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

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Evaluation of the Cord King FM-50 Firewood Processor

M.P. Folkema

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143 PLACE FRONTENAC, POINTE CLAIRE, QUE., CANADA H9R 4Z7
2112 WEST BROADWAY, VANCOUVER, B.C., CANADA V6K 2C8

PREFACE

The Cord King FM-50 is designed to produce firewood from low quality hardwoods. Although of primary interest to small, independent operators located near urban centres, FERIC Member companies may also be interested in the results of this evaluation, particularly if one or more of the following factors are applicable to their operations:

- low quality hardwoods unsuitable for other products are available (particularly if close to population centres).
- low quality hardwood residuals impede scarification or other forest management activities.
- bush camps, garages or office buildings are heated with wood.
- there are seasonal or periodic employment considerations.
- there are seasonal or periodic requirements for loaders, trucks, etc.

Grateful appreciation is extended to Greg Kells and Bruce Phillips of Cord King of Canada Inc., to the owner/operator (who prefers to remain anonymous) of the unit studied by FERIC, and to FERIC personnel John Courteau, Doug MacGregor, Kim Hadley and Michel St. Amour for their contributions to this project.

A film (Super 8mm - 15 min. duration) of the Cord King FM-50 in operation was made by FERIC. It can be loaned upon request.

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SUMMARY

A Cord King FM-50 firewood processor, modified for manual operation only, was recently studied by FERIC. The machine, which has a list price of C$75,000, required two operators. In addition, a knuckle-boom loader operator placed logs onto the FM-50's live deck.

The machine studied by FERIC was one of the first FM-50 units sold by Cord King of Canada Ltd. It was located in the southern part of the province of Quebec, a few kilometres from an urban centre. The FM-50 was owned and operated by a former logging contractor who had gone into the firewood business on a full-time basis.

The FM-50 processed culled hardwood tree lengths from sawlog and veneer logging operations. The tree lengths were cut into log lengths ranging from 1.5 to 9 m, depending mainly on the degree of crookedness, prior to being loaded onto the FM-50's live deck.

The results of FERIC's studies are shown in the table below:

Table S-1. Summary of Productivity

	Study I (May 1982)	Study II (June 1982)
Study duration, hours (or PMH)	5.38	5.19
Av. log length, m (ft)	4.3 (14.2)	4.3 (14.2)
Av. log diam. small end (i.b.), cm (in)	20.8 (8.2)	17.8 (7.0)
Logs processed per PMH	43	52
Firewood bolts per log	10.7	10.7
- cut only, % of bolts	49%	58%
- cut & split, % of bolts	51%	42%
Net firewood production per PMH, full cords*	3.86	3.65

* A full cord is a stacked measure 1.22 x 1.22 x 2.44 m (4 x 4 x 8 ft). This report assumes that one full cord contains 2.26 m^3 (80 ft^3) of solid wood.

INTRODUCTION

During the past few years, due to the rapidly increasing price of petroleum fuels, many Canadians have installed wood heating systems in their homes and buildings. This has created a large new market for firewood, particularly in urban centres where homeowners often do not have ready access to woodlots where they can harvest and process their own fuelwood.

Fuelwood prices, reflecting the recent surge of interest in wood heating, have also increased. Although some variation exists, most firewood dealers in the metropolitan areas of Ontario and Québec (e.g. Hamilton, Montréal, Ottawa) now (Nov. 1982) charge from $40 to $50 per 40-cm (16-inch) face cord, delivered price. Since it takes about three face cords to comprise one full cord, the wood sells at $120 to $150 per full cord. At this price the wood offers little or no saving as compared to heating with oil*.

Most existing firewood producers have low-budget, labour-intensive operations, and as a result they suffer from low productivity and high per unit costs. They must thus charge a high price for their product. Although there have been several manufacturers of firewood processing machines in the United States, this equipment has shown mixed results [1]. The most frequent complaints are that productivity has been too low relative to the cost of the machines and that downtime levels have been higher than expected. Machine limitations in respect to the diameter, length and crookedness of the logs that can be processed have also proved troublesome.

This report outlines FERIC's evaluation of the Cord King FM-50 firewood processor, a Canadian-built machine having a list price of $75,000 f.o.b. Smith Falls, Ontario. The observed production of the Cord King machine, when compared to that of other firewood processor units, indicates that the Cord King can process (cut & split) firewood at considerably lower costs than other existing methods, permitting the Cord King owner to sell his product at a lower price. The end result of lower prices for firewood will likely encourage more homeowners to convert to wood heating systems.

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* As a rule of thumb, for air-dried hardwood firewood burned in an air-tight stove under "average" conditions, the break-even price for wood in dollars per full cord is equal to the price of oil in cents per Imperial gallon. Since the current price of #2 heating oil is about 145 cents ($1.45) per gallon this means that the break-even price for firewood is now $145 per full cord. NOTE: This rule of thumb applies to "mixed species" of hardwoods. For dense hardwoods (e.g. sugar maple, oak spp., yellow birch), the break-even price can be up to 30% higher than for "mixed species".

The increased use of wood heating for homes and buildings is encouraged by federal and provincial governments. Wood heating usually replaces or augments systems using non-renewable petroleum fuels, some of which must be imported into Canada. Firewood is a renewable fuel. The processing of firewood generates employment and local industry to a much higher level than petroleum fuels [2]. It can provide markets for low grade hardwoods that are currently not utilized. This can contribute to improved forest management. The firewood produced in Canada in 1981 was estimated at 5 million m^3; industrial roundwood was 165 million m^3 [2].

TECHNICAL INFORMATION & MODIFICATIONS

The Cord King FM-50 is the product of nearly $1 million of risk capital and more than five years of research, development and testing. Design of the unit was started in 1976 by G.D. Kells of Ottawa. The first prototype was completed in early 1978; considerable testing followed. Although the unit worked reasonably well, it required additional work to increase speed, reduce the manufacturing cost and improve safety features. Re-design was done by Hyd-Mech Engineering Ltd. of Woodstock, Ont. using private and government funding (Fed. Dept. of Ind., Trade & Com.). The development of three (3) FM-40 prototypes was completed in March 1981. These units were tested extensively and modified as necessary. Since that time, nine (9) more units, called FM-50's were built. The FM-40's had a smaller diameter saw. The FM-40 and FM-50 units are located as follows: 6 in Ontario, 5 in Quebec and 1 in California.

Technical Information: The FM-50 is a completely mobile machine mounted on a two-axle trailer (see Fig. 1). The trailer dimensions are 10.53 m in length, 3.2 m in height and 2.44 m in width with the log deck folded for transport. The weight of the entire unit is 8165 kg. These specifications permit the processor to be easily moved on public highways. Signal and brake lights are provided on the trailer. Adjustable legs on the front and rear of the machine permit the unit to be free-standing and very stable; or if preferred the tractor unit can remain attached.

Powered with a John Deere 56-kW (75 Hp) diesel engine, the FM-50 has a "live" log deck that extends 2.7 m beside the machine, a 1.37-m diameter circular saw capable of cutting logs up to 58 cm (23 in) in diameter and a log splitter capable of handling lengths up to 67 cm. Small diameter logs can by-pass the splitter; larger logs are split either 2 ways or 6 ways using a hydraulically-controlled log centering device. NOTE: Several other designs of splitting blades, eg. 2/4, 2/8 or 2/10 are also available as an option.

