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Dewatering Pulp and Paper Mill Sludge Using the Kamyr Ring Press

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Dewatering Pulp and Paper Mill Sludge Using the Kamyr Ring Press

by

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for the

Technology Development Branch
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Abstract

At the Canadian Pacific Forest Products Limited pulp and paper mill in Gatineau, Quebec, waste is pressed before burning using a Kamyr Ring Press. The innovative design of this press, developed by the Centre de recherches industrielle du Québec, makes it an interesting alternative to the disc, belt, or screw presses commonly used in the pulp and paper industry.

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Acknowledgements

The assistance of Kamyr, Inc., and particularly Erwin R. Funk, with data collection and analysis is gratefully acknowledged.

Section 1

Introduction

1.1 Canadian Pacific Forest Products Limited

1.1.1 Facilities

The Canadian Pacific Forest Products Limited mill in Gatineau, Quebec, produces 1500 metric tons(t) of standard newsprint per day. The pulping facilities include a groundwood mill, a refiner pulp mill, and a semichemical mechanical pulp mill, each contributing roughly one third of the total production. The mill consumes 30 000 U.S. gal (113 600 L) of water per minute and rejects it (after treatment in a primary clarifier) into the Ottawa River.

1.1.2 Effluent Treatment

Suspended solids in the mill wastewater settle in the primary clarifier, forming a sludge bed (Figure 1). This sludge is collected and pumped to vacuum filters where its consistency* is raised to 18% solids. The sludge from one of the filters is then passed through the Kamyr Ring Press to raise its consistency to ±40% solids. The consistency of the sludge exiting from the Vee Press used in the past, for comparison, ranged from 22 to 28%. After mixing with bark, the sludge from the Kamyr Ring Press is burned in a refuse boiler. About 60 to 100 t (bone-dry basis) of sludge are extracted from the clarifier each day. Of this, 50 to 60 t are burned and the remainder is trucked to a dump site some 30 km from the mill.

1.1.3 Energy Usage

Manufacturing pulp and paper typically requires 9.3×10^9 J of steam per tonne of paper for cooking the wood chips, heating

