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

Technical Note No. TN-82
January 1985

Production and Performance of Ground Skidding Equipment in Interior B.C.:

FMC FT-180/John Deere 550 System

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PREFACE

The author wishes to thank the personnel of Crestbrook Forest Industries, Canal Flats Division; Kootenay Tractor & Supply Ltd. of Nelson (FMC distributor); and the logging contractor, family and crew of Howard Exploration Ltd. for their assistance during this project. The author is also indebted to FERIC staff member Kristi Francoeur who checked and arranged the manuscript for final publication.

Information in this report is given in metric units. Imperial units may occasionally be shown in parenthesis. Appendix III contains a list of common conversion factors.

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SUMMARY

The FMC FT-180 Fast Track Log Skidder, a smaller version of FMC's 200 series tracked skidders, has been introduced to the B.C. Interior. Crestbrook Forest Industries Ltd. received the first Canadian prototype in 1980. A pre-production model began extensive field tests at their Canal Flats Division in the Columbia Valley in mid-1983. The FT-180 worked in conjunction with a John Deere 550 crawler tractor. Both machines were operated by a contractor. Crestbrook's main objective was to determine if an FT-180/small-tractor system could form another alternative (to cable logging) for harvesting on slopes of 30 to 50 percent.

FERIC monitored the daily performance of this system between July 1983 and March 1984. A 3½ month period in the middle of the study was deleted from the sample because the FMC was withdrawn from service to await redesign of the final drives.

Two distinct operating areas were recorded during the balance of the trial. The first was a summer-logged clearcut having sidehill slopes between 35 and 60 percent. The machines worked from prepared trails, skidding trees with an average volume of 0.4 m^3. The second area was a winter-logged right-of-way road access, with a maximum running-surface slope of 9 percent. The trees were large, averaging 1.7 m^3 each.

The contractor restricted the FMC to skidding activity as much as possible. The tractor did skidding as well, but it also did all the trail building and most of the landing activities (decking, cleaning). The tractor usually worked the shorter skids and the FMC the longer ones. In the clearcut, and particularly during the cleanup phase, the tractor often bunched trees in advance of the FT-180.

In both areas, volume per productive skidding hour was at least 50 percent greater for the FMC than for the small crawler. On a per-eight-hour-shift basis, the total system production averaged 72 m^3 in the clearcut and 151 m^3 on the R/W. Table S-1 contains other key results from the study.

TABLE S-1. Basic Study Results.

	CLEARCUT		RIGHT-OF-WAY	
	FMC FT-180	JD 550	FMC FT-180	JD 550
Study period	July 7 to Sept. 6/83		Jan. 4 to Mar. 8/84	
Total calendar days available	62	62	45	45
Distribution of days				
- shifts worked	42	45	28	35
- repair or service shifts	1	1	3	0
- weekends	15	12	10	9
- legal holidays	2	2	0	0
- other lost shifts	2	2	4	1
<u>Time and Production During Shifts Worked</u>				
Hours in productive work, %	89.1	83.4	79.1	79.4
Availability, %	92.5	92.4	83.4	87.7
Volume per productive skidding hour, m^3	8.0	5.2	17.1	11.4
Trees per productive skidding hour	20.5	13.3	10.1	6.7
Turns per productive skidding hour	2.4	2.2	2.7	2.8
Volume per 8-hour shift, m^3	55.6	16.3	108.0	43.2
Trees per 8-hour shift	143	42	64	26
Turns per 8-hour shift	16.8	6.9	16.9	10.7
Average tree volume, m^3	0.39		1.70	
<u>Total System Production</u>				
Volume per 8-hour shift, m^3	71.9		151.2	
Tree count per 8-hour shift	185		90	
Turns per 8-hour shift	23.7		27.6	

SOMMAIRE

La débusqueuse à chenilles rapides FMC FT-180, un modèle réduit des débusqueuses à chenilles de la série FMC 200, fut introduite dans la région intérieure de la Colombie-Britanique. Crestbrook Forest Industries Ltd. reçut le premier prototype canadien en 1980. Des essais de longue durée sur le terrain débutèrent au milieu de l'année 1983 avec un modèle avant-production à la division Canal Flats dans la vallée de la Columbia. Le FT-180 oeuvra de paire avec un tracteur à chenilles John Deere 550. Un entrepreneur se chargea de l'opération des deux machines. Le principal objectif de Crestbrook était de determiner si un système FT-180/petit-tracteur pourrait constituer une autre alternative au débardage téléphérique pour l'exploitation de forêts en pentes de 30 à 50 pourcent.

La performance journalière de ce système fut enregistrée par FERIC de juillet 1983 à mars 1984. Les essais furent interrompus pour une période de 3½ mois au milieu de l'étude car le FMC était hors d'usage en attendant la conception finale de conduites.

Deux aires de coupe distinctes furent étudiées pour le reste des essais. La première était une coupe-à-blanc d'été sur versant de montagne à pentes variants de 35 à 60 pourcent. Les machines oeuvraient sur des sentiers préparés en débusquant des arbres ayant un volume moyen de 0.4 m^3. La deuxième aire de coupe était une exploitation d'hiver pour voie d'accès avec un maximum de 9 pourcent de pente pour la surface de roulement. Les arbres étaient de fortes dimensions avec un volume moyen de 1.7 m^3 par arbre.

L'entrepreneur limita autant que possible l'utilisation du FMC au débusquage, quoiqu'il a effectué la totalité des travaux de construction de sentiers et la plupart des travaux à la jetée comme l'empilement des billes et le nettoyage. Habituellement, le tracteur accomplissait le débusquage de courte distance et le FMC celui de longue distance. A maintes occasions, le tracteur groupait des arbres en paquets à l'avance pour le FT-180 lors de la coupe-à-blanc, en particulier lors de la phase de nettoyage.

Le volume par heure productive de débardage pour le FMC fut au moins 50 pourcent supérieur à celui de petit tracteur et ce, dans les deux aires de coupe. La production totale du système par quart de huit heures fut en moyenne de 73 m^3 pour la coupe-à-blanc et de 151 m^3 pour la voie d'accès. La Table S-1 contient d'autres résultats importants de l'étude.

TABLE S-1. Résultats de base de l'etude.

	COUPE-À-BLANC		VOIE D'ACCÈS	
	FMC FT-180	JD 550	FMC FT-180	JD 550
Période d'etude	7 juillet au 6 sept/83		4 jan. au 8 mars/84	
Total de jours disponibles	62	62	45	45
Répartition des journées				
- quarts travaillés	42	45	28	35
- quarts de réparation ou d'entretien	1	1	3	0
- fin de semaine	15	12	10	9
- congés fériés	2	2	0	0
- autres quarts perdus	2	2	4	1
Temps et production lors des quarts travaillés				
Heures de travail productif, %	89.1	83.4	79.1	79.4
Disponibilité, %	92.5	92.4	83.4	87.7
Volume par heure productive de débusquage, m^3	8.0	5.2	17.1	11.4
Arbres par heure productive de débusquage	20.5	13.3	10.1	6.7
Tours par heure productive de débusquage	2.4	2.2	2.7	2.8
Volume par quart de 8 heures, m^3	55.6	16.3	108.0	43.2
Arbres par quart de 8 heures	143	42	64	26
Tours par quart de 8 heures	16.8	6.9	16.9	10.7
Volume moyen par arbre, m^3	0.39		1.70	
Production total du system				
Volume par quart de 8 heures	71.9		151.2	
Arbres par quart de 8 heures	185		90	
Tours par quart de 8 heures	23.7		27.6	

INTRODUCTION

Ground skidding in Interior British Columbia has normally been conducted with rubber-tired articulated skidders and bulldozer-type tractors of the D-6 and D-7 size. In the mid-1970's, the Ministry of Forests imposed stricter controls on ground skidding operations in the Nelson Forest Region, with a view to reducing environmental impact. Other regions are also interested in reducing environmental-impact levels.

