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Development of 36-Inch Feller-Director

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Technical Report No. TR-48
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DEVELOPMENT OF 36-INCH FELLER-DIRECTOR

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TECHNICAL REPORT No. TR-48

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ABSTRACT

Technical Report No. TR-48 describes the development of a 36-inch feller director from inception to final prototype. It also gives performance data and machine specifications for the more recent models.

RÉSUMÉ

Le rapport technique RT48 décrit un programme de développement et de mise au point d'une tête d'abattage directionnel pour des arbres allant jusqu'a 36 po le diamètre. Il contient aussi les devis descriptifs techniques ainsi que des donnies sur la performance des modèles les plus récents.

ACKNOWLEDGEMENT

The author would like to thank Messrs. D. Little, G. MacKenzie, R. Weinard, D. Biech, and B. Graham of Northwood Pulp and Timber Ltd. for their assistance and support during the development of the feller-director. Also G. Mihaljevic, production operator, was always very helpful.

Mr. Dag Myhrman of Skogsarbeten (on loan to FERIC) contributed in the early stages and Mr. Daniel Guimier of FERIC produced the tree falling mechanics necessary for the design.

Mr. D. Fish and Mr. C. White of Anda Manufacturing in Prince George oversaw the building of all the heads and contributed a lot to the carrier development. They also conducted much of the experimental testing.

SUMMARY

This report describes the development of a 36-inch (91 cm) feller director from the "need" stage through preliminary tests, determination of design parameters, design, manufacturing, and field testing. It reviews some of the difficulties encountered during the program and describes the solutions used.

Performance data for the second prototype is given along with the specifications of the latest model.

The report concludes that the feller director head and carrier are both developed sufficiently for production and offer a viable means of felling trees up to 91 cm stump diameter under control and in safety.

INTRODUCTION

The Western Division of FERIC and Northwood Pulp and Timber Limited jointly developed a feller-director to fall the larger trees of the B.C. Interior with a minimum of butt damage. This work can be done manually, but fewer hand-fallers are being attracted into this strenuous and hazardous work, and hand-fallers have difficulty in felling the trees directionally. Tree shears, which have been widely used during the past decade, cause unacceptable butt damage to valuable peelers and sawlogs.

Sawing has greater potential than shearing for wide application and butt damage reduction. One approach to the butt damage problem which continues to show promise is the chain saw incorporated into mechanical felling heads. Initial disadvantages such as slower cutting, greater equipment complexity, the need for better-trained operators, and the fact that sawing may not eliminate all butt damage needed to be overcome.

In 1976, during discussions between Northwood and FERIC, it was recognized that one machine could not offer a comprehensive solution as operating conditions varied too greatly with location.

However, the most pressing needs were identified and the general parameters for a machine to meet those needs were jointly established:

(a) a felling unit for trees up to 36 inches diameter,
(b) severence by saw to reduce butt damage,
(c) a felling head to have directing ability to minimize breakage and skidding costs,
(d) a felling head to be boom-mounted and equipped with stump grippers to contain felling forces,
(e) a felling head capable of grappling and moving or bucking felled timber to provide access for the machine to standing timber,
(f) a carrier with low ground pressure and steep terrain capability.

PROCEDURE

A review of the general objectives indicated that considerable background information would be necessary before proceeding. Therefore, as a result of meetings held during 1976 and 1977, the following program was instituted.

(1) Review those felling heads most nearly approaching the general objectives.

(2) Obtain and study all applicable patents.

(3) Produce a felling head/carrier unit from available equipment to approach as closely as practical the general requirements, and allow operating characteristics to be studied.

(4) Obtain pertinent data through field studies.

(5) Revise the general objectives if necessary and determine specific design criteria for the feller director.

The characteristics of existing larger saw-type felling heads were investigated and compared with the general requirements. Also, a search was made for patents covering saw-type tree-felling equipment. This produced many leads but not much applicable information.

Meanwhile, a used FMC 200 Series track skidder and an OSA 640 felling head were provided by Northwood as the main components of the research vehicle. They also purchased a Cranab FK9060 boom and swing assembly to carry the head. During this time FERIC provided the technical input, the design facilities, and the coordination of the modifications. A Prince George fabricating shop was chosen to do the work and the resulting machine (Figure A) was ready for field tests in May 1977.