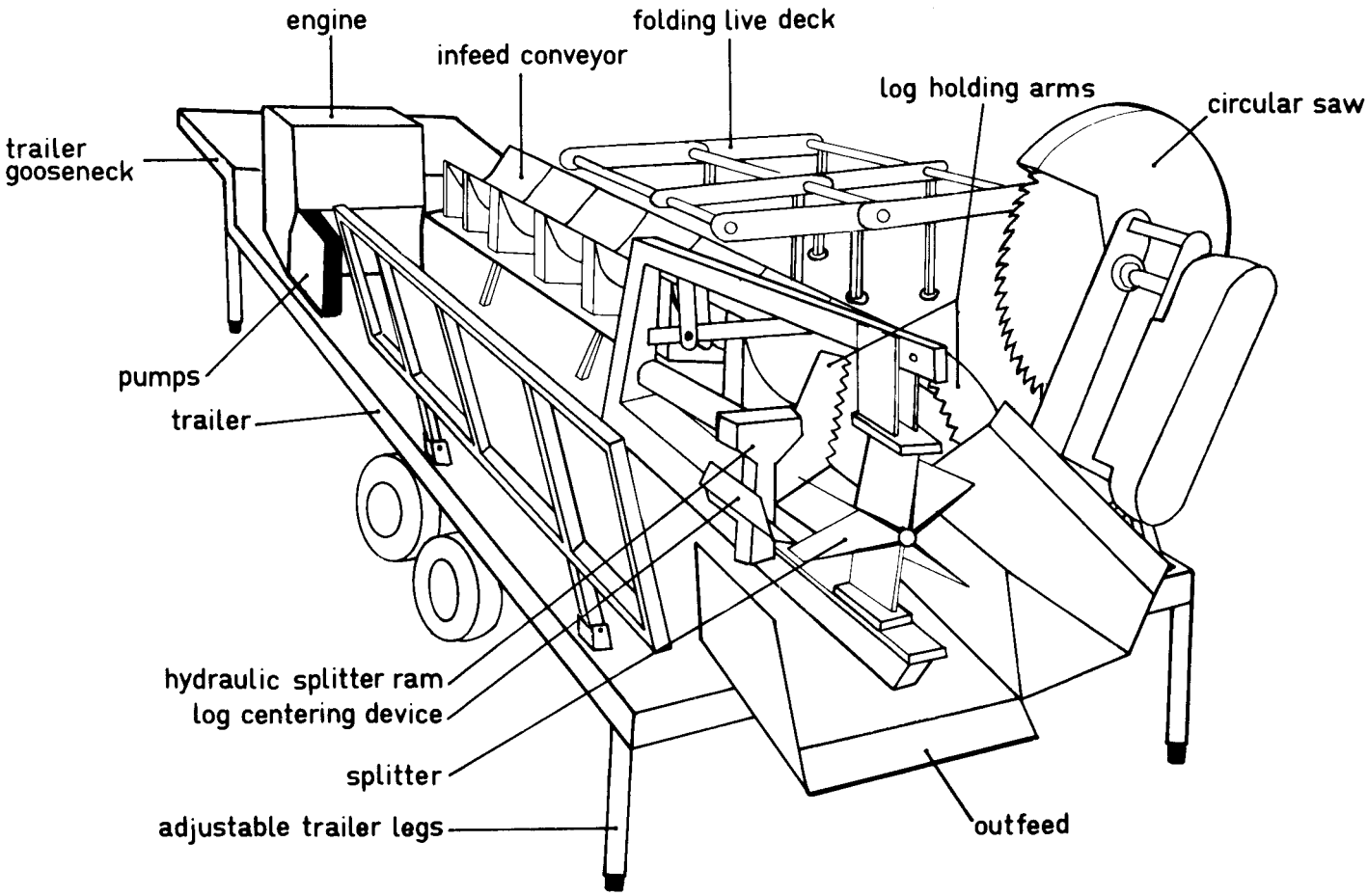

Figure 1. Main components of the Cord King FM-50 firewood processor. Outfeed shown is modified for manual operation of the machine. The reader can compare this with the automatic/manual version in Appendix A.

The FM-50 can be operated either in the AUTOMATIC MODE with the hydraulic valves under the controlling action of the electrical system (see Appendix B for details), or in the MANUAL MODE through operator control of the levers. Although FERIC observed the FM-50 in both the automatic and manual modes, FERIC data was collected only on the manual mode.

Modifications: The FM-50, as studied by FERIC, had been modified by the owner to permit manual operation only. All the electrical controls, limit switches, etc. that were used for automatic operation of the machine were removed. This was done to reduce the

complexity of the machine and to eliminate the high level of repair time, both diagnostic and active, relating to the automatic control system. Two other changes were made mainly to increase the productivity of the FM-50:

1. The speed of the infeed conveyor was increased by 1/3 by installing a larger sprocket on the drive shaft.

2. The outfeed end of the FM-50 was modified to permit removal of the "log stop" and to permit firewood bolts to fall directly onto the outfeed conveyor (see Fig. 1). Bolt lengths were now estimated by the operator through use of a marked panel.

Technical specifications for the Cord King FM-50 are provided in Appendix A and B. A conversion table for converting from Metric to Imperial units of measure is provided in Appendix C.

OPERATING SEQUENCE & STUDY PROCEDURE

The FM-50 studied by FERIC operated in the manual mode only using two operators on the machine (see page 3). The first man operated the live deck and conveyor controls, plus the saw and transfer table. The second man operated the log levelling device and the splitter; he also cleared up any clogging of wood which occurred at the splitter or on the bottom of the outfeed conveyor.

The operating sequence consisted of the time elements listed below. It assumes that the loader operator is capable of keeping the FM-50 log deck filled.

Position: A log is flipped from the log deck onto the conveyor using the log indexer. The log is advanced the correct distance past the saw (usually 40 cm (16 in)) ready for the first cut.

Processing: Processing begins after a log has been positioned for the cut. It includes all the time required to cut the log into firewood lengths and splitting the wood if required. The number of "cut only" sections and the number of "cut and split" log sections were recorded for each processing cycle.

Moving: To move the FM-50, the (empty) log deck was retracted hydraulically, the engine of the tractor unit was started up, the trailer legs were lifted and the unit was moved, usually from 3 to 5 m. NOTE: During FERIC's study the FM-50 was moved only a few times per day due to the 8-metre height of the tree-length pile. If a front-end loader is used instead of a knuckle-boom loader, moving may be even less frequent.

Delays: Were treated in different ways depending on their duration.

0-5 cmin : were included in the time element during which they occurred (Table 1).

5 cmin - 15 min : were recorded as "delays" shown in Table 2.

> 15 min : were not considered as part of productive time (PMH) and were therefore excluded.

The procedure used in analyzing the productivity was similar for both studies. The diameters of a sample of 100 tree lengths were measured in 3-m sections. Log taper factors were thus derived. The volume of each log processed by the FM-50 was determined by measuring the small end diameter, inside bark, of the log, by counting the number of firewood bolts produced (to determine total log length) and by using the taper factor.

THE OPERATION

The Cord King FM-50 studied by FERIC was located in a large, fenced, processing yard, a few kilometres from an urban centre in the southern part of the province of Québec. The owner of the FM-50 was formerly a small logging contractor who had owned/operated his own skidder and knuckle-boom (truck-mounted) loader for about 15 years prior to starting in the firewood processing business.

He had begun a firewood producing business four years earlier on a part-time basis using chain saws plus a hand-operated wood splitter. During this time he continued with logging activities, but at a reduced scale. During his third year in the firewood business, he discontinued logging and purchased a Cord King FM-40 (an early version of the FM-50 capable of processing logs up to 45 cm (18 in) in diameter) and used it for 6 months before trading it in on a FM-50. He had used the FM-50 for 3 months on a daily basis prior to FERIC's study on the machine.

During 1981, the operation produced 4000 full cords of firewood, mostly using the FM-40. For 1982, the production, using only the FM-50, was expected to exceed 5000 full cords. The wood used by the FM-50 consisted of culled hardwood tree lengths from sawlog and veneer harvesting operations located 180 kilometres away. The cost of the long haul was offset by the low wood cost (at roadside) due to a lack of other markets. The species mix was 80% sugar maple (A. Saccharum), 15% yellow birch (B. alleghaniensis) and 5% beech (F. grandifolia). Trucking and unloading at the firewood processing yard was done by the company that carried out the logging. Payment was on a weight basis.

The Cord King FM-50 could process logs up to 9 m in length. However, if the tree lengths were crooked, they had to be cut into shorter lengths to permit feeding on the conveyor.

After the logs were processed (see "Operating Sequence and Study Procedure"), the firewood was transported from the machine using an outfeed conveyor (see Fig. 2) that was fastened with a chain to the back of the FM-50. Fluid power for the hydraulic motor on the conveyor was supplied by the FM-50. NOTE: Due to the great height (8 m) of the tree-length pile the firewood pile sometimes blocked the output end of the outfeed conveyor. In such cases a skidder was used to lower the height of the pile (see Fig. 2).