The forest industry has responded by examining alternate logging methods. In 1975, the FMC high-speed tracked skidding vehicle was introduced to B.C. (Powell 1978). The FMC 200 series offered low ground pressure and the ability to work on slopes of up to 45% without skid trails. This made the machine attractive for sensitive or steeper sites. In 1976, Crestbrook Forest Industries of Cranbrook, B.C. began experimenting with small crawler tractors, of the D-3 and D-4 size range, for logging on slopes of up to 80% (McMorland 1980). Skid trails were built by the same size machine that did the skidding. Surface widths of those trails were approximately 2 metres, compared to about 3.2 metres for those built by larger machines. Combined with wider trail spacing, the small tractor system resulted in a reduction in soil disturbance of about 1/3, compared to cutblocks developed by large crawlers.

The success of FMC skidders prompted a 1978 meeting between American and Canadian equipment distributors and forest products companies, and FMC engineers. The objective was to discuss the introduction of a smaller version of the FMC skidder. Crestbrook personnel were important participants at this meeting. They were interested in a small FMC that would complement their small-tractor operations. Design criteria were established at that meeting (Kootenay Tractor news release, undated; and Johnson 1981). In addition to retaining the gradeability and flotation characteristics of the large machines, the criteria included:

- parts standardization with the 200 series;
- simplified design, for serviceability and access for repair;
- a fixed skidding arch;
- as narrow, but stable, a design as possible;
- a redesigned, sturdier blade than the 200 series;
- cab and controls designed for safety and ease of use; and
- lowest possible cost.

FMC Corporation proceeded with design work on the FMC FT-180 Fast Track Log Skidder. Crestbrook received the first Canadian prototype in 1980. Modifications were necessary, but a pre-production model was returned for further field testing in late 1982. The results of this test were inconclusive -- the contractor experienced machine and operational difficulties and became discouraged with the project. In late spring of 1983, a second contractor accepted the FT-180 on a trial basis. The machine was to be operated in conjunction with a John Deere 550 crawler tractor. Crestbrook's primary objective was to determine if an FT-180/small tractor combination could form another alternate system (to cable logging) for harvesting on slopes of 30 to 55 percent. Secondly, they were interested in determining a measure of mechanical reliability for the FT-180.

FERIC was invited to monitor the introduction and performance of this two-machine system. Each machine was equipped with a Model DSR Servis Recorder (event recorder). The operators provided a daily recorder chart and report form to FERIC, which included turn and piece counts as well as details of non-productive time. Periodic summaries were issued to the contractor, the company and the distributor.

The study was started in July 1983 and continued through to March 1984. However, the FT-180 did not operate for about 3½ months during this time, as the machine was taken out of service while new final drives were designed and fabricated. In addition, the contractor was placed on a specialty cleanup job (removal of beetle-infested trees) for a further two weeks. These two periods were deleted from the study.

Machine and Operation Description

Figure A shows the FMC FT-180 and John Deere 550 used by the contractor. Table 1 shows a brief summary of machine specifications. More complete manufacturers' specification sheets are located in Appendix I. The price for the FMC includes import duty. Individual applications for rebate of this duty can be made through the distributor.

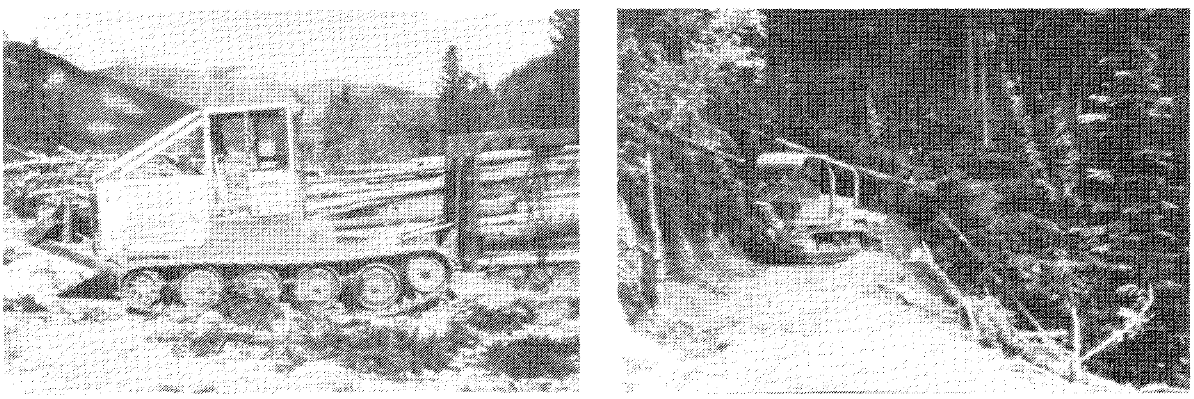

FIGURE A. FMC FT-180 and John Deere 550.

FMC Woodlands equipment is distributed in British Columbia solely by Kootenay Tractor and Supply Limited, 323 Vernon Street, Nelson, B.C. V1L 4E3. Telephone: (604) 352-5301. Branches are located in Campbell River, Prince George and Kamloops. John Deere equipment is available from John Deere's distributor network in the province.

TABLE 1. Basic Specifications for the FMC FT-180 and JD 550.

	FMC FT-180 16 in (41 cm) track	JD 550 16 in (41 cm) track
Vehicle weight, equipped for skidding	8 936 kg	7 175 kg
Payload	8 165 kg	not specified
Engine : make	Det. Die. GM3-53T	JD Turbo
: no. of cylinders	3	4
: net power @ governed rpm	88 kW @ 2600	58 kW @ 2200
Transmission : no. of gears	3 for., 3 rev.	3 for., 3 rev.
: speed in high gear @ approx. 18 kN (4000 lb) pull	10.8 km/h	5.2 km/h
: maximum speed forward	24.8 km/h	9.2 km/h
Winch : drum diameter	23 cm	user option
: cable capacity, 16 mm cable	81 m	
: line pull - bare drum	102 kN	
- full drum	63 kN	
Maximum vehicle width	2.13 m	2.20 m
Length : track on ground	2.29 m	1.85 m
: overall, excluding blade and arch	5.28 m	3.00 m
Ground clearance	41 cm	36 cm
Ground pressure, kPa (psi)	47.6 (6.9)	46.9 (6.8)
Price November 1984 : woods-equipped except for lines. Tax extra.	$161 000 fob Nelson	$92 000 fob Cranbrook

The FMC used by the contractor was a Cable Arch (CA) model. According to the distributor, the planned fixed-arch option did not place enough of the load weight on the carrier. However, several models of Arch Grapples (AG) and Swing Grapples (SG) are available for the FMC line of equipment, including the FT-180.