The initial tests were conducted east of Prince George near Northwood's McGregor camp and were later continued 300 miles west, near Houston, B.C. During the seven weeks of operation, the unit operated on firm and soft ground, sidehill slopes, and in all tree sizes up to the 56 cm (22 in.) capacity of the OSA 640 head. Five studies were conducted

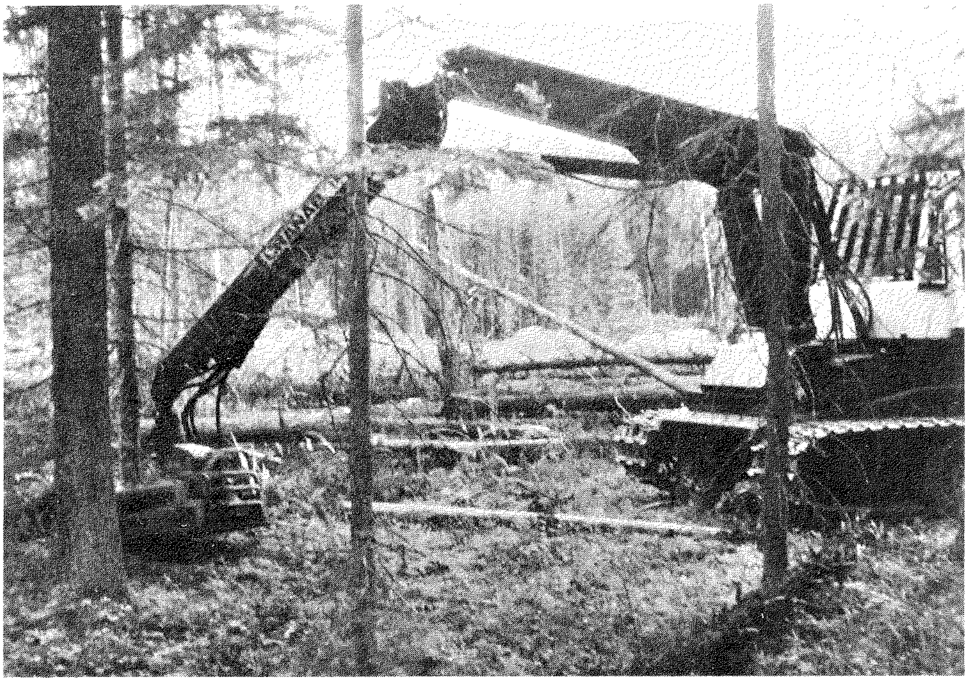


FIGURE A. First Carrier With OSA 640 Head.

in which the unit cut test plots of trees measured, mapped, and identified by species. Machine movements were timed to determine the relative importance of carrier manoeuvering, head placing and cutting, and tree handling times. The results of these time studies are summarized in Table 1.

The following points were resolved:

(a) The FMC was suitable as a steep terrain felling-head carrier. Its stability was adequate and manoeuvrability was good with pivot steering.

(b) Tree spacing permitted the carrier to operate within the stand and fall outward toward the cleared area.

(c) The OSA 640 head required considerable upward force from the stick to achieve tree-falling direction. To provide this lift, the carrier had to be moved close to each tree cut, and thus could not exploit the reaching capability of the boom.

(d) Because of (c) above, it was determined that a pusher arm would be needed.

(e) The Cranab FK9060 boom was satisfactory except for low swing power. This prevented the unit from clearing cut trees from the carrier path and prevented the development of a good cutting pattern.

TABLE 1. First Carrier with OSA 640 Head. (56 cm (22-inch) capacity)

	% of Total Time	min*
Move in stand	24.8	0.26
Brushing	8.1	0.09
Felling cycle (min) a) Swing empty 0.15 b) Position + cut 0.32 c) Swing loaded 0.17 0.64	59.9	0.64
Delays	7.2	0.08
Total cycle time	100.0%	1.07
Number of trees per move		1.3

*Average time per tree (min).