The FM-50 was operated on a one-shift per day basis, 8 to 10 hours per day, 5 days per week for 7 or 8 months per year. The remaining months were spent on firewood deliveries, using the same personnel. Hand piling of firewood for air drying was done by a fourth person, as required, on a piece-work basis (see Fig. 2).

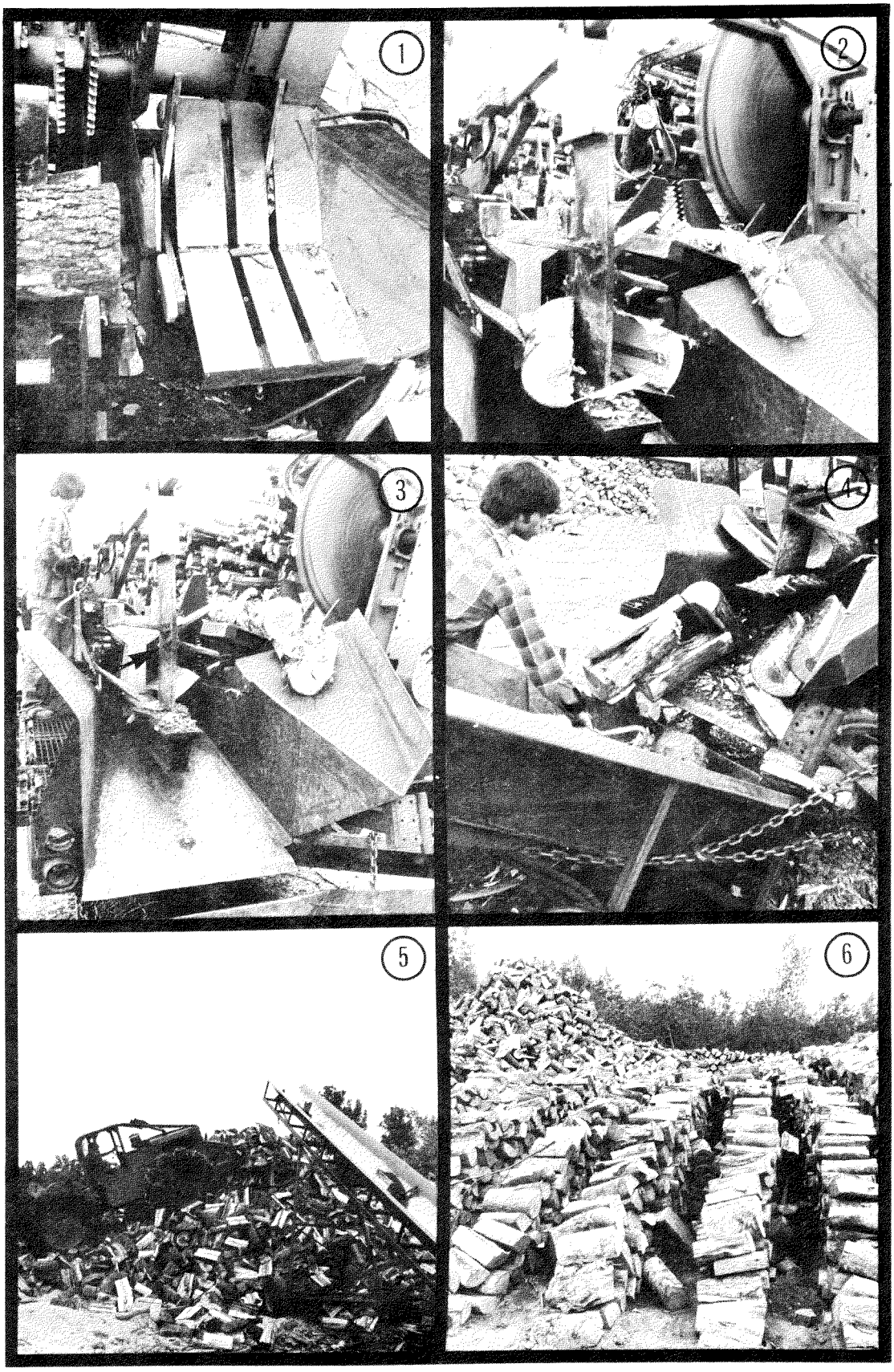

Figure 2. Cord King FM-50 firewood processor, 1: log clamps are shown in open position; also tilting transfer table with kicker arms, plus partly modified outfeed section can be seen, 2: outfeed modified for manual operation - note log clamps in their closed position, 3: the lower blades on the 6-way splitter had a tendency to break off (arrow), 4: the outfeed conveyor is shown being unplugged, 5: a skidder was used to lower the height of the firewood pile, 6: firewood piled for drying.

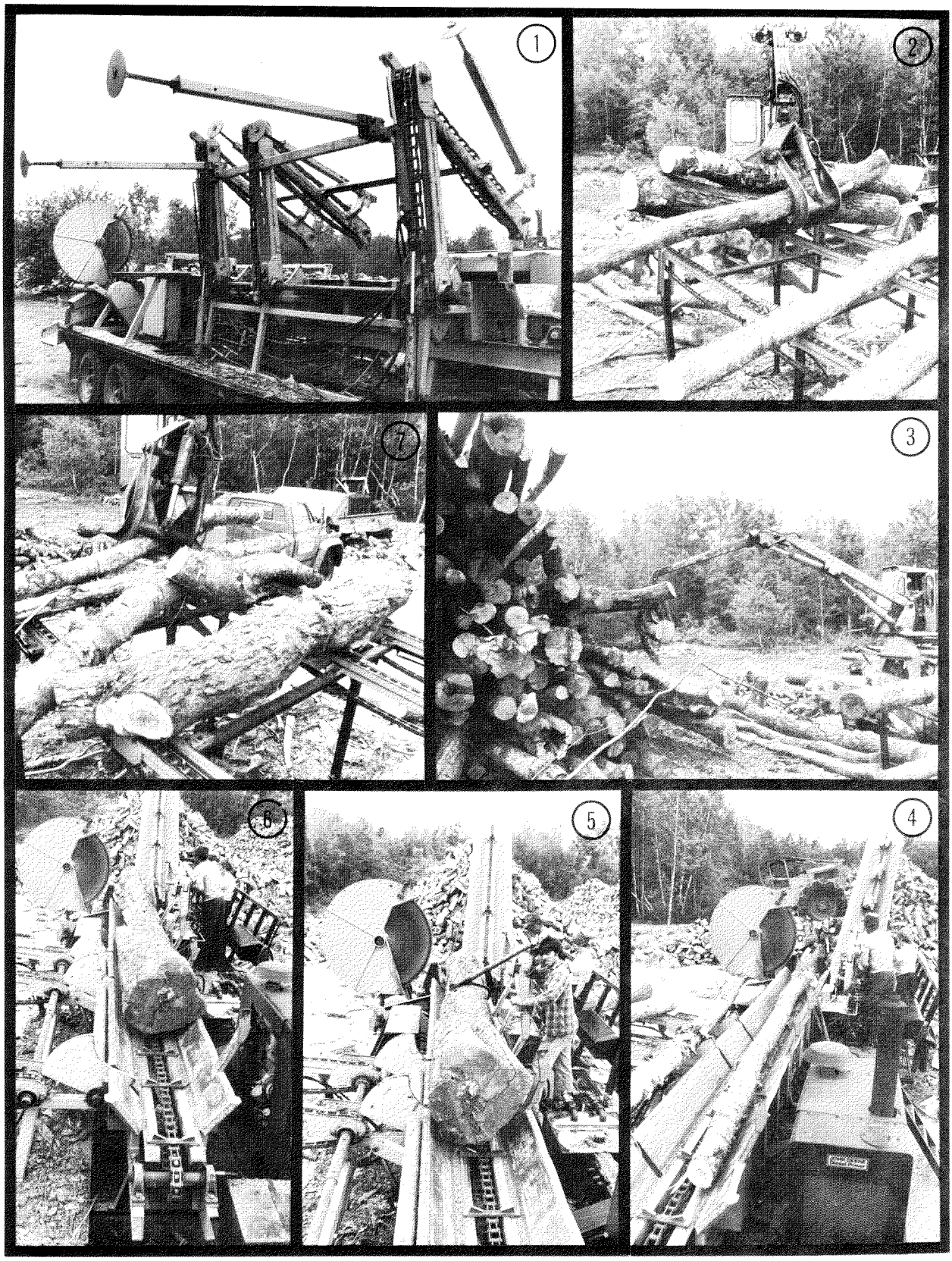

Figure 3. Cord King FM-50 firewood processor operation, 1: the live deck shown in its retracted position - the legs are not folded down yet, 2: a Barko 80 loading logs onto the live deck, 3: the intertwined tree-lengths plus the pile height posed a few problems for the Barko 80, 4: long, straight logs facilitate speedy processing, 5,6: large or crooked logs sometimes become jammed against the conveyor sides - a cant hook was required to permit the log to contact the conveyor chain, 7: cull or crooked logs were easily processed. NOTE: manpower shown in photos is excessive since visitors are present in # 3, 4, 5 and 6.