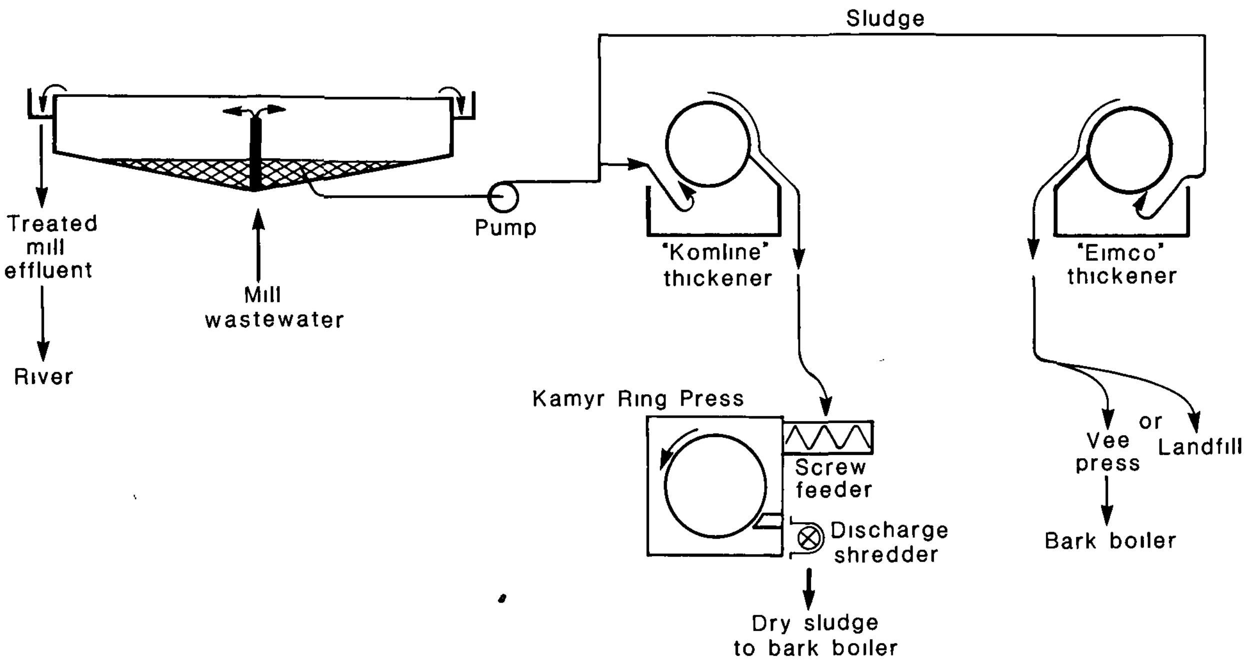

Figure 1 Mill Effluent Treatment

* Throughout this report, the term consistency is used to denote dryness

water, or drying the paper. The steam is generated by burning natural gas, heavy fuel oil, and wood residues in large power boilers. The Gatineau mill uses steam at a rate of 475 000 to 820 000 lb/h (215 500 to 371 900 kg/h) With the existing facilities, only 50 000 lb (22 700 kg) of steam are generated per hour by burning wood residues (sludge and bark). Plans are currently under way to construct a new boiler that will generate up to 300 000 lb (136 100 kg) of steam per hour by burning wood refuse and sludge alone This will eliminate the need to transport sludge and other wood residues to landfill sites. It will also considerably reduce the amount of fossil fuels required and, therefore, expenditures on fossil fuels.

1.2 Kamyr Ring Press

The Kamyr Ring Press is designed to dewater fibrous suspensions (sludge). It consists of one or more rotating channels mounted on a common shaft (Figure 2). The compacting pressure required for dewatering is attained from frictional forces in the rotating channel, the walls of which are comprised of a slotted casing lined with screen plate. Pushing friction from the moving channel progressively compacts the fibers toward a discharge outlet. At the same time, the liquid is pressed out through the screen holes. At the discharge outlet, an adjustable restrictor plate controls the consistency of the exiting sludge cake (Figure 3).

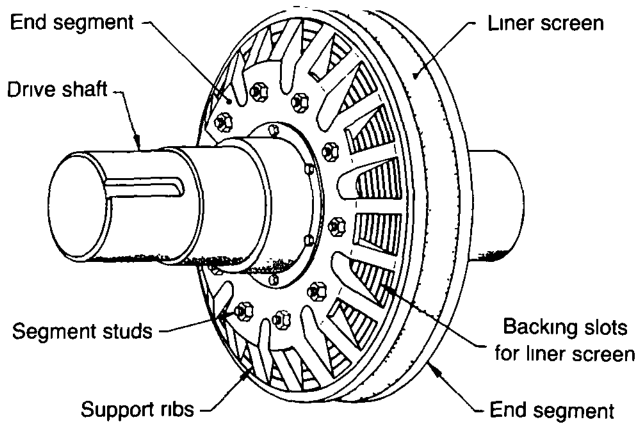

Figure 2 Kamyr Ring Press Single Channel Rotor (from *Ring Press Information Guide*, Kamyr Bulletin No. KGD1804-MEO189)

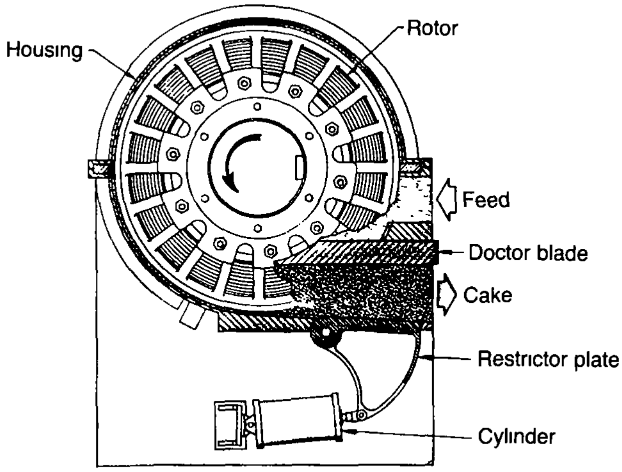

Figure 3 Kamyr Ring Press Operation (from *Ring Press Information Guide*, Kamyr Bulletin No. KGD1804-MEO189)

1.2.1 Specifications

Press model:	48 in./3 ring
Drive motor:	200 HP,* 1800 rpm (normal running HP: <100)
Drive gear reducer:	399.9:1 ratio
Press rpm:	3
Feed screws:	3, with motors, 5 HP and reducers
Feed screw rpm:	135
Cylinders for back pressure:	3, operating at 150 psig**
Sludge:	Supply consistency: 16-20% (bone-dry basis)
	Freeness: 80-120 CSF***
	pH: 5-5.5
	Temperature: 10-20°C
Press capacity:	50 t/d (bone-dry basis)

* 1 HP = 746 W
** 1 psig = 6 897 kPa
*** CSF, Canadian Standard Freeness

Section 2

Project Development

The moisture content of clarifier sludge exiting from the Reitz "Vee" presses used at the Canadian Pacific Forest Products Limited mill in Gatineau, Quebec, in the past typically ranged from 72 to 78% (Table 1), which prevented efficient burning in the bark boiler. This high moisture content also limited the quantities that could be burned. As a result, large volumes of sludge had to be trucked to a landfill site.