The distributor has also noted that the parts standardization of the original design criteria was primarily confined to the undercarriage and suspension, of which about 75% is interchangeable with the larger machines. The blade criteria were established at a time when difficulties had been encountered with the 200 series blade. Since then, blades for both sizes of machine have been strengthened. The current warranty provided by the FMC Corporation is 6 months on the machine, and 2000 hours/2 years on the skidder track (subject to periodic inspections and written reports by the distributor).

The operational trials were conducted at Crestbrook's Canal Flats Division in the western foothills of the Rocky Mountains. The contractor normally operated with two machines, one faller and one landing bucker. Full trees were skidded to roadside landings. After manual processing, the log lengths were decked. Self-loading highway trucks transported the logs to the Canal Flats sawmill. One-way haul distances ranged between 50 and 70 km.

With few exceptions, the FT-180 was committed to skidding activity only. It normally made the longer skids, while the tractor was used on the shorter skids. In addition to skidding, the tractor also built the skid trails and performed nearly all the landing duties (decking, cleaning, etc.).

MACHINE PERFORMANCE DATA

Area Description

Two operating areas were recorded for the FT-180/small tractor system. Area 1 (shown in Figures B and C) was a 19 ha (approx.) cutblock harvested during summer conditions at the beginning of the study. Sidehill slopes ran to 60 percent. Species composition was about equally composed of pine and spruce, with small amounts of balsam and Douglas fir. The cruise compilation showed, per hectare, 265 m^3 and 620 merchantable stems, for an average tree volume of approximately 0.4 m^3. Skid distances for the FMC normally averaged 250 m to 350 m (horizontal distance), with occasional trails having skid distances up to 500 metres.

FIGURE B. Skid-Trail Pattern for Area 1.

This photo was taken from the top of the main downhill trail servicing the near side of the draw. Trail slope averaged 42% to the edge of the landing, a distance of about 300 m (slope distance). The steepest trail section was 54% over a distance of about 50 m. Both sidehills above the draw were logged first, followed by the bottom. The contractor built the trails with the JD 550.

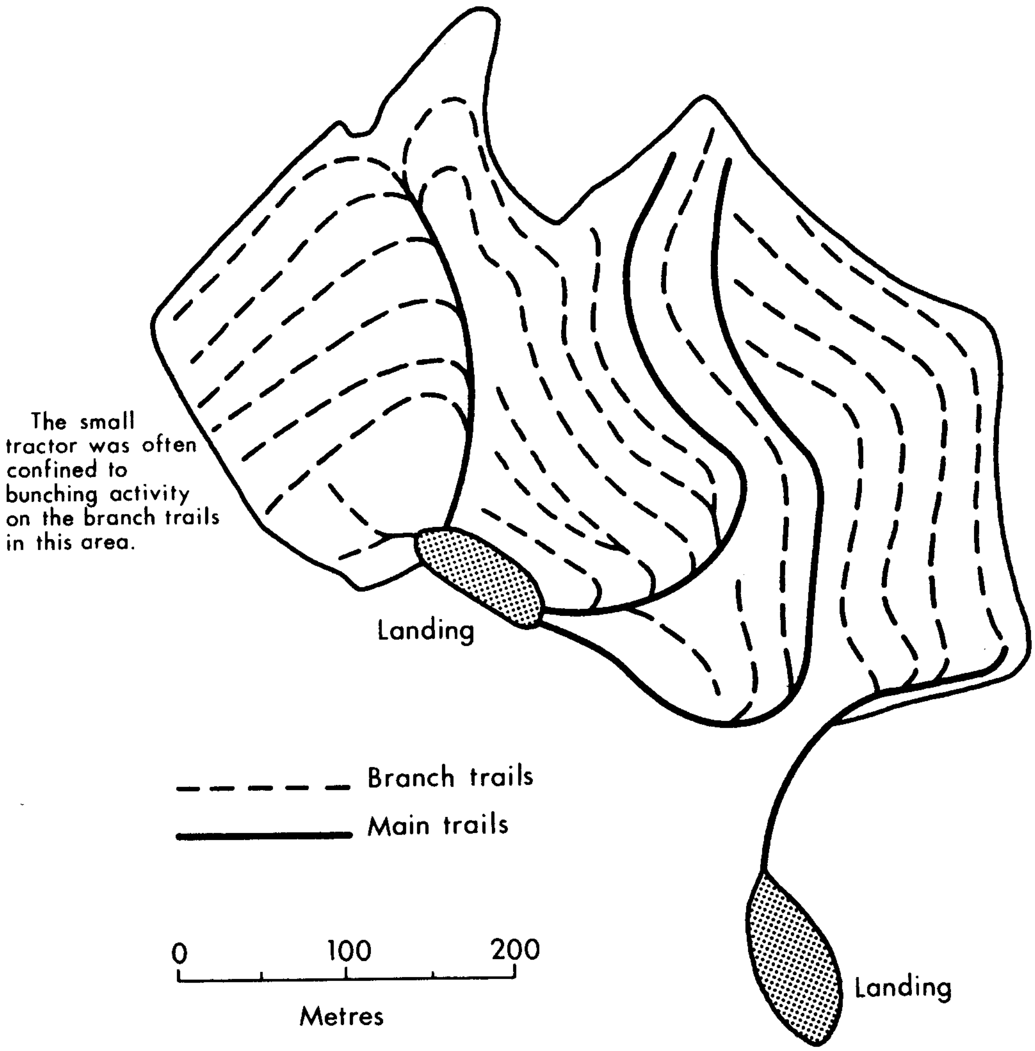

FIGURE C. Sketch Map of Area 1.

Area 2 was harvested by the machines when the FT-180 returned from having the new final drives installed. The contractor spent from late January to early March in this area, which involved clearing right-of-way (R/W) timber for road access. Tree species was primarily large spruce, with minor amounts of other species. Average tree volume, based on skidded production, was 1.7 m^3. The nine landings along the R/W were located 450 to 800 m apart. As much as possible, the machines skidded to a landing from both directions, but skid distance still ranged to 600 m for the FT-180 and to 300 m for the tractor.

Results

The data presentations in this section utilize a new format that has been used for recent interim reports and monthly machine summaries. Please refer to Appendix II for further explanation of the format and terminology.

Tables 2 through 6 summarize the information collected during the monitoring period.

Table 2 contains the calendar time summary, showing the distribution of shift types. Production occurred on between 62% and 78% of all calendar days. On a five-working-day-per-week operation, the weekends account for 28.6% of the potential weekly shifts. The "weekend" distributions for the machines indicate that some activity (in these cases, both productive and repair shifts) occurred on weekends. In addition, the contractor worked on some of the statutory holidays during the study period.

TABLE 2. Calendar Time Distribution.

Identification	Area 1 - Clearcut				Area 2 - Right-of-Way			
	FMC 180		JD 550		FMC 180		JD 550	
Usual shift length, hours	8.0		8.0		8.0		8.0	
Report period	July 7 to Sept. 6/83				Jan. 4 to March 8/84			
Calendar days in period	62				45			
Number of shifts per calendar day	1				1			
	# of shifts	%	# of shifts	%	# of shifts	%	# of shifts	%
Possible shifts in period	62	100	62	100	45	100	45	100
Shifts worked (with production)	42	68	45	73	28	62	35	78
Repair or service shifts	1	2	1	2	3	7	0	0
Subtotal	43	70	46	75	31	69	35	78
Weekends (# of shifts of no activity)	15	24	12	19	10	22	9	20
Legal holidays (# shifts)	2	3	2	3	0	0	0	0
Shifts lost for other reasons *	2	3	2	3	4	9	1	2
Subtotal	19	30	16	25	14	31	10	22
*Reason for lost shifts								
Wait parts	-		-		3		-	
Operator absent -- illness	2		2		1		1	

Table 3 shows time and production summaries for shifts worked. The data are tabulated by area and then by machine. Total volumes were obtained for each of the areas from the truck weight scale records. This volume was apportioned to each machine based on the piece counts supplied by the operators. The average tree volumes were calculated from the total volumes and the piece count. Separate decking and hauling of each machine's production was not possible because of small landings. Trees were normally skidded from the top, but some trees in Area 2 were butt skidded.