RESULTS & DISCUSSION

The main results of FERIC's studies are summarized in Table 1 and 2.

Productivity

Table 1 indicates that the log length (4.3 m) was similar for both studies. The average volume per log was however higher for Study I (0.21 m^3) than Study II (0.16 m^3).

The number of logs processed per productive machine hour (PMH) was 43 for Study I and 52 for Study II. For both studies, the delays were similar and accounted for 15% of the total time. (NOTE - this level of delays should be considered "normal" for a well-run operation (see also [1] page 7)). What accounts for the difference in logs processed per PMH? One factor is log size - the larger volume per log of Study I should be noted. The rest of the difference was not identified.

The net firewood production (after deducting 2% of the gross volume due to sawdust) was similar for both studies. For Study I the volume of firewood produced was 8.74 m^3 of solid wood (3.9 full cords*) per PMH; for Study II it was 8.28 m^3 of solid wood (3.6 full cords*) per PMH.

Loading, Live Deck & Infeed Conveyor

Loading: During FERIC's studies a Barko 80 knuckle-boom loader with a 1/5-cord pulpwood grapple mounted on a 10-year old, single-axle GMC tractor unit was used to supply the FM-50 with logs. The loader operator normally pulled/lifted 3 to 6 tree lengths from the tree-length pile, dismounted from the cab, cut each of them into 2 or 3 logs using a chain saw, re-mounted the loader and then filled the live deck. This method was used because of the high tree-length pile (8 m). NOTE: a front-end loader could be used where tree-length piles are lower and/or where logs must be brought to the FM-50. Two disadvantages would be that their forks could damage the FM-50 live deck; also it will be more difficult to place crooked or short logs onto the live deck.

Live Deck: The folding live deck, which extends and retracts hydraulically, is well designed. Two sections of the 3-section design are close together permitting short logs (1.3 m) to be processed (see Fig. 3). The log indexer, used to transfer logs onto the infeed conveyor, also worked well.

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* A full cord is a stacked measure 1.22 x 1.22 x 2.44 or (4 x 4 x 8 ft). This report assumes that one full cord contains 2.26 m^3 (80 ft^3) of solid wood.

Table 1. Productivity Summary

	Study I		Study II	
Date of study	May 1982		June 1982	
Study duration, hours[1] (or PMH)	5.38		5.19	
Number of logs processed	232		268	
Ave. log diameter, small end (i.b.), cm (in)	20.8	(8.2)	17.8	(7.0)
Log length, m (ft)				
- average	4.3	(14.2)	4.3	(14.2)
- range	2.0-8.1	(6.7-26.7)	1.8-8.9	(6.0-29.3)
- Stand. dev.	1.4	(4.5)	1.3	(4.2)
Volume per log, m^3 (ft^3)				
- average	.207	(7.31)	.164	(5.78)
- range	.03-1.25	(1.0-44.3)	.025-.98	(.9-34.8)
- Stand. dev.	.21	(7.2)	.15	(5.2)
	cmin[2]	% of total time per log	cmin[2]	% of total time per log
Position log	10.2	7.4	8.0	6.9
Process (cutting & splitting)	107.3	77.1	90.7	78.1
Moving time	-	-	-	-
Delays	21.6	15.5	17.5	15.0
TOTAL	139.1	100.0	116.2	100.0
LOGS PROCESSED PER PMH[3]	43.14		51.62	
FIREWOOD BOLTS PER LOG	10.67		10.65	
- cut only, % of bolts	49%		58%	
- cut & split, % of bolts	51%		42%	
GROSS PRODUCTION PER PMH, m^3 (ft^3)	8.92	(315.2)	8.45	(298.2)
MINUS 2% LOSS[4] DUE TO SAWDUST m^3 (ft^3)	-.18	-(6.3)	-.17	-(6.0)
NET FIREWOOD PRODUCTION PER PMH, m^3 (ft^3)	8.74	(308.9)	8.28	(292.2)
NET FIREWOOD PRODUCTION, PER PMH, full cords[5]	3.86		3.65	
PRODUCTION PER SHIFT[6], full cords[5]	25.1		23.7	

[1] This includes operational delays, mechanical breakdowns and personal delays less than 15 minutes (see Table 2 for a summary). Delays greater than 15 minutes were not considered as part of productive time (PMH) and were therefore excluded.

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

[3] PMH = Productive Machine Hour.

[4] To produce .4 m (16 in) firewood bolts 2% is lost as sawdust. See U.S.D.A. publication NA-FR-17, p. 4 [1].

[5] One full cord contains 2.26 m^3 (80 ft^3) of solid wood. This conversion factor is also used in U.S.D.A. publication NA-FR-17, p. 4 [1]. NOTE: "Full cords" should not be confused with "face cords"; the latter contains only about 1/3 the solid wood of the former.

[6] "Production per shift" assumes 6.5 PMH per shift.

Table 2. Summary of Delays

	Study I (% of delay time)	Study II (% of delay time)
Log jams on infeed conveyor (corrected with a cant hook or chainsaw)	18	15
Trouble feeding crooked log between saw clamps	7	16
Placing large bolt into splitter	6	1
Clearing splitter	13	8
Outfeed conveyor plugged at base	6	3
Oiling splitter base	1	2
No logs - log deck empty	8	53
Operator delays	23	1
Miscellaneous	18	1
TOTAL	100%	100%
Delays as % of total time	15.5	15.0

Infeed Conveyor: The FM-50 owner had increased the speed of the infeed conveyor by 1/3 by installing a larger drive sprocket. NOTE: Cord King will supply this feature on all future units built (see p. 19).

The concave shape of the infeed conveyor trough resulted in some delays (see Table 2) when feeding large diameter crooked logs. These logs tended to jam against the conveyor sides while the conveyor chain continued to advance. A cant hook was used to loosen such logs to permit them to make contact with the conveyor chain (see Fig. 3). Sometimes a chain saw was required. FERIC recommended a higher profile on the chain to overcome this problem (see p. 19).

Holding Clamps & Circular Saw

Holding Clamps: When the circular saw descended, the log holding clamps were (mechanically) activated. The holding clamps pressed against both sides of the log, thereby holding it securely in place during sawing, and released when the saw was retracted. NOTE: A spring-filled cylinder on the clamps was used to supply constant pressure for all log sizes. This device functioned well.

Circular Saw: The FM-50 used a 1.37-m (54-in) diameter, double-bevelled, inserted tooth circular saw having 54 replaceable teeth that cost $1.85 each to replace. The saw was belt-driven at 1000 RPM (not measured by FERIC) and was capable of cutting logs up to 58 cm (23 inches) in diameter. The saw performed well during FERIC's studies. NOTE: The owner of the FM-50 usually sharpened his saw with a hand file, a slow process. He also reported problems with the tool used for removing replaceable teeth. Cord King have since provided a service kit which includes a jockey grinder with jig, plus a new impact-type tooth remover. A random sample of 253 firewood bolts measured by FERIC yielded an average length of 41.4 cm (16.3 in). Ninety percent of the lengths were between 35.6 and 47.5 cm (14.0 to 18.7 in). This level of accuracy was judged by FERIC to be quite acceptable.