In April 1985, a 40 in. Single Ring Press (Figure 4) developed by the Centre de recherches industrielle du Québec in collaboration with Kamyr, Inc. was tested at the Gatineau mill (Figure 5). The tests showed that sludge cake consistencies of 38 to 45% could easily be attained (Table 2).

Based on these results, a project proposal was prepared and submitted suggesting that considerable savings, in terms of energy costs and costs associated with transporting sludge

Table 1 Moisture Content of Sludge, Reitz "Vee" Press, August 1985

	Press No 1		Press No. 2	
Date (Aug)	Moisture Content Before (%)	Moisture Content After (%)	Moisture Content Before (%)	Moisture Content After (%)
1	--	--	81.8	77.5
2	81.1	--	80.1	76.1
5	79 0	76 2	79.4	76.6
6	79.9	71.4	78.9	76 4
7	80.0	74.2	78.0	76.9
8	83.5	82.2	82.9	76.5
12	83.7	83.5	--	--
13	--	--	--	--
14	--	--	78.2	--
15	76.7	72.2	--	--
16	82.6	--	79.8	77.6
19	78.5	--	--	--
20	78.7	--	80.8	--
21	80.8	78.4	79.8	70.4
22	78.8	--	82.7	--

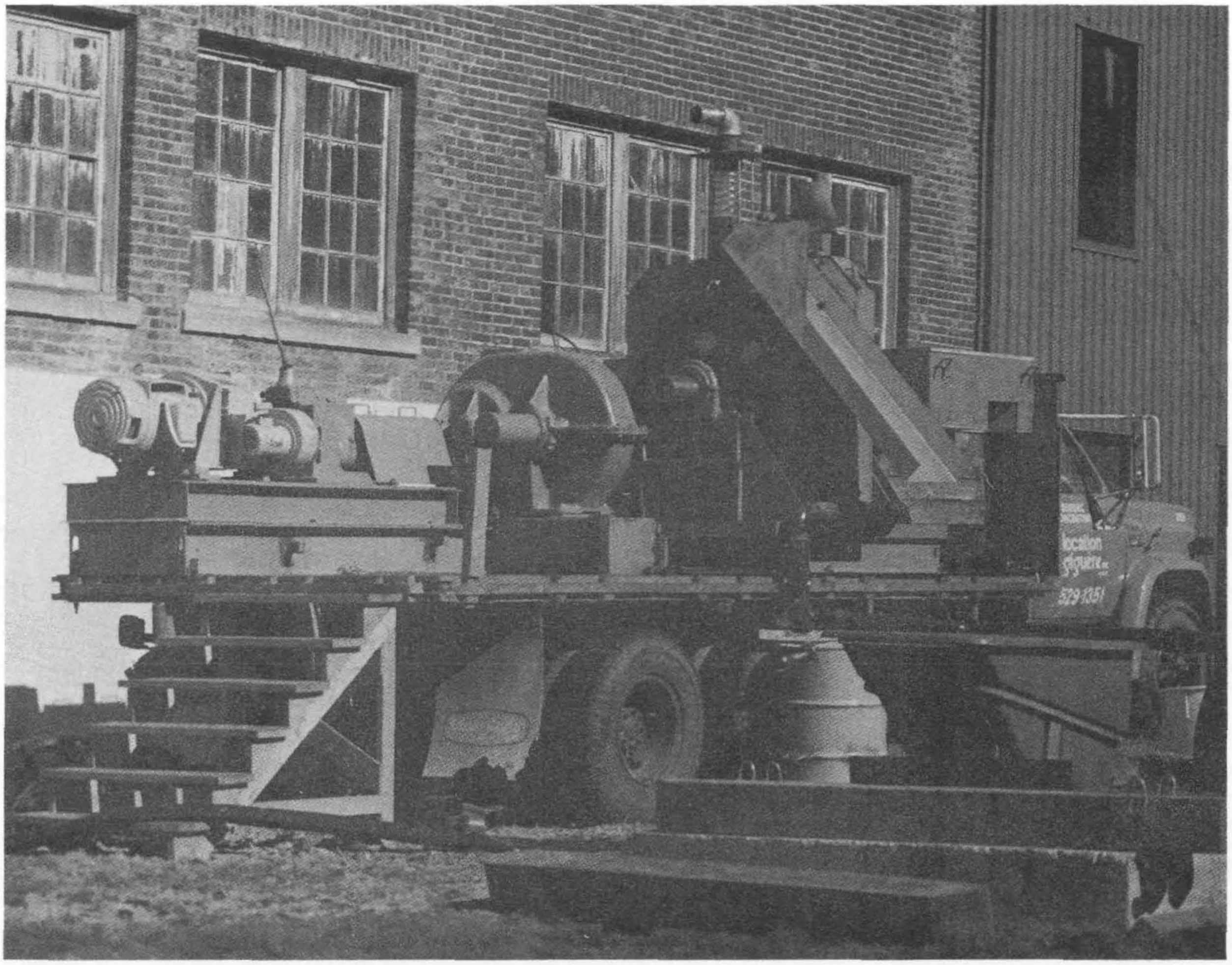

Figure 4 40 in. Single Ring Portable Ring Press

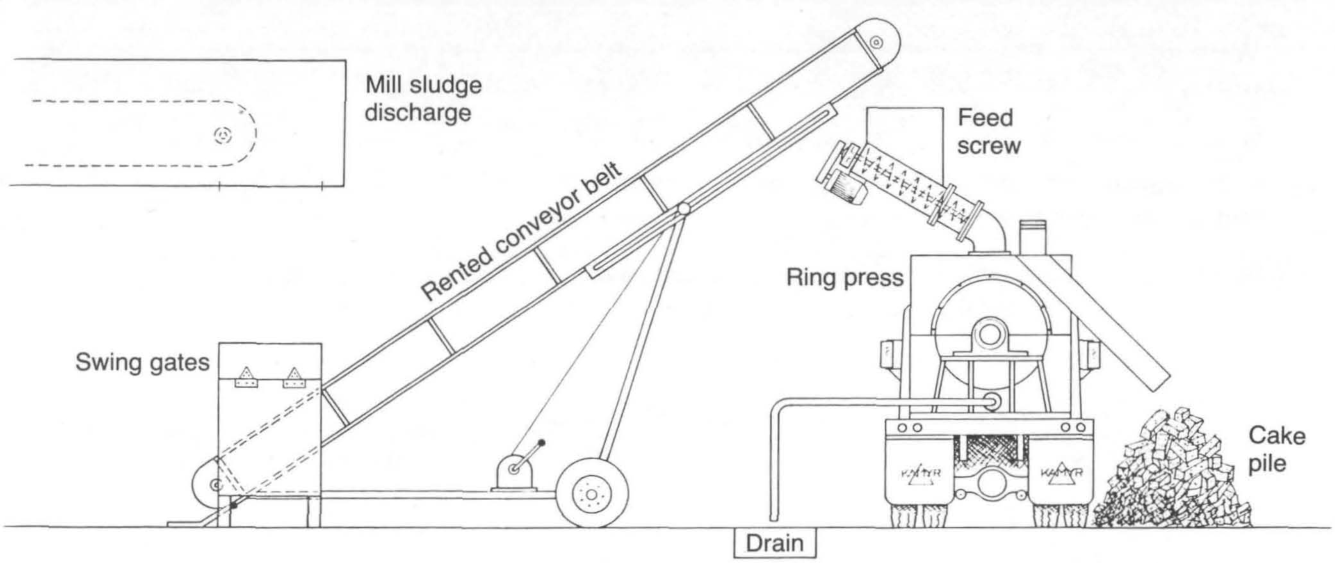

Figure 5 Ring Press Trial Arrangement

Table 2 40 in. Single Ring Press Test Results, April 1985

	Test Number				
	1	2	3	4	5
Press (rpm)	2.75	2.75	2.75	3.5	4.0
Cylinder (psig)	17.8	12.0	29.5	29.5	29.5
Feed screw (rpm)	110	110	110	110	110
Inlet (psig)	0.5	1.0	1-10	1.0	----
Discharge (psig) (maximum)	235	200	320	400	----
Peak torque (in.-lb)* x 100 000	4.75	4.35	5.15	5.50	----
Horsepower consumed at peak torque	20.7	19.0	24.0	30.5	----
Inlet consistency (%)	16.5	14	----	----	----
Filtrate consistency (%)	1.00	0.86	1.00	----	----
Cake consistency (%) (Kamyr)	42.2	34.8	48.7	48.9	----
Cake consistency (%) (CIP Lab)	38.0	39.6	44.7	44.0	----
Wet rate (t/d)	23.5	38.9	33.6	35.6	----
Production at CIP consistency (t/d on bone-dry basis)	8.9	15.4	15.0	15.7	----

