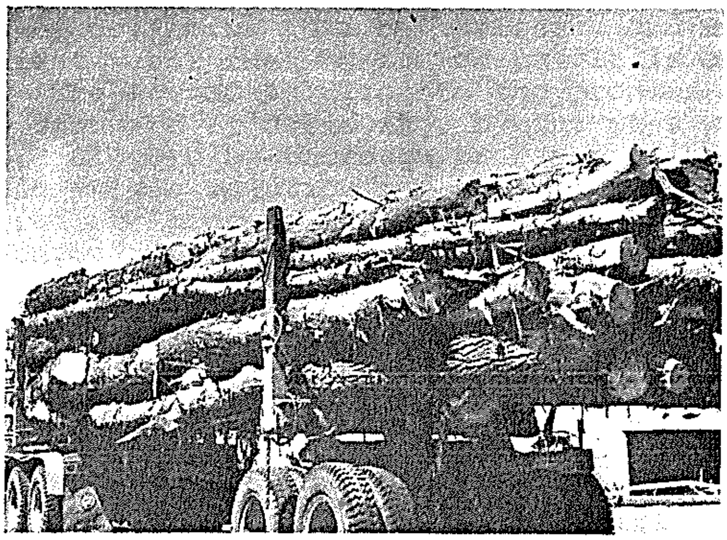
As regards logs for sawmilling, there is thus a day to day continuing need for supervision to maintain delimbing standards. Allowance must be made for the inevitable gap between specification and performance; a gap which requires constant pressure on workers in the bush for it to be kept reasonably small. Performance related to the simple requirement of flush delimbing is clearly understood by all concerned. The complication of a relaxation would not help.

4.2 DELIMBING FOR PULP LOGS:

In general the standard of delimbing for logs for pulp and paper etc. is lower in practice than that for saw logs because smaller logs of lower value with a higher proportion of branches are involved, but within this group there are differences. All mills generally assumed that any pine log not good enough to be used in its round condition or as a saw log could be used for chipping. Branches do not chip satisfactorily, however, and can cause serious troubles especially in continuous digesters. The only other quality question that arises with pulp logs is a minor one concerning minimum diameter. If the diameter is less than about 7.5 cm, the small end tends to shatter in the drum debarker, giving rise to an undesirable proportion of oversize slivers among the chips. Pegs on logs for chipping are therefor the most undesirable defect in pulp logs. They are also common.

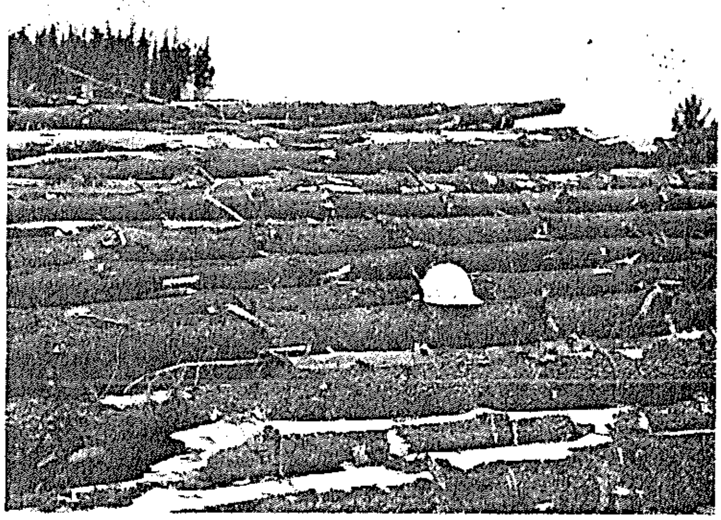
The standard required for logs for direct grinding on stones is as high as that required for sawlogs, the only difference being a matter of size. Substantial pegs can prevent adequate debarking in the drum debarker. Much more important in practice is the fact that pegs cause overheating of the stones. The paper production people consider that flush delimbing is essential for stone groundwood production. For chipping for refiner groundwood production, so high a standard is not necessary. The practice for Panpac is to subject the logs to one flail pass in the bush (leaving branches on the underside of the logs), cut the logs at the mill to a maximum length of 2.4 m and pass them through a drum debarker. The debarker tears off any remaining long branches and, because the branches on the logs currently being supplied are small, wears off enough of the remaining branch pegs to allow complete bark removal. The result is logs clean enough for chipping prior to being passed to the disc refiner for reduction to pulp. Tasman also has a disc refiner but insists on a higher standard of preparation in the bush involving more than a pass of the chain flail and completion of delimbing by chainsaw. This is said to be because the chips produced in their field chipper, or the logs to go to the Kawerau Mill for chipping may or may not be routed to the disc refiner. They may possibly go to the digestors. Because of lack of sufficient drum capacity some of the logs for chipping at the mill may have to be debarked by ring debarker for which good delimbing is required. Tasman experience has been that for chips for digestors and particularly for continuous digestors, flail delimbing is inadequate. This is partly because each pass of the flails introduces some pumice dust into logs and chips, especially in field chipping, and the dust causes excessive wear in screens and elsewhere in the mill machinery. The main trouble with branches and pegs which happen to get through the debarking system intact, as can happen with ring or hydraulic debarking, is that in the chipper the branches tend to be cut into short cylindrical lengths, not thin chips, and these do not cook properly in the continuous digestor. A piece as small as 5 cm long by 2 cm diameter will pass through a digestor little reduced in size, but meanwhile it has taken up digestor capacity and has absorbed valuable chemicals. There is provision for screening out and recycling imperfectly cooked chips, but the addition of these branch fragments tends to overload the system. They also tend to block the screens before they reach the digestor. Paper people at N.Z.F.P. say that any chip over 0.8 cm thick causes problems (failure to cook completely, excessive use of chemicals, screen blocking), but that almost all the trouble of this type is caused by factors other than inadequate delimbing. Trouble is caused by pegs and persisting long branches at N.Z.F.P. jamming in the chipper throat from time to time and by adding to the accumulation of waste around the yard which is a real problem at this mill.