Splitter & Outfeed Conveyor

Splitter: The splitter is composed of three main parts; the ram, the blade and the centering device. The ram is activated by a 12.7-cm (5-inch) cylinder; the blade is removable and permits 2-way splitting or a 6-way split on large logs. The centering device is used to center large diameter logs for 6-way splitting. This can be done with a hydraulic self-centering device or manually using a control valve lever. On the FM-50 studied by FERIC, the self-centering device was not used since the manual control was faster.

The only problem with the splitter unit (according to the FM-50 owner) was that the lower blade of the 6-way splitter had a tendency to break off. Re-welding was difficult due to the problem of welding from below, due to the high carbon content of the steel plus the need to pre-heat the steel to avoid differential cooling and resulting weld cracks. NOTE: Cord King have since tried to correct this problem by doubling the thickness of the blade and raising the center of the splitter 5 cm (2 in).

Outfeed Conveyor: The 6-m high outfeed conveyor observed by FERIC was built by the owner at a cost of $6000. Cord King Inc. have indicated that they can supply a better (i.e. wider) conveyor at a similar cost. The clogging of wood observed by FERIC was due to the design of the conveyor, since it was only 30 cm (12 in) wide. Cord King's conveyor which is 60 cm (24 in) wide, eliminates bridging or clogging.

Engine, Hydraulics & Controls

Engine: The FM-50 was equipped with a 56-kW John Deere diesel engine which normally operated at 2300 RPM. The fuel consumption was reported by the owner to be 7.2 L per operating hour. Fuel tank capacity was 113 L.

Hydraulics: On the FM-50, all cycle functions except the saw rotation (which used shafts and V-belt drive) are hydraulically driven. Fig. 4 indicates that each function is controlled by a single valve and that the 10 functioning spools are grouped into 4 valves.

Gresen valves are used throughout. No problems with sticking valves were reported by the owner; this is probably due to suitable back pressures on each system.

Several improvements were required. Cord King has already made changes on their most recent units (see p. 19).

1. The automatic centering arm for the 6-way split was not used because it was faster to operate it manually. Removal of the upper centering arm would improve operator visibility of the saw table.

2. Improved seating/support should be provided for the operators.

3. The centering and splitting control valves should be located together for the second operator.

Controls: The FM-50 studied by FERIC was designed to be operated in the Automatic mode with Manual override controls (see Appendix A). It was noted earlier that all production figures in this report are based on Manual operation of the controls. For Manual operation the control valves were divided between the two operators as shown in Fig. 4.

The advantages of the Automatic mode are:

1. Only one operator is required. (NOTE: However, due to irregular-shaped trees, jamming of the conveyor and other problems - it is usually better to have two operators).

2. The use of a butt plate ensures exact lengths. This may be important for packaged firewood.

3. Straight, smooth tree lengths or logs are ideal for the automatic mode.

4. Operator workload is reduced.

The disadvantages of the Automatic mode are:

1. Automatic electrical controls add complexity to the machine and will contribute to a higher level of repairs. The FM-50 electrical components are placed in weather-proof enclosures that are rubber mounted to minimize shock. The wiring is enclosed in weatherproof cable. However, the effects of dirt, shock, vibration, corrosion, ice, etc. on the electrical controls will still be significant.

2. Repairs to the electrical control system are likely to be difficult for most FM-50 owners to carry out themselves. Personnel skilled in electrical repairs are unlikely to be employed in firewood processing. NOTE: The owner/operator of the FM-50 studied by FERIC, after several electrical problems (mainly with the micro-switch on the splitter) disconnected the electrical control system and operated the FM-50 manually. Cord King have corrected the splitter micro-switch problem on subsequent FM-50 units; several FM-50's are used exclusively in the automatic mode.

3. Accidents are more likely to occur using the automatic mode. FERIC is aware that several persons have been injured while diagnosing malfunctioning limit and proximity switches. An improper electrical signal can activate a hydraulic device. These accidents happened when a second person manipulated a control function while a mechanic was making adjustments; the mechanic was not aware of the other person's action. These type of accidents can be prevented (e.g. "safety tag" system used in industry).

4. The automatic system electrical components add at least $5000 to the cost of the FM-50.

FERIC's experience in evaluating other logging and processing equipment indicates that the electrical control system on the FM-50 should be considered a disadvantage for operations where the owner has limited mechanical/electrical experience. FERIC has recommended to Cord King that they also offer a manual unit with no electrical controls at a lower price; this type of unit in FERIC's opinion would be suitable for at least 50% of potential users.

FERIC recommends that the currently available automatic/manual version of the FM-50 unit should be considered where most or all of the following factors are applicable.

1. Skilled maintenance personnel are available.

2. Long, straight, smooth tree lengths or logs are supplied to the FM-50.

3. The FM-50 is protected from precipitation and ice - e.g. pole barn. A tarpaulin can also be used if necessary.

4. Exact lengths are required - e.g. firewood packaged in boxes.

Trailer Design & Mobility

The FM-50 is mounted on a trailer deck, 10.5 m in length, supported by two 'I' beams (5.6 x 20.1 x 0.6 cm) and by two axles rated at 4,500 kg each. The trailer is equipped with 4 tires (9.50 - 16.5). About 75% of the weight rests on the two axles; the remainder on the trailer tongue. The FM-50 unit observed by FERIC had previously been transported to various demonstrations in Eastern Canada and the United States with a 1971 GMC 5-ton truck unit. No problems with the truck or FM-50 occurred during this period according to the truck driver/demonstrator. NOTE: FERIC's main concern with the trailer design was the limited amount of ground clearance (approx. 25 cm) under the two axles which could pose a problem if the unit is transported on poor quality roads. Consideration should then be given to larger axles, rims and tires. The manufacturer should provide better protection for the signal and tail lights on the trailer, as several of the lights on the FM-50 studied by FERIC had been broken during processing activities. Cord King have since made improvements on their latest units (see p. 19).

Noise

The circular saw on the FM-50 (similar to most other circular saws) created high noise levels. FERIC's measurements indicated that the noise level ranged from 90 to 106 decibels (on the A scale) at the operator's position, with the peak noise levels occurring when the saw was cutting. Since this greatly exceeded the acceptable limit (adopted by the U.S. Dept. of Labor in 1969) for prolonged operator exposure, it is recommended that protective ear covers or plugs be worn at all times by FM-50 operators.

The noise levels (on the A scale) were also recorded at various distances from the saw. The measurements were made in a straight line, with a slight breeze (2-4 kilometres /hour) blowing perpendicular to the line of measurement. The results are shown graphically in Fig. 5.