TABLE 3. Time and Production Summary for Shifts Worked.

Identification	Area 1 Summer Clearcut; Sidehill Slope to 60%				Area 2 Winter Right-of-Way; Maximum 9% Slope			
	FMC 180		JD 550		FMC 180		JD 550	
No. of SHIFTS WORKED (with production)	42		45		28		35	
Usual shift length, hours	8.0		8.0		8.0		8.0	
TIME (hours)	total	av. / shift	total	av. / shift	total	av. / shift	total	av. / shift
Productive Machine Hours (PMH)								
Skidding	289.2	6.9	140.4	3.1	176.4	6.3	127.6	3.7
Trailbuilding	0	0	30.8	0.7	0	0	18.8	0.5
Landing duties	1.0	<0.1	85.0	1.9	1.7	0.1	59.4	1.7
Other work	5.9	0.1	41.5	0.9	0	0	9.0	0.3
Non-Productive Time								
Mechanical - repair	4.9	0.1	10.0	0.2	13.0	0.5	18.2	0.5
- service	20.1	0.5	16.5	0.4	19.1	0.7	15.1	0.4
Wait time - parts	0	0	0.7	<0.1	0	0	0	0
- mechanics	0	0	0	0	5.4	0.2	0	0
Non-mechanical - landing changes	1.8	<0.1	3.7	0.1	1.4	0.1	2.3	0.1
(# of changes)	5		7		2		4	
- other non-mechanical	9.3	0.2	28.5	0.6	8.3	0.3	20.0	0.6
Total	332.2	7.9	357.1	7.9	225.3	8.0	270.4	7.7
PRODUCTIVE TIME RATIO (Productive hours / Total hours)	89.1 %		83.4 %		79.1 %		79.4 %	
AVAILABILITY (for SHIFTS WORKED only)	92.5 %		92.4 %		83.4 %		87.7 %	
PRODUCTION								
Volume produced, m³	2306.6		724.0		3024.3		1457.0	
" " (cunits)	(814.6)		(255.7)		(1068.0)		(514.5)	
Tree count	5936		1863		1781		858	
Turns skidded	699		308		473		360	
Maximum skid distance, m (approx.)	500		300		600		300	
Average tree size, m³	0.39		0.39		1.70		1.70	
m³ per Productive Skidding Hour	8.0		5.2		17.1		11.4	
Trees per " " "	20.5		13.3		10.1		6.7	
Turns per " " "	2.4		2.2		2.7		2.8	
Volume per turn, m³	3.3		2.4		6.4		4.1	
Trees per turn	8.5		6.0		3.8		2.4	
Minutes per turn	24.8		27.4		22.4		21.3	
Volume per shift worked, m³	54.9		16.1		108.0		41.6	
Trees per shift worked	141		41		64		25	
Turns per shift worked	16.6		6.8		16.9		10.3	
Production per 8-hour shift								
m³	55.6		16.3		108.0		43.2	
Tree count	143		42		64		26	
Turns	16.8		6.9		16.9		10.7	
Total System Production								
Volume per shift worked, m³	71.0				149.6			
Trees per shift worked	182				89			
Turns per shift worked	23.4				27.2			
Per 8-hour shift								
m³	71.9				151.2			
Tree count	185				90			
Turns	23.7				27.6			

Note: AVAILABILITY for SHIFTS WORKED

$$= \frac{\text{Total hours - sum of (repair + service + wait parts + wait mechanics)}}{\text{Total hours}} \times 100\ \%$$

Time distribution - The FMC spent an average of 83% of total time in skidding, with most of the remainder in downtime and landing changes. The category "other work" involved the cleanup of an overturned truckload of logs. The tractor's time distribution was different: an average of 43% of total time was spent skidding, but other productive categories accounted for a further 39 percent. The largest of those was "landing duties", composed of log-piling (decking) and cleaning of debris. "Other work" for the tractor was nearly all associated with bunching activity. The tractor would prepare bunches at trail side for the higher speed FMC, particularly on the longer skids. This procedure was used frequently during the cleanup stage at each area.

During the winter conditions (Area 2), productive time was less and delay times were greater per shift than in the summer (Area 1). This was true for both machines and resulted in lower availability in the winter.

Production - Volume production per turn, per skidding hour and per shift were approximately doubled in Area 2, as compared to Area 1, for both machines. The piece count dropped by approximately half for each of those categories, but the average piece volume was more than 4 times as large.

Turn times were faster in Area 2 by about 10% for the FMC and about 20% for the tractor, although the average skid distances were slightly longer. No detailed studies were conducted, but at least two factors help explain the faster turns. In Area 2, Hookup and Unhook times were probably lower than those from Area 1 because fewer pieces/turn were brought in. Secondly, Area 2 was a right-of-way where the maximum slope on the running surface was no greater than 9 percent. This compares to main trail slopes of up to 40% on Area 1.

Comparing the two machines in the same area shows that the FMC produced about 1.4 and 1.6 times more volume (per turn and per skidding hour) than the tractor. On a per-shift basis the FMC produced 2.6 to 3.4 times more, reflecting that the FMC had about twice as many skidding hours per day as the JD 550 (the tractor had other job duties aside from skidding).

On an 8-hour-shift basis, daily production for the FT-180/ small-tractor system averaged:

Clearcut	72 m^3	(185 trees)
R/W	151 m^3	(90 trees)

Tables 4 to 6 summarize non-productive time. For each machine, the data from both areas have been totalled together.

Table 4 summarizes non-productive time from operational or personnel reasons. On a per-shift-worked basis, the tractor averaged 1.3 delay occurrences and 41 minutes per shift in these categories. The FMC averaged 0.6 occurrences and 22 minutes per shift, or about half that of the tractor. Most of the difference is accounted for by the category "operator bucking logs". All 55 occurrences for the tractor operator were in Area 1. A landing bucker was on the operation, but was being trained and required assistance and instruction during this period.