Pulp logs are usually not so well prepared as saw logs and the following photographs are indicative:



Radiata pine pulp logs - an acceptable standard.

(Fig.25)



Contorta pine logs for chipping - delimbing standard considered "a little too rough".

(Fig.26)

The point concluded from the bush and mill inspections is that it is accepted in the industry that although branch pegs on pulpwood are highly undesirable at the mill, they are difficult to get rid of completely and economically by existing means. The delimbing of saw logs presents no great difficulty as the branches are few per tonne and the logs are of comparatively high value and can carry the cost. The trouble with pulp logs is that they are generally small and branchy and the value of the product is too low to carry much expenditure on its improvement. However it seems there is an economic necessity to find some cheaper means of delimbing than by chainsaw, and some more efficient means that by the chain flails available to date. The Panpac solution to the problem of accepting a low standard of delimbing, by one pass with a chain flail, followed by thorough processing in drum debarkers, is only a solution for them because they use the disc refiner process and because they have adequate drum capacity. The disc refiner process is less sensitive to pegs on logs than either stone grinding or digestive pulping as used by Tasman and N.Z.F.P.

4.3 POTENTIAL FOR REDUCING LOG TRIM QUALITY IN NEW ZEALAND:

For sawlogs, clean flush delimbing is essential and no relaxation of trim standard can benefit the economics of the process. There is a continuing need for close contact and understanding between the staff of mill and bush to ensure that the required standard is maintained.

For pulp logs the situation is different. For groundwood complete flush delimbing is as important as it is for saw logs. For other forms of pulp logs, clean delimbing is desirable although not so vitally important. The delimbing of logs for stone grinding or for chemical conversion in digestors accounts for a considerable part of the total cost of the logs delivered at the mill and yet the standard of delimbing leaves a good deal to be desired. Relaxation of the standard will not help in current mills not designed to accept a lower delimbing standard. With appropriate mill equipment incorporated however, it is feasible to accept a lower standard of trim.

- 5 -

NEW MANUAL TECHNIQUES

Manual trimming techniques currently in use in New Zealand, using the chainsaw, evolved from the methods used for trimming of large size old crop Radiata with low branch content. The method used is to simply progress along the stem delimbing with the tip of the chainsaw bar. With the more recent concentration on utilising the New Zealand crops such as Ponderosa, Contorta, Corsican, etc., and some utilisation of Radiata thinnings, the manual delimbing technique used has not changed, in spite of the need to work on trees of small size and high branch content with branches located the full stem length.

5.1 ALTERNATIVE MANUAL TECHNIQUES:

The development of specific manual techniques for efficient trimming with chainsaw has occurred in Europe. In this area different techniques are advocated for the different tree characteristics covering such trees as:

- Trees with non straight stems and infrequently placed large diameter branches
- Trees with straight stems and branches growing in whorls at regular positions all along the stem
- Trees with straight stems and a large number of small diameter branches growing at irregular positions all along the stem
- Trees with straight stems and branches confined to the upper section of stem only.