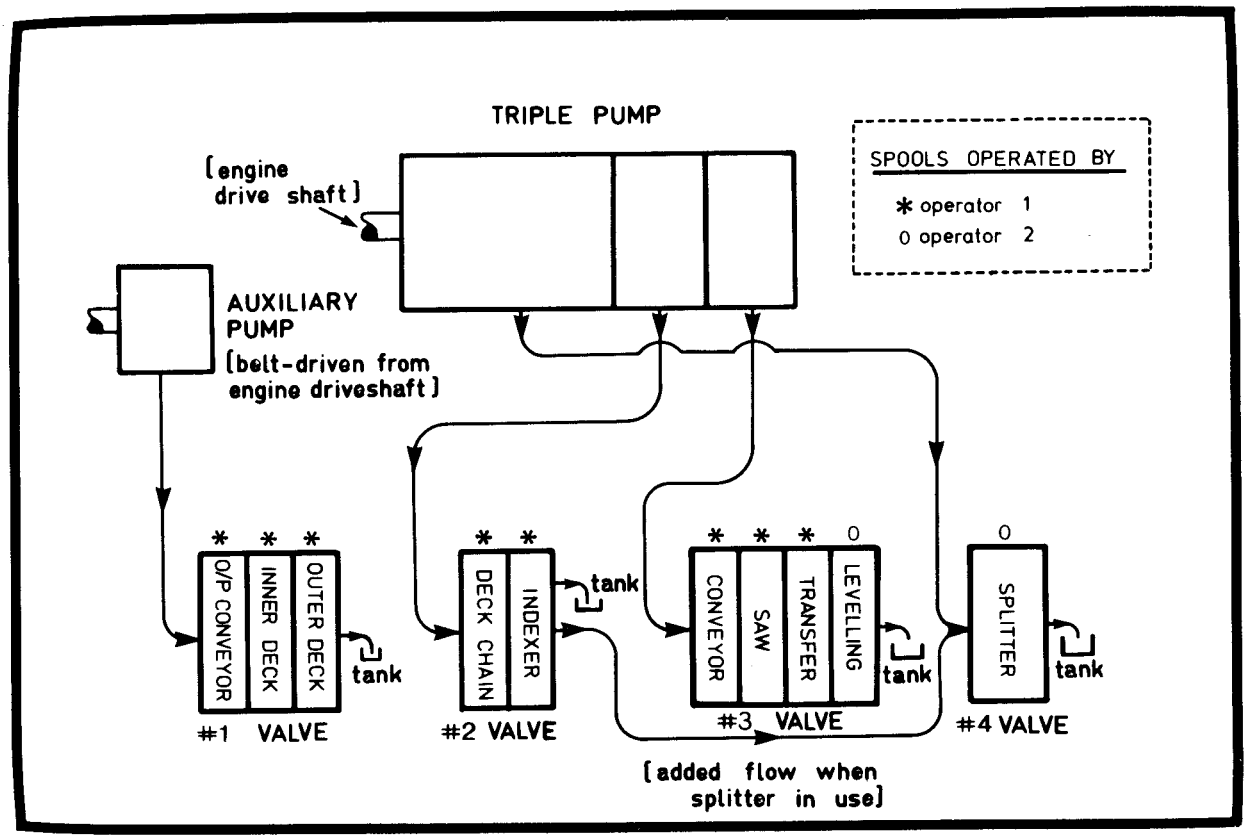

Figure 4. Hydraulic flow distribution diagram for the manually operated FM-50. NOTE: For the automatic mode, one more spool is required on the # 3 valve for the "log stop".

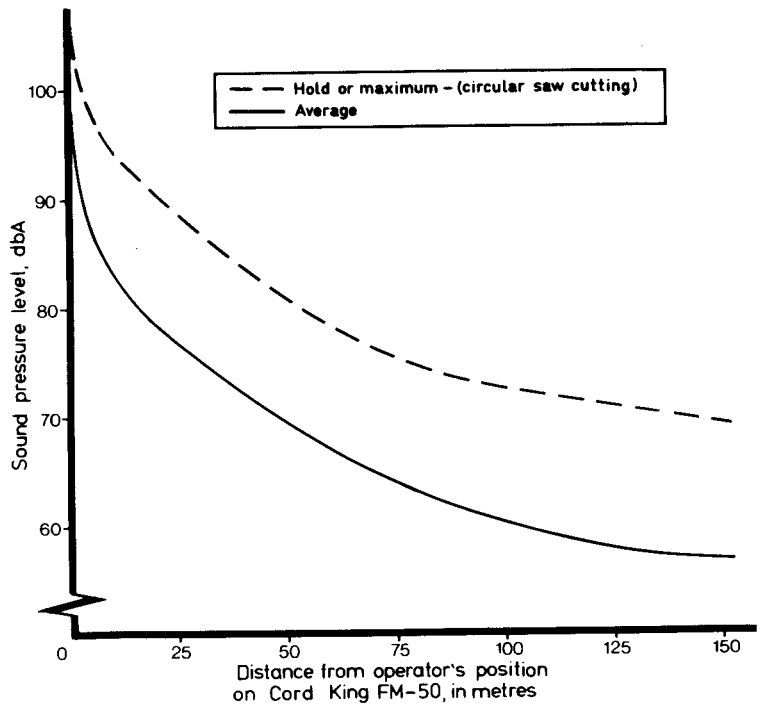

Figure 5. Noise levels measured at various distances from the saw on the FM-50. The measurements were made in a straight line with a 2-4 kilometre per hour wind blowing perpendicular to the line of measurement.

COMPARISON OF FIREWOOD PROCESSORS

A 1980 U.S.D.A. report [1] describes the LaFont SM-100 firewood processor as the most automated firewood manufacturing system available - at that time. The U.S.D.A. results are compared to those of the Cord King FM-50 in Fig. 6 and Table 3. It is obvious that the Cord King is more productive and versatile than the LaFont SM-100. The productivity of the Cord King also compares favourably with that of the CTR Inc. 3600 firewood processor (see Fig. 7 and Table 3), mainly because the FM-50's circular saw cuts faster than the CTR's chain saw and because all the CTR's functions must be controlled manually by a single operator, e.g. cutting one bolt and splitting another simultaneously is difficult.

During the past three years, as a direct result of the increasing demand for firewood, considerable effort has gone into the design of firewood processors. The most popular models are compared in Table 3. It is noteworthy that the CTR Inc. 5100 model (see footnote on Table 3) can be used for multi-stem processing of small diameter trees. The Cord King FM-50, in comparison, is limited to processing one tree at a time. However, small diameter stems normally do not require splitting; thus the cycle time on the FM-50 is decreased. FERIC observations on the manually-operated FM-50 indicated that the saw could make a cut every 3 seconds for long, small diameter logs not requiring splitting. The production penalty on the Cord King, when processing these small trees will be limited.

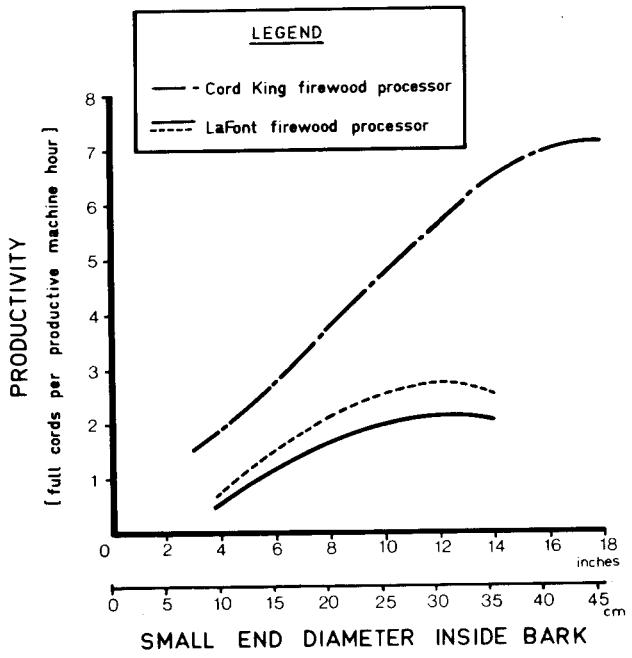

Figure 6. Firewood processing time related to log diameter. The LaFont curves are based on U.S.D.A. studies of three operations [1]. The solid line (LaFont) shows actual results which include 38 percent nonproductive (delay) time. The dotted line (LaFont) presumes 15% delay time - the same level as for the Cord King curve.

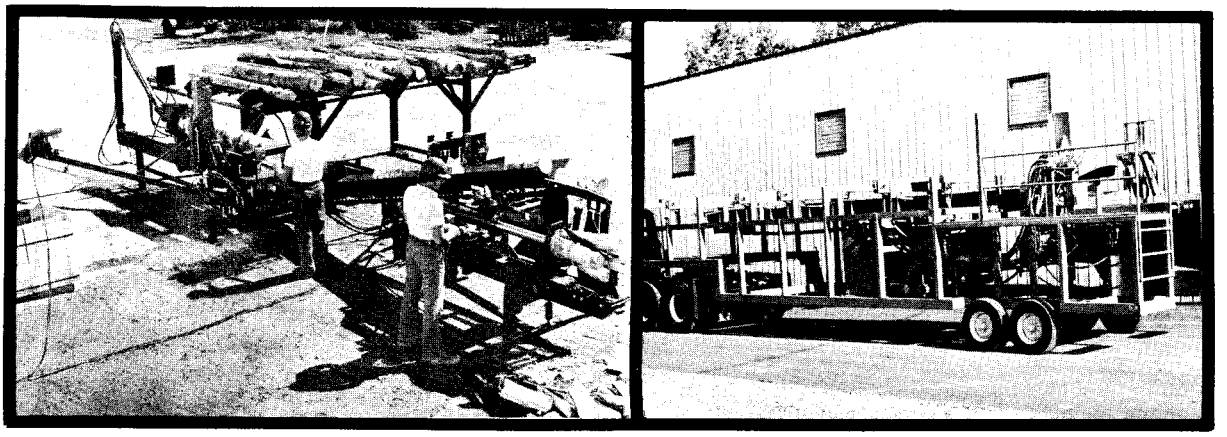

Figure 7. Left: LaFont firewood SM-100 processor. Right: CTR 3600 STL-FWP firewood processor (photos supplied by La Font and CTR).