TABLE 4. Summary of Non-Productive Time.
(Non-Mechanical Causes, including Wait Time)

Category	FMC 180			JD 550		
	No. of occurrences	Total time		No. of occurrences	Total time	
		hours	%		hours	%
Operational						
Landing changes	7	3.2	12	11	6.0	11
Wait mechanic (mostly moves to/from area)	3	5.4	21	-	-	-
Wait parts	-	-	-	1	0.7	1
Operator bucking logs	1	0.3	1	55	21.1	38
Operator assisting other equipment or operation	4	3.8	15	8	11.1	20
Machine assisting other equipment	4	3.0	11	-	-	-
Unexplained blanks on Servis Recorder chart	2	0.4	2	8	2.3	4
Carrier stuck	3	1.3	5	3	3.0	5
Shutdown or early quit : rain	2	2.4	9	2	2.8	5
Idle : equipment blocking trail/road/landing; blasting activity; wait for trees to be felled; wait instructions.	9	3.3	13	6	1.9	3
Fill mud hole on travel path	-	-	-	4	3.2	6
Planning : receive instructions; determine trail placement	-	-	-	2	1.0	2
Tree or log stuck in cab	1	0.4	2	-	-	-
Subtotal	36	23.5	90	100	53.1	96
Personnel						
Coffee breaks	3	0.7	3	4	1.3	2
Visitors	3	1.4	5	-	-	-
Unexplained blanks on Servis Recorder chart	-	-	-	1	0.8	1
Personal delay	1	0.6	2	-	-	-
Subtotal	7	2.7	10	5	2.1	4
GRAND TOTAL	43	26.2	100	105	55.2	100

Mechanical downtime is listed in Tables 5, 6a and 6b. Table 5 is an overview showing that between 12 and 16 hours of repair and service were required to keep each machine productive for 100 hours. Repair and service time both within and outside normal operating shifts was included. To place these numbers in perspective, an eight-hour shift that had one-half hour of mechanical downtime would give a ratio of 6.7 hours/100 PMH. If that shift also had a half-hour of non-mechanical downtime (which further lowers the productive hours for the shift) the ratio would be 7.1 hours/100 PMH. The results show that the FMC 180 required about 25% more mechanical attention than the John Deere 550.

TABLE 5. Summary of Active Maintenance.

Identification	FMC 180	JD 550
Active repair and service hours on:	hours	hours
A) shifts with production		
- in-shift	57.1	59.8
- after-shift	0	0
B) shifts without production	15.4	4.0
Total Repair and Service Hours	72.5	63.8
Total Productive Machine Hours	474.2	512.5
Mechanical Downtime Ratio ((repair + service hours) / 100 PMH)	15.3	12.4

Tables 6a and 6b detail repair and service activities for the FMC 180 and John Deere tractor, respectively. Service activities (fuelling, greasing, cleaning) were normally carried out during the daily service period at the end of the shift. Occasionally, some of the functions occurred during the course of the shift, and are therefore listed separately.

TABLE 6a. Summary of Non-Productive Time (Mechanical Causes) for the FMC FT-180.

Category		Problem	No. of occurrences	Total time hours	Total time %
CARRIER	Drive train	final drives : repair or replace	1	11.0	
		Tracks : track came off 2 = 1.3 h; : tighten track 2 = 0.8 h	4	2.1	
		repair emergency brake	1	0.9	
		Subtotal	6	14.0	19
	Frame	repair support bracket(s)	1	3.9	5
	Motor	repair transmission oil filter	1	3.8	5
	Cooling system	clean radiator	9	2.8	
		reverse fan blades	1	0.5	
		broken heater hose	1	0.3	
		Subtotal	11	3.6	5
	Cab	repair seat	1	0.2	<1
Total : CARRIER			20	25.5	35
ATTACHMENTS -- Lines		cable wound around sprocket	1	3.1	
		chokers : repair 8 = 1.8 h; : replace/add 3 = 0.5 h	11	2.3	
		mainline : replace 4 = 1.4 h; : repair 2 = 0.6 h	6	2.0	
Total : ATTACHMENTS			18	7.4	10
TOTAL ALL REPAIRS			38	32.9	45
SERVICE		warm up	63	18.0	
		daily service period (undifferentiated items)	62	16.3	
		change oils or filters	3	2.4	
		check fluid levels	5	1.5	
		clean machine	2	0.9	
		add oils (undifferentiated items)	1	0.5	
Total : SERVICE			136	39.6	55
GRAND TOTAL			174	72.5	100

TABLE 6b. Summary of Non-Productive Time (Mechanical Causes) for the JD 550.

Category		Problem	No. of occurrences	Total time hours	Total time %
CARRIER	Hydraulics	replace hoses	10	4.9	
		tighten or replace fittings	3	0.9	
		Subtotal	13	5.8	9
	Frame	unexplained repair to frame	1	5.0	
		repair guarding	1	0.6	
		Subtotal	2	5.6	9
	Motor	repair transmission	1	2.1	
		repair exhaust	2	0.9	
		engine would not start	1	0.5	
		Subtotal	4	3.5	5
	Drive train	repair guarding	1	0.8	1
	Cooling system	clean radiator	1	0.1	<1
Total : CARRIER			21	15.8	25
ATTACHMENTS	Winch & controls	unexplained winch repair	3	3.9	
		repair winch control cable	2	1.8	
		Subtotal	5	5.7	9
	Lines	mainline : repair 6 = 1.5 h; : replace 2 = 0.9 h	8	2.4	
		chokers : repair 4 = 1.3 h; : replace/add 1 = 0.2 h	5	1.5	
		Subtotal	13	3.9	6
	C-frame/blade	welding on C-frame	1	2.0	
		tighten bolts on frame	1	0.6	
		repair blade cable	1	0.2	
		Subtotal	3	2.8	4
	Arch/fairlead	install arch	1	4.0	6
Total : ATTACHMENTS			22	16.4	26
TOTAL ALL REPAIRS			43	32.2	50
SERVICE		warm up	69	18.6	
		daily service period (undifferentiated items)	64	11.7	
		change oils or filters	1	0.4	
		clean machine	1	0.7	
		fuel up	1	0.1	
		grease machine or attachments	1	0.1	
Total : SERVICE			137	31.6	50
GRAND TOTAL			180	63.8	100

From these data, the following observations can be drawn:

FT-180:
- 78% of repair hours on carrier, 22% on attachments
- two largest carrier categories -- Drive Train and Frame

JD 550:
- 49% of repair hours on carrier, 51% on attachments
- two largest carrier categories -- Hydraulics and Frame

In addition to the data listed in Table 6a, the FMC also experienced final drive problems. The machine was removed from service for about 3½ months during the middle of the trial. FMC Corporation redesigned and manufactured new final drives, after which the FT-180 returned to the woods in January 1984 and worked without any major problems until breakup. During breakup the contractor purchased the machine.

The John Deere tractor experienced no major or extraordinary repair or service problems during the study. All downtime that occurred was rectifiable by the user at the job site.

USER COMMENTS

The contractor and his crew were responsible for completing daily report forms for each machine. While most of their comments pertained to daily operational descriptions or the specifics of downtime causes, some comments were related to the design, ease of operation or maintenance, and operational capabilities of the equipment. These are listed below, by machine type.

FMC FT-180

- high-centered on log on steep trail
- hard to turn machine around on trails
- when muddy and wet, winch hard to pull out
- FT can't do cleanup -- takes too much time getting decent drag. Can clean up only if prebunched by tractor.
- hole in transmission oil filter -- rare breed of filter -- can't get locally
- mud seems no problem for FT -- tractor got stuck empty, but FT pulled drags right through

JD 550

- most of morning trying to get out of mudhole -- sure need FT-180 in a hurry -- would be better for the mud
- pretty muddy for tractor -- can skid only certain areas
- stuck in mud, hung up on stump
- blade hydraulic line broke -- tough place
- stuck again -- tractor can't skid across mudholes
- couldn't skid with tractor -- afraid it would wreck trail

In addition, during the study and in a final interview, the contractor had commented on some of the differences he felt existed between machines. His views are condensed in point form below. The FT-180 is compared individually with an FMC 220CA, a small tractor and a rubber-tired skidder. The contractor has experience with all of those machines.