REQUIREMENTS FOR NEW FELLER-DIRECTOR

As a result of the field experience and the various tests, specific design objectives for the new feller-director head were jointly established.

1) Range of tree diameters: 15 cm (6 inch) to 91 cm (36 inch).

2) Good bar and chain protection such as that provided by OSA 640's double anvil head.

3) Stump grippers should have two moving arms to keep all sizes of tree centralized in the head and reduce boom movement.

4) Use a standard-type saw chain (for availability and cost) and a narrow bar (to reduce head size and weight).

5) Bar section thick enough to protect return of chain.

6) Push arm needed to move in same direction as saw movement (i.e. holding wood to act as hinge).

7) Dual-pressure hydraulic system on pusher to minimize "barberchairing."

8) $\pm 90^{\circ}$ horizontal head rotation about boom.

9) $\pm 10^{\circ}$ transverse head tilt.

10) $\pm 15^{\circ}$ fore and aft head tilt.

11) Manifold mounted valves in head.

12) Automatic chain oiler.

13) Bucking and grappling capability.

14) Maintenance ease.

36-INCH FELLER-DIRECTOR DESIGN

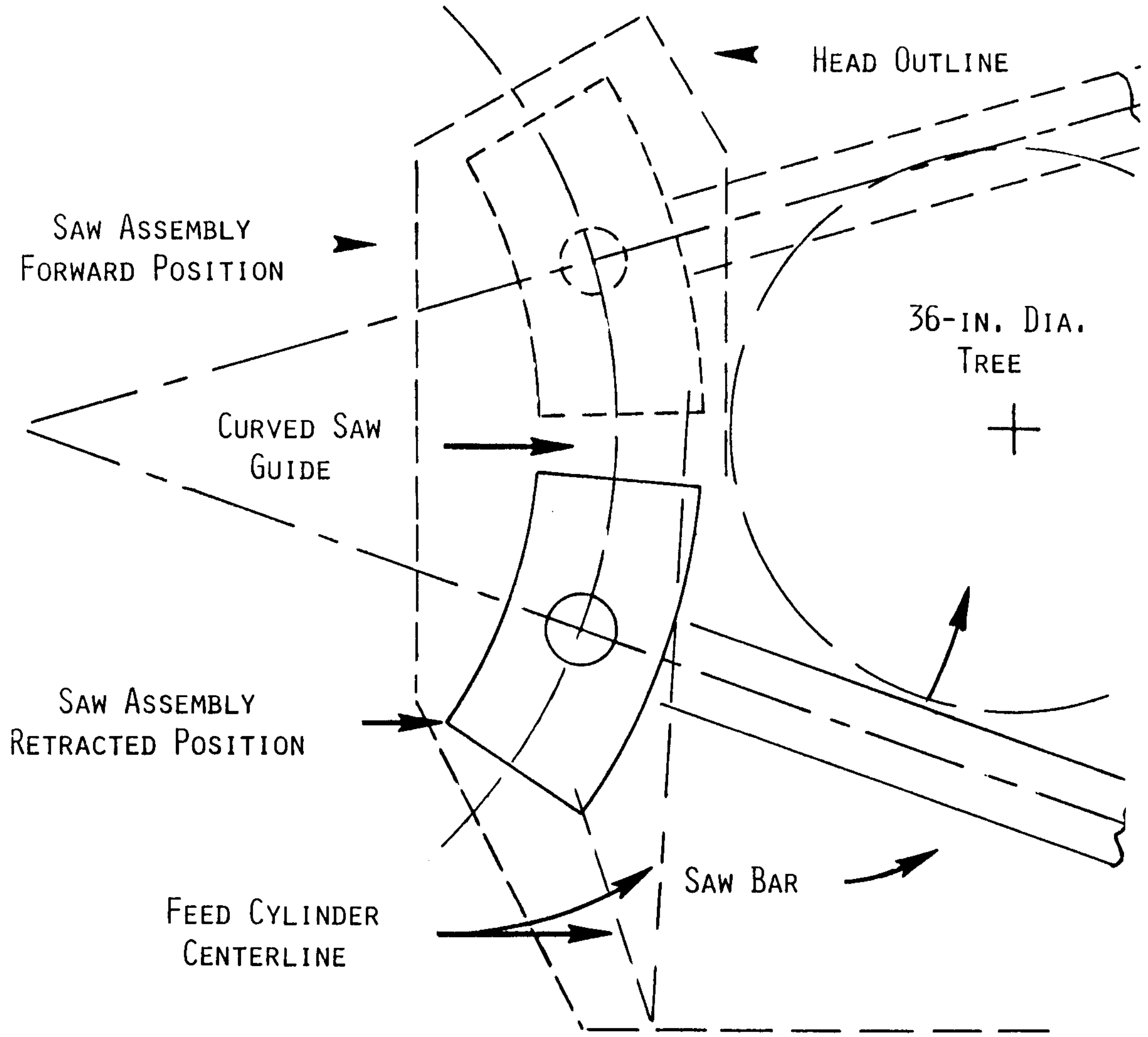
Once the objectives had been determined, design consisted of establishing the best compromises to result in a practical felling head.