The most popular technique used is the Swedish developed "lever method", where the chainsaw is mainly supported by the tree stem during delimbing which is done with the heel of the bar. A specific systematic pattern is used to proceed along the stem. The "lever method" is designed for use on trees with straight stems and branches growing in whorls at regular positions all along the stem, thus tending to support the felled stem above ground level. It is also used in a modified form to handle trees with straight stems and branches in whorls confined to the top section of the stem only, thus resulting in trees that tend to lie flatter on the ground after felling.

The Swedish "lever method" is described and illustrated in an excellent manner in *Ref.*[1], and the modified form is outlined again in an excellent manner in *Ref.*[2]. Appendix II indicates the general nature of these techniques.

5.2 SUITABILITY OF ALTERNATIVE TECHNIQUES TO NEW ZEALAND APPLICATION:

Both the above techniques, the "lever method" and its modified form, are considered to be directly suitable for application in New Zealand either in conjunction with manual or mechanised felling.

Trees such as untended Ponderosa, have branches growing in whorls at regular positions all along the stem. The Swedish "lever method" should be directly applicable. Similarly, production Radiata thinnings more commonly will have whorls of branches at regular positions on the upper section of stem and the stem will tend to lie close to the ground after felling. The modified Swedish method should be directly applicable here.

No results of trials of these methods in New Zealand are known. It is therefore recommended that consideration be given to such a trial. It is reported however that manual trimming production rates on mechanically felled trees is higher than on manually felled trees. This aspect then offers further potential to reduce the high labour involvement in trimming.

[1] "Work Technique for Limbing", A Husqvarna Publication.

[2] "Efficient Limbing with a Power Chain Saw", A Stihl Publication.

- 6 -

CONCLUSION AND DISCUSSION

This study has aimed to meet its objective, "to examine possibilities for reducing the costs and high labour involvement in the process of trimming trees", by investigating three main areas being the suitability of mechanisation, the mill acceptance of a lower trim standard, and the option of alternative manual techniques.

6.1 THE BEST MEANS OF REDUCING COST AND LABOUR IN TRIMMING:

Mechanisation of the delimbing process offers potential to both reduce cost and manpower involvement with the following specific constraints:

1. The cost saving potential only exists with smaller volume New Zealand trees (stem size range 0.2 cu.m. to 0.3 cu.m.) such as Ponderosa, Contorta, and early Radiata production thinnings.
2. By virtue of the equipment offering, mechanisation is restricted to forests on generally flat terrain.
3. While all mechanised delimbing concepts reduce the labour involvement in trimming, only specific machine concepts offer the potential to reduce costs. The concept with most potential in New Zealand is the multi-stem delimbing device which is an attachment type unit capable of local construction and which is used in conjunction with standard New Zealand logging machinery such as tractors and skidders. It should operate between felling face and landing and should not cost more than approximately $60,000. Mechanisation along these lines will require a small amount of final manual trimming to maintain the trim quality required by most N.Z. mills. With single stem delimbers, the concept of an attachment type unit capable of local construction and which is used in conjunction with a standard New Zealand logging machine, also offers a cost-saving potential provided initial cost is less than $30,000. A marginal potential to reduce cost exists with custombuilt feller-delimbers, but only under favourable conditions of utilisation, maintenance cost, production rate and tree size.

The relaxation of current New Zealand mill acceptance standards for delimbing does not currently offer any real potential to reduce the costs or labour consumption of manual trimming. This is due to a number of aspects, the major limitation being posed by the capabilities of current mill debarking and log chain equipment. However, with appropriate mill equipment incorporated such as drum debarkers, it is feasible to accept a lower standard of log trimming in the smaller diameter logs for pulp, and new pulp mills being planned should consider this option. This option does not exist for saw logs, where clean flush delimbing is essential.

Alternative manual trimming techniques are available and would seem quite suitable to reducing the cost and labour consumption in trimming the small stem volume relatively branchy New Zealand trees such as Ponderosa, Contorta, Corsican, and Radiata thinnings. Both the Swedish "lever method" and modified Swedish method referred to in Section 5 of this report are recommended for trial and evaluation.

6.2 AREAS REQUIRING FURTHER DEVELOPMENT AND RESEARCH:

This project to date has examined and reported on possibilities for reducing the cost and labour involvement of trimming.