Table 3. Comparison of Firewood Processors

	LaFont Corp. SM-100 [1]	CTR Inc. 3600 STL-FWP	Cord King FM-50
Price (Can. $) f.o.b. Toronto (factory direct price) Dec. 1982	$71,000[1]	$82,000[2]	$75,000
Location of manufacturer	Prentice, WI	Union Grove, NC	Smith Falls, Ont.
Diesel engine, kW (HP)	60 (80)	63 (85)	56 (75)
Mobility	option (at higher cost)	yes (5th wheel)	yes (5th wheel)
Saw type	chain saw	chain saw	circular saw
Max. log diameter, cm (in)	46 (18)	60 (24)	58 (23)
Log length required, m (ft)	2.4-3.0 (8-10)	2-10 (6-30)	1.5-10 (4-30)
Weight, kg (lbs)	10,000 (22,000)	8,200 (18,000)	8,200 (18,000)
Productivity, full cords per PMH (assumes 20 cm (8 in) i.b. av. log size)	1.9 (see Fig. 8)	not available[3]	3.7 (see Fig. 8)
Operators required[4]	2 or 3[5]	1	1 or 2[6]
Live deck	yes	option (at higher cost)	yes
Outfeed conveyor	option (at higher cost)	yes (small size)	option (at higher cost)
Warranty	6 months (parts)	90 days (parts & labour)	6 mo. (parts & labour)
Units sold (to Dec/82)	50[7]	5[8]	9

1 U.S. $50,000 base price - plus 12% duty, Can. $ exchange and shipping.
2 U.S. $58,000 base price - plus 12% duty, Can $ exchange and shipping.
3 See paragraph 1, p. 17.
4 Not including the loader operator.
5 Three operators if second splitter was required.
6 FM-50 can be operated with one operator if in automatic mode.
7 LaFont Corp. also manufactures a smaller lower capacity firewood processor, the SM-80.
8 CTR Inc. also manufactures the 5100 model firewood processor. The 5100, according to CTR Inc., can be used for multi-stem processing of small diameter trees; the 3600 for single (larger volume) stems. The price of the 5100 is approx. Can. $100,000. It has 2 splitter units and requires 3 operators. Five units have been sold. It has not been studied by FERIC to date.

RECENT MODIFICATIONS

FERIC's studies of the Cord King FM-50 were carried out during May and June, 1982. The effect of various improvements carried out by the machine owner were studied and discussed with Cord King Inc. Also, a number of additional improvements were recommended by FERIC. Cord King Inc. have responded positively to these suggestions and have incorporated these, plus other improvements, into their latest FM-50 units:

1. The live deck was modified to provide better support for long logs.
2. The infeed conveyor was lengthened .5 m (18 in). Also, the conveyor height was increased 5 cm (2 in) and the sides widened to reduce feeding problems with large or crooked logs.
3. The infeed conveyor speed was increased 1/3 by using a larger drive sprocket.
4. The indexer and live deck controls have been moved to facilitate operation.
5. The transfer table lip was modified to reduce jamming by branch stubs.
6. The log stop was redesigned to a side swing type. Also, the reject shute now permits unsplit bolts to fall directly onto the outfeed conveyor.
7. Better bearings are provided on the saw pivot shaft.
8. For the 2/6 way splitter, the vertical and side blades have been doubled in thickness - also the center of the splitter has been raised 5 cm (2 in).
9. To improve operator visibility, the operator's platform was raised 5 cm (2 in). Expanded metal (instead of wood) was used for flooring throughout.
10. A service kit was provided for circular saw maintenance.
11. Trailer lights were better protected.
12. The rear stabilizing legs were activated hydraulically instead of manually.
13. The FM-50 will be available with a high ground clearance option.
14. A manually-operated version of the FM-50 will be available at $5000 less than the manual/automatic version.

CONCLUSIONS

The Cord King FM-50 was considered by FERIC to be a well-designed, versatile firewood processor. The machine is compact; yet it is capable of handling a large range of log diameters (up to 58 cm (23 in)) and lengths (1.5-9.0 m (4.5-30 ft)). The machine is mobile, and can be easily hauled to a new location. The unique design of the folding deck adds to the portability of the machine, since this permits it to meet normal highway haul regulations.

The FM-50's design indicates that in spite of the "new" nature of this product it appears to be a reliable, smoothly-functioning unit. The extensive experience of the designers (Hyd-Mech) with logging equipment, plus the operating/development experience obtained by Cord King of Canada Inc. during the past 5-6 years, are important factors in this respect.

Although production costs with the FM-50 have not been closely studied by FERIC, there are indications that the FM-50 can produce firewood at considerably lower costs as compared to conventional (labour-intensive) methods. In the Montréal area in December 1982 there were several producers using the Cord King FM-50. Their selling price for fire wood was generally $10 to $20 per full cord (delivered or "pick-up" price) lower than their competitors.

The productivity of the FM-50 during FERIC's studies averaged 3.7 full cords per PMH, with an average log size of about 20 cm (8 in.) inside bark. The expected daily productivity (assuming 6.5 PMH per day with similar size logs) would be 24 full cords, or more. Assuming 160 working days per year for the FM-50 this would result in a total production of 3844 full cords of firewood annually. Based on the above assumptions, owners of the Cord King FM-50 could consider an operation producing 3500 to 4000 full cords of firewood annually to be feasible.

Due to the large volumes of firewood that can be produced with the FM-50, FERIC expects that most users will experience difficulties in organizing and carrying out other aspects of the firewood business, e.g. marketing and delivery of the product. FERIC hopes to prepare and publish during 1983 a handbook titled "Handbook on High-Capacity Firewood Processing Centres".

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1. Monahan R.T., Warluft, J.L. 1980. Prospectus: Firewood Manufacturing and Marketing. U.S.D.A. Forest Service, NA-FR-17. 25 p.

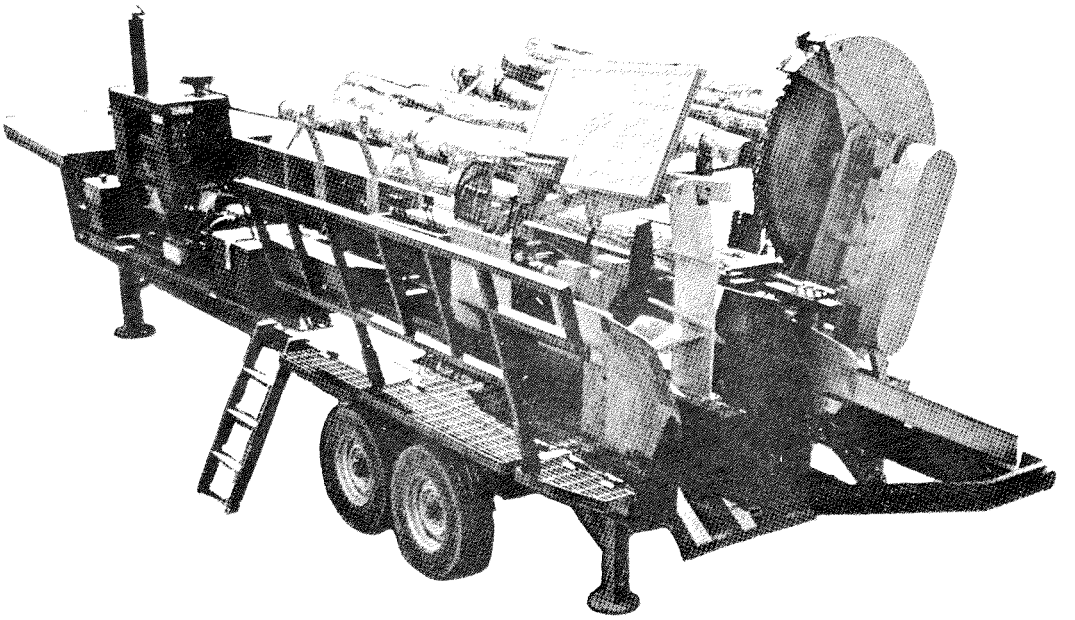
2. Graham, S. 1981. Woodfuel Supply Business in Canada: An Overview. Report prepared for: Con. & Ren. En. Branch, Dept. of En., Mines & Res. Can. 133 p.