Initial layouts showed that head size (and thus weight) were largely dependent on the saw bar ability to traverse a 36-inch diameter area. Also, the final holding wood should be located so that the push force causes "hinging" action for direction control. In early layouts, a 15 cm wide bar with a parallel feed was considered. This achieved the desired compactness and correct holding wood location but no simple, reliable feed was found. All trial designs based on pivoting the bar around a single point resulted in excessive head size and weight. Finally, a combination of translation and rotation using a curved saw guide and a single feed-cylinder was developed (Figure B).

It was known from previous observations that the return side of the saw chain is vulnerable to damage as the tree butt slides or "kicks-back" across the bar, often catching the chain. Various wedge-shaped bars were considered to protect the chain but they were all complex and expensive. It was theorized that if the head could be clamped securely to the tree with no "kick-back" space allowed, a relatively standard bar could be used. This entailed pushing outwards from a U-shaped head so that all tree sizes could be clamped to the back of the head opening.

Determining power requirements was also a problem in that no accurate data were available. FERIC had taken some total power readings but they were for smaller trees. How the total power requirement pro-rated to larger trees and divided into frictional and cutting power was not accurately known. The decision became one of providing excess power capacity until more information was available. A Volvo F11-78 hydraulic piston motor was chosen as it had suitable capacity in the speed range, was a reasonable size, and its output shaft had adequate side-load capacity to withstand chain pull during cutting.

Directing forces could be applied in several ways such as through a kerf wedge or pusher arm. A pusher arm was chosen after noting all the following requirements expected of this mechanism:



(Canadian and U.S.
Patents pending.)

FIGURE B. Geometry of Bar and Track.

a) provide preload to ensure head is securely attached to the tree,
b) keep kerf open during cut,
c) provide horizontal force to minimize "kick-back" tendency,
d) direct tree fall.

An existing computer program was modified to provide horizontal and vertical dynamic forces at the butt of a falling tree as well as rotational times. These data were used to determine the required structural strengths and hydraulic flows for the head.

Stump grippers convey the felling forces from the head to the stump. If this is done, the carrier and boom do not encounter these forces or the tree weight unless a grappling or bucking function is included. Of course, the normal operational forces arising from brushing and miscellaneous impacts still exist. Two gripper arms and cylinders were chosen over one as layout and calculation showed their combined weight to be less than other assemblies. Also by locating the gripper pivot points on each side, the head could be pulled to the tree and centralized. The grippers are below the saw plane but the vertical distance they required was not critical. Tests had indicated that sand, stones and butt flare prevented cutting closer than 15 cm (6 in.) from the ground in any event. Force analysis also showed that the grippers must resist a downward force during pushing. Therefore, a box support structure was fabricated beneath the grippers to reduce overhang when closed and to minimize flexing.

HEAD ENCLOSURE

The enclosure or structural frame of the head must provide the following:

a) structural strength and relationship between components,
b) protection of components,
c) means of locating head on tree.