Note. Test No. 5 was not completed because operation of the press at that rpm became erratic. The press had a tendency to hold the sludge and suddenly extrude it relatively wet.

* 1 in.-lb = 0.11298 N•m

to landfill sites, could be realized through the use of this type of press (Appendix A).

A contract was then signed with Environment Canada, within the scope of the DRECT program, to buy, install, and operate a Kamyr Ring Press to demonstrate its potential use in the paper industry. Subsequently, a 3 ring 48 in. Ring Press was delivered to the Gatineau mill in August 1987.

Section 3

Ring Press Operation

A log detailing the operation of the Kamyr Ring Press is presented here followed by comments on problems encountered and test results.

3.1 Log of Events

Date	Event
April 19, 1985	Ring Press trials commenced with a 40 in. truck press.
October 16, 1986	Order submitted to Kamyr, Inc. for a triple-ring press.
May 28, 1987	Performance test of feed screws carried out using sludge. The sludge bridged in the inlet feed box.
August 11, 1987	Feed screws retested using a modified feed box and agitator pins on the screws (Figure 6). The agitator pins created too much agitation, which retarded throughput.
September 11, 1987	Feed screws retested again using a smaller number of agitator pins (Figure 6). The feed screws performed very well.
November 26, 1987	Initial start-up of Ring Press Discharge cake consistency was approximately 30%, with an air cylinder pressure of 80 psig being applied to the restrictor plate (Figure 3).
November 30, 1987	Air compressor used to increase cylinder pressure. Resulted in one of the restrictor plates bending at a pressure of 100 psig.
December 9, 1987	Cheek plates installed on both sides of each of the three outlets to increase discharge friction (Figure 7).
December 11, 1987	Stronger restrictor plates installed; started operating at a pressure of 80 psig
December 14, 1987	Air compressor again used and began operating at a pressure of 100 psig.
December 16, 1987	Nitrogen bottle installed to test operation at cylinder pressures up to 150 psig. Discharge cake consistency increased to 41.2% at 150 psig cylinder pressure.
January 14, 1988	Small air compressor installed to increase pressure on cylinders to 120 psig.

January 15, 1988	Komline filter drive modified to increase speed by 50%.
January 18, 1988	Komline filter and Ring Press operated together. Sludge production was 55 t/d (bone-dry basis) at a filter speed setting of 70%
January 21, 1988	Shredder stopped but Ring Press continued running due to faulty interlock (Figure 1). As a result, the screens were scored The Ring Press packed sludge into the shredder tightly, causing damage to the shredder (Figure 8)
January 22-28, 1988	Performance tests conducted.
January 29, 1988	Meeting held at CIP to discuss Ring Press modifications necessary to improve operation. Modifications agreed upon were as follows: Improving cake consistency (1) Replace damaged screen (2) Increase cylinder pressure (3) Lengthen outlets to increase outlet friction Improving wear resistance (1) Apply chrome plating to screens (2) Use replaceable wear plates on doctor blades (3) Use replaceable wear plates on restrictor plates
July 20, 1988	Ring Press was stopped because a screen plate was found in the shredder. An inspection revealed that the stainless steel screens were worn out by the abrasive sludge. The Ring Press was removed from the mill to undergo modification.
December 29, 1988	Ring Press restarted after modifications completed, i.e , new chrome screens, longer outlet, new doctor blades with wear plates, and new restrictor plates with wear plates (Figures 9 and 10).
March 8, 1989	Cake consistency tests performed at various cylinder pressures. A cake consistency of 41.3% was attained at a cylinder pressure of 145 psig.
August 29-30, 1989	Performance tests conducted. Production of 59.6 t/d (bone-dry basis) with a cake consistency of 42.1% was attained at a cylinder pressure of 150 psig.
August 31, 1989	Ring Press inspected for wear. Chrome-plated screens showed no visible signs of wear after 9 months of continuous operation. The hardened wear plates on the doctor blades and restrictor plates showed no signs of abrasive wear. The tips of the doctor blade wear plates, however, had broken off two of the doctor blades.
November 17, 1989	New chrome-plated doctor blades were ordered. The doctor blade wear plates were omitted.