Mechanisation of delimbing, the option considered to have best potential to reduce cost and labour, has already started in particular New Zealand harvesting operations. There is thus a need to:

(a) Stimulate, guide, and assist the developments most suited to New Zealand, such as the locally built low cost delimbing attachments for common N.Z.logging machines.
  - Multi-stem delimbers offer best potential and detailed evaluations should be carried out on devices such as the Gate delimber, the Jaws delimber, and the more recently built chain flail delimbers.
  - Single stem delimbing attachment devices also offer some potential, and the Bolstad prototype delimbing unit referred to in Section 3.1 should be noted with respect to its potential in pruning operations as well as delimbing.

(b) Monitor overseas machines and advise on their suitability. As a relatively remote small country, the New Zealand logging industry cannot afford to import expensive equipment with no real long term application in the country.

The trial and evaluation of the two alternative manual techniques for chainsaw log trimming operations as outlined in Section 5 should be arranged with local trials.

APPENDIX I

MACHINE DELIMBING COST ANALYSES

Basic information used in estimating delimbing machine operating costs is as follows:

MACHINE EXAMPLE:		*BOLSTAD DELIMBER*	*CAN CAR PROCESSOR*	*MULTIPLE TOOTH JAW DELIMBER*	*PANPAC CHAIN FLAIL*	*JOHN DEERE 74 HARVESTER*
MACHINE FUNCTION:		*Delimb*	*Delimb & cut to length*	*Delimb*	*Delimb*	*Fell & Delimb*
Purchase cost	C	$30,000	$100,000	$30,000	$60,000	$150,000
Life in years	Y	5	7	5	5	7
Residual value	V	$ 3,000	$ 10,000	$ 3,000	$ 6,000	$ 15,000
Depreciation sum	D	$27,000	$ 90,000	$27,000	$54,000	$135,000
Scheduled daily hours		8	8	8	8	10
Scheduled life hours	S	10,000	14,000	10,000	10,000	17,500
Utilisation	U	75%	75%	75%	75%	75%
Productive machine hours	P	7,500	10,500	7,500	7,500	13,125
Average Investment	A	$19,200	$ 61,428	$19,200	$38,400	$ 92,142
Interest and Insurance	I	$ 2,688	$ 8,600	$ 2,688	$ 5,376	$ 12,900
Repairs and Maintenance	R	$30,000	$100,000	$30,000	$60,000	$150,000
Fuel, servicing and lube	F	$15,000	$ 50,000	$15,000	$30,000	$ 75,000
Hourly operator cost	O	$4.50	$4.50	$4.50	$4.50	$4.50

The following assumptions are used:

Residual value (V) = 10% of purchase cost (C)

Depreciation sum (D) = C - V

Scheduled work days per year = 250 days

Scheduled life hours (S) = 250 x life in years (Y) x scheduled daily hours

Productive machine hours (P) = Utilisation (U) x (S)

Average Investment (A) = $\frac{C(Y + 1) + V(Y - 1)}{2Y}$

Interest and Insurance (I) = 14% of average investment (A)

Repair and maintenance (R) = 100% of purchase cost (C)

Fuel, servicing and lube (F) = 50% of repair and maintenance cost (R)

From the above basic information and assumptions, the machine operating costs and production costs are calculated as follows:

MACHINE EXAMPLE:	*BOLSTAD DELIMBER*	*CAN CAR PROCESSOR*	*MULTIPLE TOOTH JAW DELIMBER*	*PANPAC CHAIN FLAIL*	*JOHN DEERE 743 HARVESTER*
Depreciation Cost per hour (D/P)	\$ 3.60	\$ 8.57	\$ 3.60	\$ 7.20	\$10.28
Interest and Insurance Cost per hour $(\frac{I\ Y}{P})$	\$ 1.79	\$ 5.73	\$ 1.79	\$ 3.58	\$ 6.88
Repair and Maintenance Cost per hour $(\frac{R}{P})$	\$ 4.00	\$ 9.52	\$ 4.00	\$ 8.00	\$11.43
Fuel, Service and Lube Cost per hour $(\frac{F}{P})$	\$ 2.00	\$ 4.76	\$ 2.00	\$ 4.00	\$ 5.71
Operator Cost per hour $(\frac{O}{U})$	\$ 6.00	\$ 6.00	\$ 6.00	\$ 6.00	\$ 6.00
Total Operating Cost per hour	\$17.39	\$34.58	\$17.39	\$28.78	\$40.30
Probable Machine Production Rate	$18m^3/hr$	$15m^3/hr$	$25m^3/hr$	$30m^3/hr$	$20m^3/hr$
Production Cost per m^3	\$ 0.96	\$ 2.30	\$ 0.69	\$ 0.96	\$ 2.01