To fulfil these requirements an estimate of the applied loads was made using tables of tree characteristics for the maximum expected tree sizes and a computer printout of dynamic tree-falling forces. From these, the design and layout proceeded. Other factors considered were:

a) size and shape to permit easy placement of head on trees,
b) overall weight,
c) access to components,
d) openings to permit discharge of debris, sawdust, snow, etc.,
e) manufacturing convenience.

After fabrication and assembly were complete, the various motions were tested on short logs brought to the shop for that purpose.

Several hydraulic problems arose but after these were corrected, further shop tests indicated the Mark I head was ready for the field (Figure C).

FIGURE C. Mark I Head Mounted on First Carrier.

FIELD TESTS

Summer Testing--1978

The Mark I field tests took place in mid-May 1978 at McGregor and were, in general, promising although a number of problems of varying severity arose.

After these were rectified the unit was then returned to McGregor where it underwent further tests.

Winter Testing--1978/1979

During the freeze-up period of 1978, a new direct-acting back shoe was designed and installed on the head (Figure D). When the unit returned to the woods in January 1979, usage showed that the shoe addition had largely solved chain problems. Also, during this time, the director worked successfully in low temperatures and in up to 2.1 m of snow. Except for snow packing around the saw return limit switch in the head, no major snow problems were encountered. (The switch was moved to a more protected area.) A brief time study of the unit was conducted as part of another project* and the pertinent results appear in Tables 2 and 3. Also included are comparative results for the Albright and Dika directors obtained during other FERIC machine evaluations.

Summer and Winter Program--1979

On returning to the field after break-up in June 1979, the feller director had its first production operator who remained with the machine until the October freeze-up. During this period, it became increasingly clear that the felling head itself was operating reasonably well but a better carrier would be required--preferably one with a rotating upperworks to improve the operator's field of vision.

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*Non-Shear Felling Heads - Winter Conditions, FERIC, 1979.

The FMC-type undercarriage was satisfactory, therefore a composite unit was designed and built using an FMC undercarriage and drive components, and a modified Drott 40 upperworks, boom and stick. Since the experimental head work was largely over, a new head was also built which contained some minor changes such as a wider rear shoe and a sequence valve, rearrangement of valve locations, relocation of the electrical junction box, and enlarged debris openings.

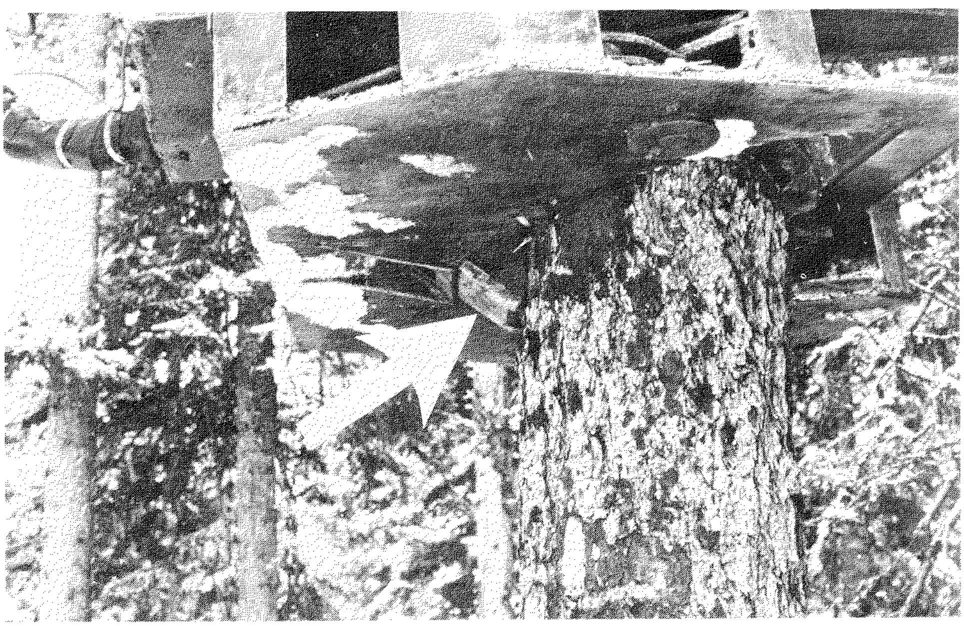

FIGURE D. Sliding Back Shoe.