3. Williamson, K. 1981. Commercial Firewood Production: A Case Study and Discussion. Report prepared for Office of Economic and Community Development, Tennessee Valley Authority, Knoxville, Tennessee. 40 p.

APPENDIX A

TECHNICAL SPECIFICATIONS

CORD KING FM-50
MOBILE AUTOMATIC FIREWOOD PROCESSING SYSTEM



Standard design version	- Mounted on two axle trailer - Overall dimensions - length: 34'7" (10.53 m) height: 10'6" (3.2 m) width: 96" (2.44 m)
Engine	- John Deere industrial diesel (75 H.P. / 2500 RPM)
Construction of FM-50	- Heavy duty channel and tubular steel
Log deck	- 9' (2.74 m) hydraulic powered, hydraulic folding
Log diameter	- Maximum diameter: 23" (58.4 cm) Minimum diameter: 3" (7.6 cm)
Log length	- 4' (1.21 m) to 40' (12.19 m)
Deck loading	- Recommended hydraulic knuckleboom of fork lift
Cutting length range	- 12" (30 cm) to 24" (60 cm) adjustable
Sawing operation	- Automatic
Saw	- Circular saw 54" (1.37 m) diameter inserted tooth
Bolt conveyor	- 18' (5.5 m) length
Splitting cylinder	- 5" (12.7 cm) diameter
Splitting stroke	- 26 1/2" (67 cm) maximum
Cylinder force	- 25 tons (22.7 metric tons) maximum
Cycle time	- 6 seconds automatic
Log centering	- Hydraulic controlled, automatic
Splitting blade	- Removable 2-way / 6-way
Splitting function	- Automatic split into 2 or 6 pieces
Weight	- 18 000 lbs. (8165 kg) approximately

CORD KING OF CANADA
HEAD OFFICE
97 NORMAN STREET
OTTAWA, ONTARIO
CANADA K1S 3K5
(613) 238-6709

MARKETING OFFICE
R. R. 1
RACINE QUÉBEC
CANADA J0E 1Y0
(514) 532-2356

CORD KING OF CANADA INC.

APPENDIX B

AUTOMATIC CONTROL SYSTEM

The electrical control system can be divided into four groups of components - operator's switch box, limit switches, main control box, and auto valve bank. In addition, there is a pilot light box which permits the operator to monitor the signals from the limit switches (see Fig. B.1). The operator's switch box enables him to select the operating mode of the machine and intervene as required. The limit switches are scattered about the machine and send signals indicating the position of various mechanical components to the main control box, where these signals are interpreted and used to send the correct sequence of control signals to the auto valve bank.

The following describes how the automatic mode works: First, the operator flips a log from the log deck onto the conveyor using the indexer. From this point on the operation proceeds automatically. The conveyor, activated by the auto switch, moves the log along until it hits the log stop. Hitting the log stop triggers a limit switch that causes the saw's downward movement. On it's return the saw triggers another limit switch that activates the transfer table, which dumps the log into the splitter. Logs under 25 cm are split two ways; larger logs are held on the log centering table and are automatically centred on the 6-way splitter, by use of a hydraulically-activated sensing arm.

A limit switch on the transfer table return activates the splitter ram, which drives the wood through the splitter head. The split wood pieces are pushed onto an output conveyor by the following pieces.

NOTE: Theoretically, only one operator is required when the FM-50 is in the automatic mode. However, owner experience has shown that it is often necessary to have two operators. The second operator helps with unplugging the splitter and outfeed conveyor and assists in any other work that is required to keep the FM-50 working efficiently. See also the discussion of automatic vs. manual mode on page 13.

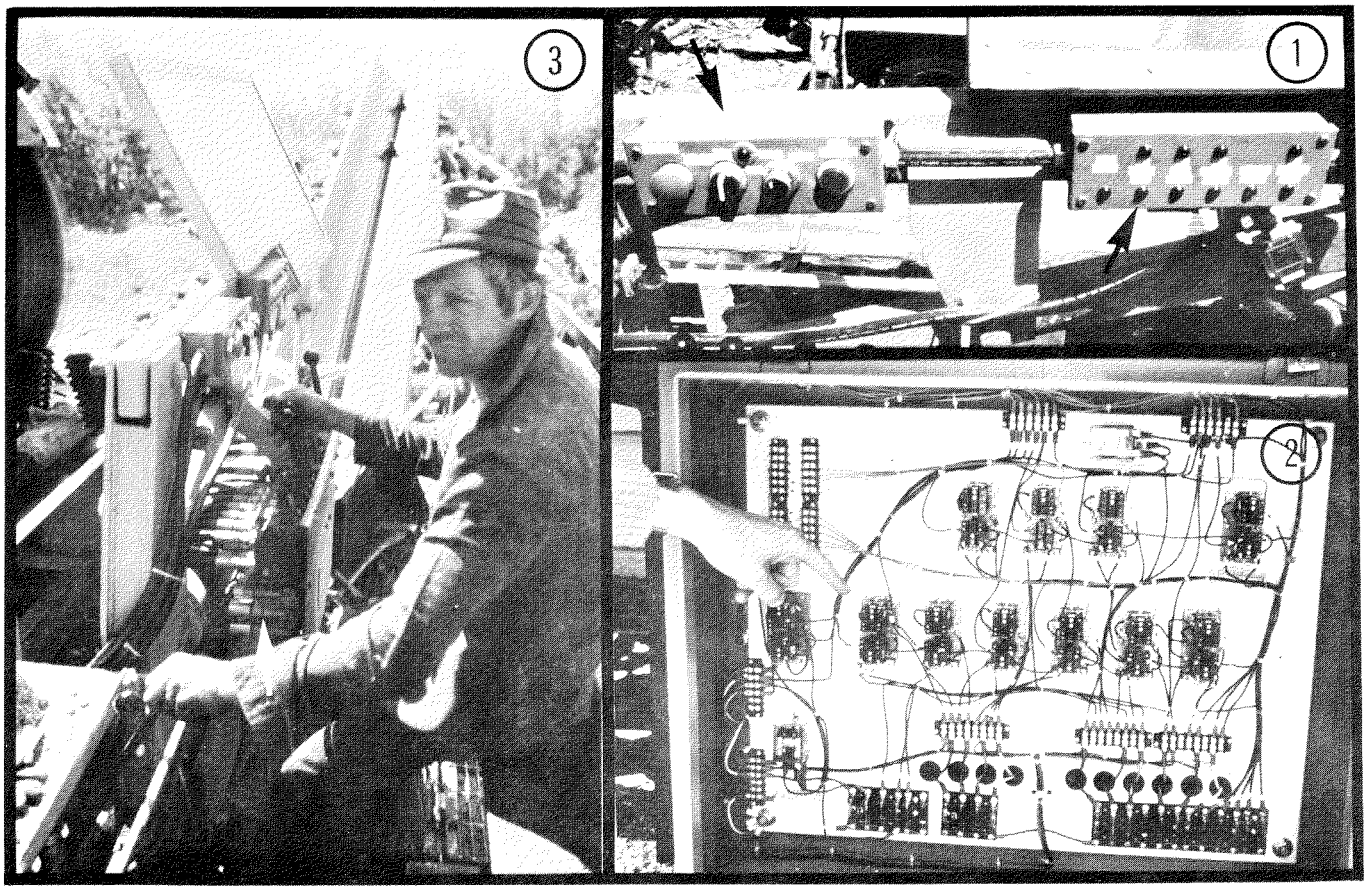


Figure B.1. The electrical control system can be divided into four groups of components-operator's switch box (see left arrow on photo 1), limit and proximity switches (not shown), main control box (see photo 2) and auto valve bank (see arrow - photo 3). The pilot light box (see right arrow on photo 1) monitors signals from the limit and proximity switches.

APPENDIX C

CONVERSION TABLE

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