Compared to the 220CA, the FT-180:

- costs about $100 000 less;
- is narrower, for use on sidehill trails;
- has better visibility; and
- has better manoeuverability.

Compared to a small tractor, the FT-180:

- has much higher speed for long distance skidding;
- can carry a larger drag;
- has a smoother ride; and
- is better at going over things (but not around).

Compared to a rubber-tired skidder, the FT-180:

- has better swamp handling ability; and
- gives a smoother ride, especially at higher speeds.

CONCLUSION

An FMC FT-180/small-tractor system has undergone lengthy field testing on the operations of Crestbrook Forest Industries Ltd. The company appears satisfied that this skidding system forms an acceptable production and cost alternative to cable logging on slopes of 30 to 55 percent. They had also been hoping that the availability of the FT-180 would be at the 85%-plus level. The measured availability (post-modification period) was 83.4% for winter conditions. Availability levels are usually lower in winter, so the year-round average should meet or exceed company expectations. Since the final drives were modified, the contractor has indicated he is satisfied with the availability of the machine. However, a precise measure cannot be obtained from the contractor's records.

This system should not necessarily be viewed as a replacement for other ground-skidding systems. During FERIC's previous study of Crestbrook's small-tractor operations, one of the cooperating contractors used a two-machine small-tractor system. Data from that study (Appendix VI and VII of Technical Report TR-37) showed that system produced a total of 13.2 m^3 per skidding hour. In comparison, this study of the FT-180/tractor combination in the clearcut showed the identical amount. While the two operations were similar in some respects (same general area and species, prepared trails leading to landings, both machines working from the same landing), they differed in others: the two-tractor study had ground slopes ranging to 80%; the average skid distance was less than 200 m compared to 250 to 350 m for the FT-180/tractor combination; and the average piece size for the FMC study was 12.5% smaller than that of the two-tractor study. If the distances and tree volumes were more similar, the FT-180/tractor combination would likely be more productive than two tractors. However, it is not known if any resulting higher productivity would offset the 70 to 80% increase in daily ownership costs from having an FT-180 instead of a small tractor.

The FMC FT-180 appears to be best suited to situations where its speed, gradeability or flotation can be utilized to advantage. Such conditions include: long skid distances (200 to 500 m); ground slopes of up to 55%; and swampy or sensitive sites. Although the machine was used on a trail network in this trial, the FMC should be capable of working on 40 to 50% slopes without trails. Top skidding can be performed with this machine (most of the trees during this study were top skidded), but it is probable that top skidding utilizes only 30 to 40% of the FT-180's design payload of 8165 kg (18 000 lb).

It is unlikely that the FMC FT-180 will receive wide acceptance as a solo machine at operations where the average tree volume is less than 0.4 to 0.5 m^3 (approximately 15 to 18 ft^3). A second, less expensive machine will probably be paired with the FT-180. The second machine should perform alternate functions, freeing the FMC to skid as efficiently as possible. Such functions include decking and trail or landing construction/extension/maintenance/cleaning. Scattered timber (as in some blocks and almost always during the cleanup phase) may require bunching by the second machine in advance of the FMC. In larger timber (0.8 m^3 and greater), higher daily production levels are easier to maintain and the FT-180 may receive greater acceptance as a solo machine.

The FT-180 may also have other applicability. It will probably replace some of the FMC 220 series machines currently in use. The FT-180 retains the desirable FMC features but is priced about $100 000 less. Also, the advent of feller bunchers like the Timbco means that tree bunches can now be prepared on steeper slopes than ever before. A skidding machine with the slope-handling ability of the FT-180 is a logical complement to steep-slope mechanized falling.

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FMC

Key Capabilities*

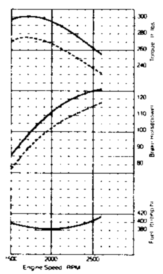
- maximum travel speed: 14.2 mph (22.9 km/hr)
- payload: 18,000 lbs. (8165 kg)
- ground pressure:

	16" (406mm) track	22" (559mm) track
0" soil penetration		
	6.90 psi	5.50 psi
	(47.58 kPa)	*(37.93 kPa)*
6" (152mm) soil penetration—		
	4.87 psi	3.90 psi
	(33.58 kPa)	*(26.89 kPa)*

*based on standard equipped machine

Power Train

- engine: GM3-53T
  118 hp at 2600 rpm
  286 ft.lbs. torque at 1600 rpm
- transmission: Clark 18340 Powershift
  3-speeds forward
  3-speeds reverse
- differential: controlled steering type
- final drive: single reduction
- fuel tank capacity: 50 gal. (189 litre)
- engine performance:



- tractive effort vs. ground speed:

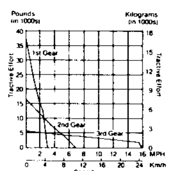


Chart based on 500' altitude and 26,000 lbs. vehicle weight

- maximum tractive effort:

1st Gear	2nd Gear	3rd Gear
40,272 lbs	17,621 lbs	5,886 lbs
(18 267 kg)	(7 993 kg)	(2 670 kg)

- maximum travel speed*:

1st Gear	2nd Gear	3rd Gear
2.9 mph	6.2 mph	15.4 mph
(4.67 km/hr)	(9.98 km/hr)	(24.79 km/hr)

*speed not affected by track width

- maximum gradeability*:

1st Gear	2nd Gear	3rd Gear
246.8%	39.0%	7.2%

*gradeability not affected by track width

Winch System

- winch: Clark W-200
- drum diameter: 9" (.23m)
- drum capacity:
  1/2" (13mm) cable: 396' (120.7m)
  5/8" (16mm) cable: 276' (84.1m)
  3/4" (19mm) cable: 192' (58.6m)
- maximum line pull:*
  bare drum: 22,904 lbs. (10 389 kg)
  full drum: 14,178 lbs. (6 431 kg)
  *developed by machinery, not based on cable strength
- maximum line speed:*
  bare drum: 319 fpm (97 m/min)
  full drum: 515 fpm (157 m/min)
  *developed by machinery, not based on cable strength

Hydraulic System

- pump capacity: 28 gpm (106 lpm)
- hydraulic tank capacity: 19 gal. (72 litre)
- system relief valve setting: 2,200 psi (15 mPa)
- filtration: one 10-micron return filter in tank w/dirt alarm
- hydraulic cylinders:
  blade: one double-acting, 4" (102mm) bore, 21" (533mm) stroke
  arch: one double-acting, 4" (102mm) bore, 27.75" (705mm) stroke

Electrical System

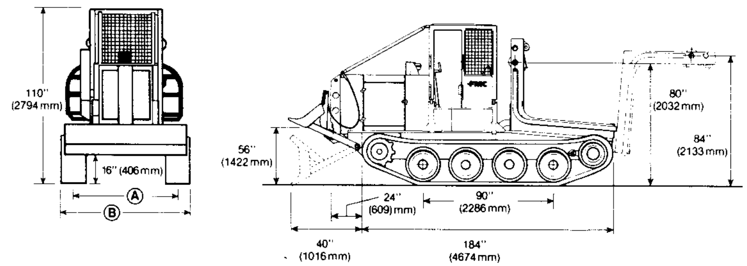
- starter: 12 volt
- battery: 150 amp hrs.
- alternator: 42 amp