TABLE 2. Detailed Time Study Results
Cycle Time Summary (minutes per tree) and Operating Factors.

	Albright Director[1]		Dika Director[1]		Northwood/FERIC Director			
	Ft. St. James		Anzac		McGregor			
	Winter		Winter		Winter[2]		Summer[3]	
All times in minutes								
Move time	.43		.46		.21		.46	
Swing empty	N/A		N/A		.09		.16	
Position and cut	.36		.43		.32		.31	
Swing loaded or Direct and return	.19		.14		.19		.13	
Felling cycle (sub-total)	.98	(89%)	1.03	(87%)	.81	(78%)	1.06	(79%)
Brushing	.05		.01		.01		.01	
Delays	.07		.15		.22		.27	
Total Time per Tree	1.10	(100%)	1.19	(100%)	1.04	(100%)	1.34	(100%)
Sample size - no. of trees	128		104		132		119	
Volume per tree, ft^3 (m^3)	49	(1.39)	40	(1.13)	66	(1.87)	52.6	(1.49)
Average dbh, in. (cm)	13.9	(35.3)	12.9	(32.8)	15.8	(40.1)	13.7	(34.9)
*Stems per acre (ha) - merchantable	178	(440)	163	(403)	149	(368)	135	(333)
- unmerchantable	34	(84)	26	(64)	25	(62)	81	(200)
- saplings	36	(89)	26	(64)	78	(193)	48	(119)
*Cunits per acre (m^3 per ha)	87	(609)	65	(455)	98	(686)	67.6	(473)
Slope range, % - along path	not measured		+1 to +5		-7 to +11		+8 to +20	
- across path	not measured		0 to 3		0 to 6		0 to +9	
Average width of path, ft (m)	not measured		20	(6.1)	31	(9.4)	not applicable	
Average stump in. (cm) - height	not measured		33.0	(83.8)	47.1	(119.6)	11	(28.0)
- diameter	not measured		17.0	(43.2)	19.3	(49.0)	18.3	(46.5)
Calculated productivity								
Trees/productive machine hour (PMH)	54.5		50.4		57.7		44.8	
Volume/PMH, cunits (m^3)	26.7	(75.8)	20.2	(57.0)	38.1	(107.9)	23.5	(66.6)

*Determined from study sample plots (average volume/acre would be less).

[1]From McMorland, B.A. 1980. Non-Shearing Felling Heads. FERIC TN-34.
[2]Mark I head on 1st carrier with non-production operator--March 1979.
[3]Mark II head on 2nd carrier with production operator--September 1980.

TABLE 3. Summary of Butt Damage (Length of Damage by Butt Diameter Class)

Butt Diameter in.	Butt Diameter cm	Damage Length Class in.	Damage Length Class cm	Albright Director[1] Ft. St. James Winter no. of trees	%	Dika Director[1] Anzac Winter no. of trees	%	Northwood/FERIC Director McGregor Winter[2] no. of trees	%	Northwood/FERIC Director McGregor Summer[3] no. of trees	%
5 - 7	13 - 19	0 - 6	0 - 15			3	75			3	60
		6 - 24	15 - 61			1	25			2	40
		24+	61+								
8 - 13	20 - 34	0 - 6	0 - 15	8	47	25	81	14	78	4	44
		6 - 24	15 - 61	6	35	2	6	4	22	4	44
		24+	61+	3	18	4	13			1	12
14 - 19	35 - 50	0 - 6	0 - 15	12	75	40	78	19	76	4	44
		6 - 24	15 - 61	4	25	4	8	3	12	3	33
		24+	61+			7	14	3	12	2	23
20 - 25	51 - 65	0 - 6	0 - 15	8	80	14	58	19	79	8	73
		6 - 24	15 - 61	0		5	21	3	13	2	18
		24+	61+	2	20	5	21	2	8	1	9
26 - 30	66 - 77	0 - 6	0 - 15	4	80	2	50	10	100	1	50
		6 - 24	15 - 61	0		1	25			1	50
		24+	61+	1	20	1	25				
31 - 35	78 - 89	0 - 6	0 - 15			1	100	5	83		
		6 - 24	15 - 61					1	17		
		24+	61+								
36 - 40	90 - 102	0 - 6	0 - 15							1	100
		6 - 24	15 - 61								
		24+	61+								
Total all diameters		0 - 6	0 - 15	32	67	85	74	67	81	21	57
		6 - 24	15 - 61	10	21	13	11	11	13	12	32
		24+	61+	6	12	17	15	5	6	4	11
Species - descending importance				Balsam Spruce		Spruce Balsam Pine		Spruce Balsam		Spruce Balsam	