APPENDIX II

SWEDISH LEVER METHOD AND MODIFIED FORM OF CHAINSAW TRIMMING

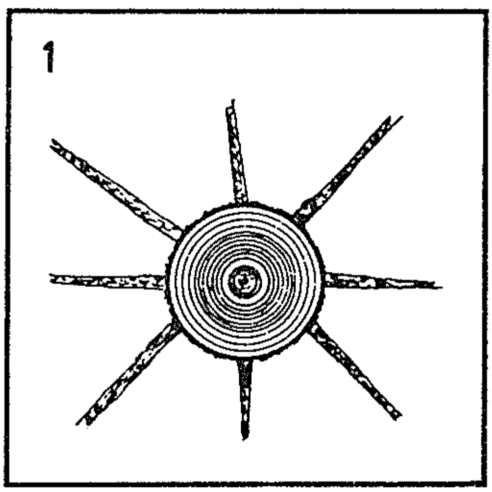
The following material has been extracted from *Reference 1* to indicate the general technique of the Swedish Lever Method for chainsaw delimbing. The modified form is similar, differing mainly in the sequence of cutting.

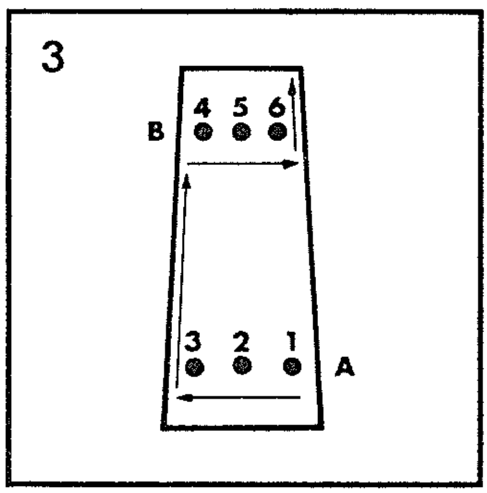
ILLUSTRATION 1: Line sketch of a log with branch grouping as seen from the felling cut.

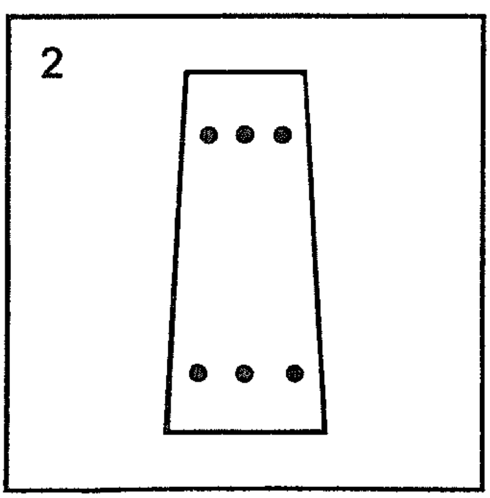
ILLUSTRATION 2: The same log as seen from above. The juncture of limbs and trees are shown by dots. For a better understanding of the systems we are illustrating only three branches per group.

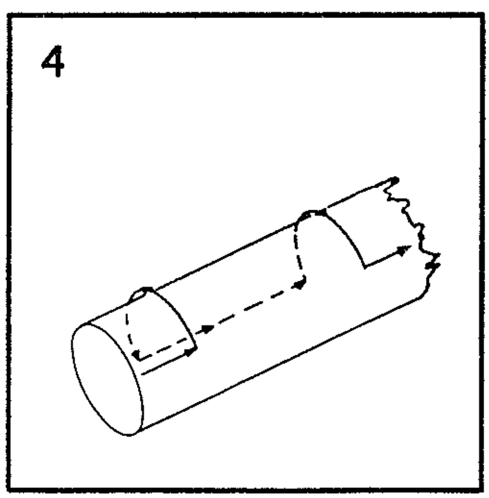
ILLUSTRATION 3: This is the correct sequence for limbing or cutting two rows of branches.

ILLUSTRATION 4: This is an interesting and easy to follow movement in which the direction of the cut is changed only once at the end of each row of limbs or branches.









Ref.1 "Efficient Limbing with a Power Chain Saw". A Stihl Publication.

The sequence of movement is further illustrated below.

The following should be noted:

a) The saw is always supported by the log.

b) All branches, even the lower branches (1 and 6), are cut with a lever action.

c) The movement is maintained, even in those cases where the weight of the tree puts tension on the limb and requires a reverse direction of cut (branches 3, 5, and possibly 6).