Standard Equipment

- hydraulic choker arch (4 roller fairlead)
- 16" (406mm) steel tracks
- Clark 18340 transmission
- Clark W-200 winch
- hydraulic decking blade w/log deflectors
- GM3-53T engine
- engine side doors
- reinforced grill
- full-plate bottom guard
- service, parking & steering brakes
- dry-type air cleaner w/hood-mounted pre-cleaner
- transmission oil cooler
- antifreeze protection to -34 degrees F (-37 degrees C)
- operator's canopy (SAE code ROPS) with side, front & rear screens & front brush deflectors
- adjustable seat w/seat belt
- gauges, including hour-meter, voltmeter, fuel, water temperature, engine oil pressure, transmission oil temperature, parking brake light & differential temperature light
- tools, including track jacks, drift pin & road arm lifter
- tool box

Optional Equipment

- fixed arch attachment (in lieu of choker arch)
- 22" (559mm) steel tracks
- cold weather starting kit, including engine oil heater, block coolant heater, battery warmer, ether starting aid. Plugs into any 110 volt system.
- light kit, including two headlights, two rear floodlights, dash-mounted switch, instrument lamp
- fuel water separator
- back-up alarm
- fire extinguisher, 2-1/2 lb for ABC class fires
- grapple packages: (consult factory for availability)
  Esco 72" (1829mm) & 100" (2540mm)
  Young 75" (1905mm) & 82" (2083mm)



Machine Weight	Lbs.	Kgs
Base machine with standard equipment	20,000	9 072
Fixed arch (in lieu of choker arch)	- 300	- 136
22" (559mm) tracks [in lieu of 16" (406mm) tracks]	+ 2,000	+ 907
Cold weather starting kit	+ 21	+ 9.5
Light Kit	+ 6	+ 2.7
Fuel water separator	+ 8	+ 3.6
Back-up alarm	+ 1	+ .52
Fire extinguisher	+ 5	+ 2.2

Dimensions affected by track size		
Size:	16" track (406mm)	22" track (559mm)
A	68" (1.73m)	74" (1.88m)
B	84" (2.13m)	96" (2.44m)

550A/6405 BULLDOZER

FEATURES

78 SAE net hp (58.2 kW)

Single lever controls all dozer functions

Power Shift transmission with torque converter

Dura-Trax™ undercarriage with:
- Boron steel, deep-heat-treated, strutted, sealed track links
- Deep-heat-treated sealed rollers; boron steel through-hardened grousers
- Sealed front idler and carrier roller

Self-adjusting, oil-cooled steering clutches and brakes

Roll-over protective structure (ROPS)

Vandal protection

ADD VERSATILITY WITH:

Winch

Fairlead and drawbar

Integral log arch

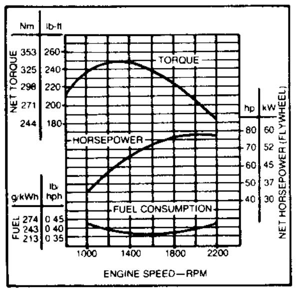
Backhoes

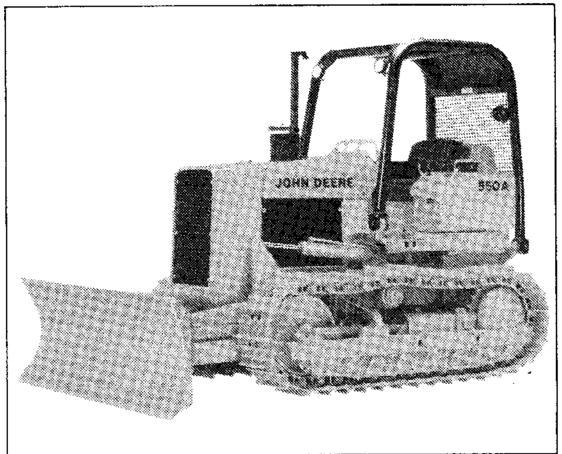
Ripper

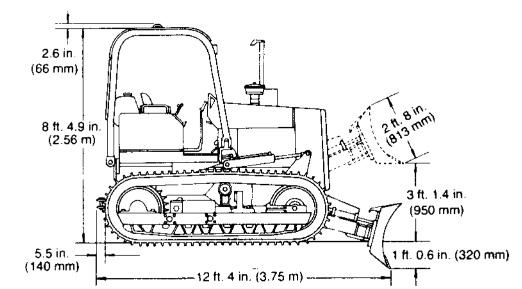
Sideboom

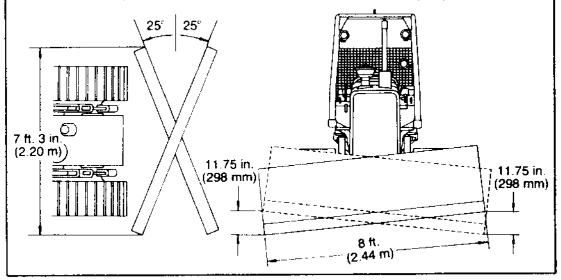
Cable plow

ENGINE PERFORMANCE









550A/6405 BULLDOZER SPECIFICATIONS

(Specifications and design subject to change without notice. Wherever applicable, specifications and design are in accordance with ICED and SAE Standards. Except where otherwise noted, these specifications are based on a unit with roll-over protective structure, full fuel tank, 175-lb. (79 kg) operator and standard equipment.)

Power (@ 2200 engine rpm):

	SAE	DIN
Gross	86 hp (64 kW)	
Net	78 hp (58.2 kW)	58.2 kW

Net engine power is with standard equipment including air cleaner, exhaust system, alternator and cooling fan. Gross power is without cooling fan. Power ratings are at standard conditions per SAE J1349 and DIN 6270. No derating is required up to 10,000 feet (3050 m) altitude.

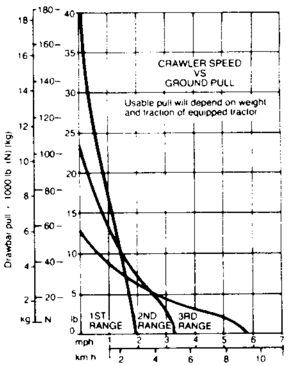
Engine: John Deere, 4-cylinder, turbocharged diesel, 4-stroke cycle

Bore and stroke ... 4.19 × 5.00 in. (106.4 × 127 mm)
Piston displacement ... 276 cu. in. (4.524 L)
Compression ratio ... 16.2 to 1
Maximum torque @ 1300 rpm ... 250 lb-ft (339 Nm) (34.6 kg-m)
Torque rise ... 34 percent
NACC or AMA (U.S. Tax) horsepower ... 28
Lubrication ... Pressure system w/full-flow filter and cooler
Main bearings ... 5
Cooling ... Pressurized w/dual thermostat and controlled bypass
Fan ... Blower
Air cleaner w/restriction indicator ... Dry
Electrical system ... 12-volt
Battery ... Reserve capacity: 180 minutes

Transmission ... Converter-driven, 3-speed forward and reverse, Power Shift

Range: Travel Speeds:

Range	mph Fwd.	mph Rev.	km/h Fwd.	km/h Rev.
1	2.05	2.44	3.30	3.93
2	3.34	3.96	5.37	6.37
3	5.73	6.80	9.22	10.94



Steering:
Steering clutches and brakes are controlled by a single lever for each track (pedal steering optional). A pedal provides braking, and lock-down for parking.
Clutches ... Oil-cooled, hydraulically actuated, multiple-disk, 11-in. (279 mm) disks; 16 friction surfaces per clutch.
Brakes ... Self-adjusting, self-energizing, oil-cooled contracting band with bonded lining.