[1]From McMorland, B.A. 1980. Non-Shearing Felling Heads. FERIC TN-34.
[2]Mark I head on 1st carrier with non-production operator--March 1979.
[3]Mark II head on 2nd carrier with production operator--September 1980.

WINTER AND SUMMER TESTS--1980

The Mark II feller-director unit (Figure E) started working in January 1980 near Prince George. It was working in about 1 metre of snow on fairly rough terrain with heavy windfall. It functioned well although a number of problems arose largely concerning the carrier:

a) warmer temperatures created a packing-type snow which accumulated around the drive sprockets and lifted the tracks off them,

b) carrier brakes were borderline because of the increased weight and the steep terrain,

c) propane cab heater was not reliable and allowed snow to freeze on the windshield obscuring vision.

FIGURE E. Second Carrier with Mark II Head.

This test was cut short by moderating weather after which a transportation accident, a track final drive failure, and a log surplus combined to keep the unit sidelined until June 1980. It was then sent back to McGregor where it remained until mid-September 1980. During this time FERIC observed the machine performance and in September conducted a detailed time study (Tables 2 and 3).

DISCUSSION

During the four-year joint development of the feller-director, considerable insight and experience in mechanical felling were gained by both FERIC and Northwood personnel. In addition, many administrative problems associated with joint programs were identified and methods of minimizing them in the future were established. Also, it should be noted that during the life of the project the emphasis shifted from the felling head alone to include the carrier so the project became much larger than originally contemplated.

All the field work was done in the Prince George area where logging activity is seasonal. This, in many instances, determined the timing of field trials. Also, experienced machine operators were not available for experimental work during active periods because production naturally took precedence over development.

Despite such difficulties, this project demonstrates that a joint development program between FERIC and a member company can be beneficial. First the need was recognized and preliminary tests conducted to determine technical parameters. From these, the felling head was designed, tested, modified and re-tested until a satisfactory unit was developed. This same procedure was then applied to the carrier.

Not all the specific design objectives, as previously outlined, were achieved. Some were technically impractical and others, as development progressed, were found to be unnecessary. For instance, a bar section to protect the return of chain proved too expensive to manufacture and it meant non-reversible bars. Also, by controlling kick-back, it was found to be unnecessary. A two-pressure hydraulic system for the push was impractical as tree conditions are too variable. Therefore, full power push was provided at all times with judgement left to the operator.

The requirement for $\pm 90^{\circ}$ horizontal head rotation was limited to $\pm 75^{\circ}$ by component location and this was found to be adequate. The requirement for $\pm 10^{\circ}$ transverse head tilt was eliminated after the first head as it was unnecessary. Conversely, several characteristics not listed were found to be necessary. Head stability during cutting is essential and a back shoe controlled by a sequence valve was added. Providing machine capability to move felled trees was originally considered important. However, specialized felling techniques evolved and reduced the need for this function.

Two detailed time studies were conducted on the director under completely different conditions. The first test, on the Mark I model, was part of a larger survey of felling heads and was a deep-snow, late-winter study. The operator was on loan from the manufacturer, and was not a production operator. Also, the operator's vision was still impaired (see Figure C).

This test showed that the machine was capable of felling all tree sizes in the specified range with little difference in time. It also showed that a tracked carrier with torsion bar suspension was effective in deep snow, although scrapers to remove snow from the drive sprockets were necessary.

The head itself was able to operate in the snow and did not pack unduly. In this test, stump heights exceeded the one-foot standard, but no special effort was made to dig the head into the seven feet of snow present. A "backhoe" action with the head could have reduced the stump height but would have taken more time. For these reasons the stump height was considered dependent on conditions and operator technique rather than the equipment. Average productivity of the unit was not established as it did not operate under production conditions long enough. However, during the shorter periods of detailed timing, the machine cut 56 trees (averaging 1.9 m^3 per tree) per hour. This, at least, indicated potential.

Testing for butt damage showed that as the tree size increased, butt damage decreased. This result is attributable to overpushing the smaller trees to ensure they clear the chain and, because of head size, to cutting clumps of smaller trees. Work is being done on automatic controls to assist the operator in determining the depth of cut and time of push. This should further reduce butt damage, particularly on smaller trees when the operator has less decision time and the amount of push available can severely overstress the tree.

The second time study was conducted on the Mark II head installed on the second carrier which had a modified Drott 40 rotating upperworks (Figure E). This improved the vision of the operator as he could look directly forward at the head. Fuel and hydraulic oil were carried in saddle tanks mounted directly over the tracks. This made the unit bulky and as heavy as a loaded FMC skidder.

The cab tilt feature, which is a characteristic of the Drott 40, had been installed fore and aft as the director normally works up and down slopes rather than across them. This required major structural additions to the carrier hull but subsequent tests showed that this capability was not used much.

The study was conducted in the summer and used a production machine operator. Shift level results are not reported as the unit did not operate long enough under production conditions for a true evaluation.

As a sequel to the previous development work FERIC, from October 1980 to January 1981, worked with the Prince George manufacturer in designing the third carrier. This unit (Figure F) used the Mark II head on the FMC undercarriage from the first carrier; a Drott 40 swing bearing and swing drive but not the tilt; and the original Cranab FK9060 mast, book and stick but not the swing. This combination enabled the feller-director to be 4 540 kg lighter and better balanced than its predecessor.

Specifications for this machine are given in Appendix I.

FIGURE F. Third Carrier with Mark II Head.

CONCLUSION

The prime objective of this project was to develop a feller-director able to extend the range of felling equipment in both tree size and terrain capability. This has now been done.

The present carrier provides good terrain capability to 35% slope, low ground pressure (0.49 kg/cm^2 or 6.9 psi), ability to manoeuvre in snow, and good visibility.

The feller-director unit offers a viable means of felling trees up to 91 cm (36 inch) diameter in safety and with directional control.

APPENDIX I

Specifications for Third Carrier and Head

CARRIER SPECIFICATIONS: (FMC undercarriage)

Overall length (over tracks)	: 495 cm (195 in.)
Overall width (over tracks)	: 262 cm (103 in.)
Overall height	
a) boom and stick down	: 343 cm (11 ft 3 in.)
b) head close to carrier for travelling	: 528 cm (17 ft 4 in.)
Overall weight (fueled)	: 15 663 kg (34,500 lb)
Ground pressure	: 0.488 kg/cm^2 (6.94 psi)
Reach in front of tracks	: 411 cm (13 ft 6 in.)
Side reach beyond tracks	: 503 cm (16 ft 6 in.)
Swing	: ±90°
Drive train components per FMC	

HEAD SPECIFICATIONS:

Weight (including mount)	: 1 339 kg (2,950 lb)
Maximum tree diameter	: 91 cm (36 in.)
Push force (horizontal)	: 4 540 kg (10,000 lb)
Head rotation (re. boom)	: ±75°
Head tilt (from horizontal)	: +15° to -90°

Hydraulic supply required:

a) approx. 114 ℓ/min @ 136 bar (30 USGPM @ 2000 psi)
(grip and push)

b) approx. 114 ℓ/min @ 136 bar (30 USGPM @ 2000 psi)
(saw boost)

c) 38 ℓ/min @ 68 bar (10 USGPM @ 1000 psi)
(pilot pressure, feed, head rotation)

Electrical supply required : 12v or 24v DC