Hydraulic System: Open-center
Control ... Single "T-bar", triple hydraulic valve
Pump ... Gear, 17 or 23 gpm (1.07 or 1.45 L/s)
Pressure ... 2250 psi (15 514 kPa) (158.2 kg/cm²)

Hydraulic Cylinders:	Bore	Stroke
Lift, two	3.5 in. (89 mm)	15 in. (381 mm)
Angle, two	3.5 in. (89 mm)	13.375 in. (343 mm)
Tilt, one	3.5 in. (89 mm)	3 in. (76 mm)

Cylinder rods ... Ground, heat-treated, chrome-plated, polished
Cylinder pivot pins ... Hardened steel (replaceable bushings)

Undercarriage: 5-roller track frame with full-length rock guards, Dura-Trax™ deep-heat-treated components.
Grouser ... 16 in. (406 mm)
Track shoes, each side ... 36
Ground contact area ... 2328 sq. in. (15 019 cm²)
Ground pressure ... 6.8 psi (46.9 kPa) (0.478 kg/cm²)
Length of track on ground ... 72.75 in. (1.85 m)
Track gauge ... 52 in. (1.32 m)
Carrier roller ... 1
Adjustment ... Hydraulic
Clearance at rear crossbar ... 14.25 in. (362 mm)

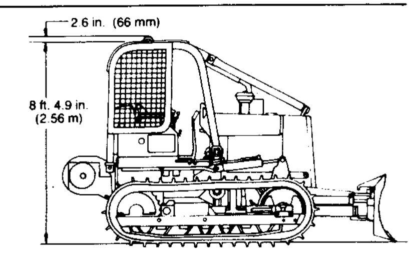
Blade: Reinforced, box-welded
Cutting edge ... 3-piece, reversible, replaceable
Center section ... 0.625 in. (16 mm)
End bits ... 0.75 in. (19 mm)

Capacities:	U.S.	Liters
Cooling system	5 gal	19
Fuel tank	36 gal	136
Crankcase, including filter	15 qt.	14.2
Transmission	13.5 gal.	51
Final drive (each)	6.25 qt.	5.9
Hydraulic reservoir	6.0 gal.	22.7
Hydraulic system	9.5 gal	36
Steering clutch housing (each side)	28 qt.	26.5

Additional Standard Equipment:
- Cold-weather starting aid
- Decelerator
- Deluxe cushion seat w/armrests
- Electric hourmeter
- Enclosed alternator w/solid-state regulator
- Front and rear bottom guard
- Front hitch
- Horn
- Key switch
- Lights
- Master electrical disconnect switch
- Outer sprocket shields
- Perforated engine side shields
- Precleaner
- Pushbutton start switch
- Rubber-mounted ROPS w/seat belt
- Trash-resistant radiator
- Vandal protection

SAE Operating Weight w/ROPS ... 15,820 lb. (7175 kg)

Special Equipment:
- Auxiliary hydraulic system w/ or w/o breakaway couplings
- Battery, 360-min. reserve capacity
- Brush screens
- Cab (includes ROPS) w/seat belt
- Cast steel end bits
- Cigaret lighter
- Front idler shields
- Limb risers w/overhead exhaust
- Pedal steering
- Radiator, abrasion resistant
- Radiator sand shield
- 16-in. (406 mm) open-center grouser shoes
- Swinging drawbar
- 13-in. (330 mm) rubber shoes
- 3-in. (76 mm) seat belt
- Winch drive



Limb risers and brush-protection assembly for roll-over protective structure

APPENDIX II

Explanation of Data-Presentation Format

The experimental data-presentation style in this report is based on a procedure which accounts for every calendar day in the month (in effect, a calendar time summary). Each day is composed of a number of shifts, and it is that number which is accounted for. On a one-shift-per-day operation, and in a month of 31 days, then 31 shifts would be itemized. If the operation runs 2 or 3 shifts, then 62 or 93 "shifts" must be accounted for.

Under this procedure, it makes no difference to the machine or system WHEN something occurred, only that something did happen and was accounted for. If the machine produces wood on a shift, regardless of quantity, then it is classed as a productive shift, or a SHIFT WORKED. If no wood is produced, the shift is classed under one of five main categories:

Repair;
Service;
Weekends;
Legal Holidays; and
Other.

The category "Other" encompasses all reasons other than the previous four categories. Examples: weather closures, break-up, shutdown for market conditions, personal vacations, sickness or injury, strikes, wait parts or mechanics.

Every operation develops a work pattern of so many days of work followed by so many days off. Usually this corresponds to five working days with Saturday and Sunday as the weekend. Other patterns are possible, but whatever the pattern, the equivalent of "weekends" can be identified. If the crew works on a weekend to produce wood (or do mechanical work) then that shift is called a SHIFT WORKED (or a REPAIR or SERVICE shift). The same applies if the extra time occurred on a legal holiday.

The mechanical performance of the machine is measured in several ways: first, from the calendar time shift distribution; second, from the in-shift Availability figure; and third, from a summary which incorporates the two. This latter item accounts for the grand total of all repair and service times, which is then related to Productive Machine Hours (PMH). The resulting ratio shows how many hours of repair and service were necessary in order for the machine to work for 100 PMH. In addition, a complete list of downtime causes, hours and number of occurrences is provided.

APPENDIX III

Conversion Factors

S.I. Unit		x	Factor	=	Equivalent
Volume					
1 cubic metre	(m^3)	x	0.3531	=	cunits
1 cubic metre	(m^3)	x	1.3080	=	cubic yards
1 litre	(L)	x	0.2200	=	Imperial gallons
1 litre	(L)	x	0.2642	=	U.S. gallons
Area					
1 hectare	(ha)	x	2.4711	=	acres
1 square metre	(m^2)	x	10.7639	=	square feet
Length					
1 centimetre	(cm)	x	0.3937	=	inches
1 kilometre	(km)	x	0.6214	=	miles
1 metre	(m)	x	3.2808	=	feet
1 metre	(m)	x	1.0936	=	yards
Proportion					
1 cubic metre/hectare	(m^3/ha)	x	0.1429	=	cunits/acre
1 (unit)/hectare	(../ha)	x	0.4047	=	.../acre
Weight					
1 metric tonne =	1000 kg				
1 kilogram	(kg)	x	2.2046	=	pounds
1 tonne	(t)	x	1.1023	=	tons (the 2000 lb "short ton")
Flow					
1 litre/second	(L/s)	x	13.1985	=	Imperial gallons/min
1 litre/second	(L/s)	x	15.8508	=	U.S. gallons/min
1 litre/minute	(L/min)	x	0.2200	=	Imperial gallons/min
1 litre/minute	(L/min)	x	0.2642	=	U.S. gallons/min
Power					
1 kilowatt	(kW)	x	1.3405	=	horsepower
Force					
1 kiloNewton	(kN)	x	0.2232	=	pounds force
Pressure					
1 kiloPascal	(kPa)	x	0.1450	=	pounds/square inch
1 kilogram/square centimetre	(kg/cm^2)	x	14.2232	=	pounds/square inch