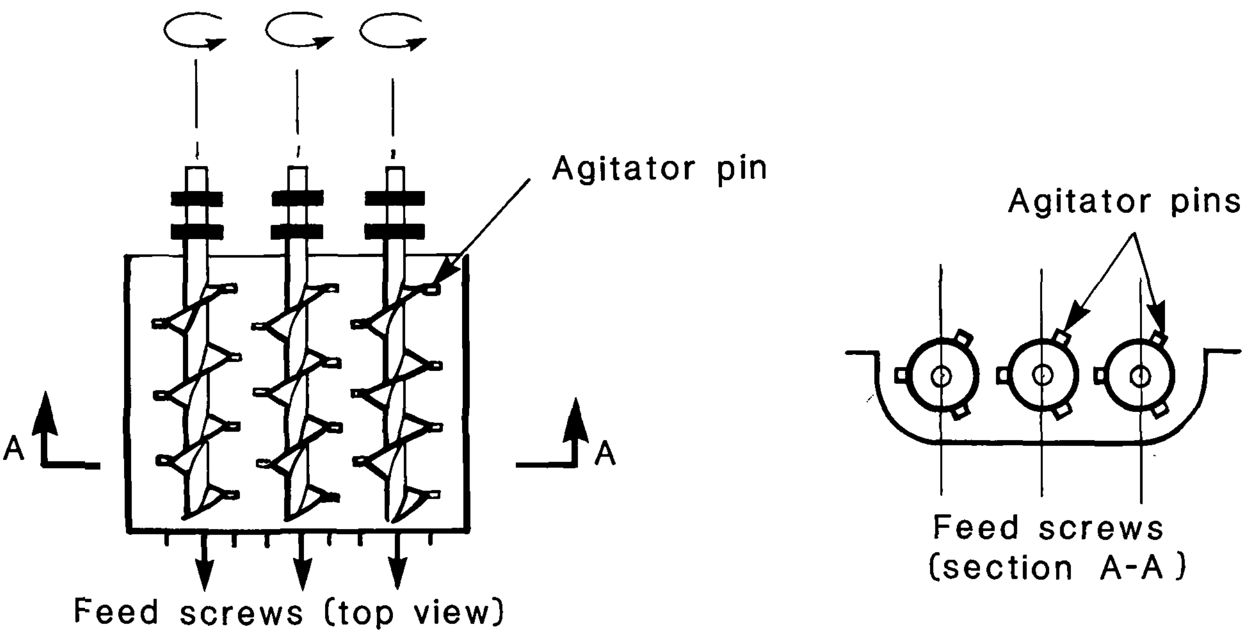

Figure 6 **Feed Screws with Agitator Pins**

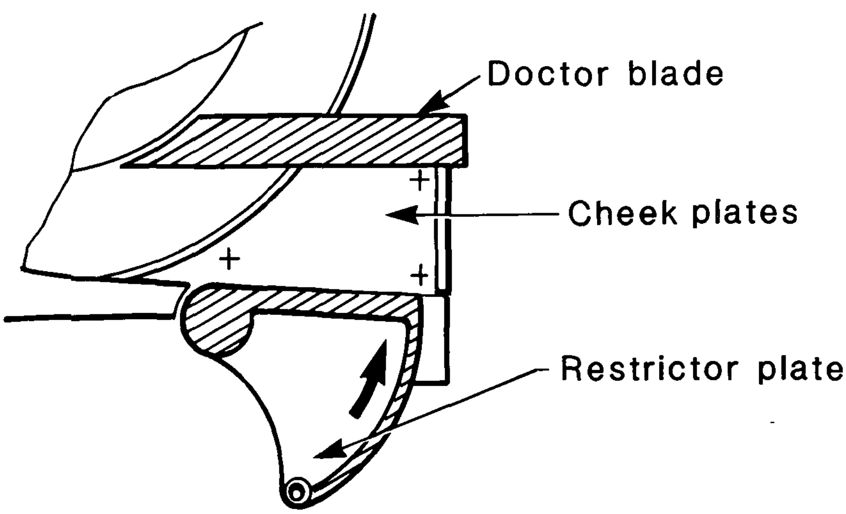

Figure 7 **Cross Section of Press Outlet**

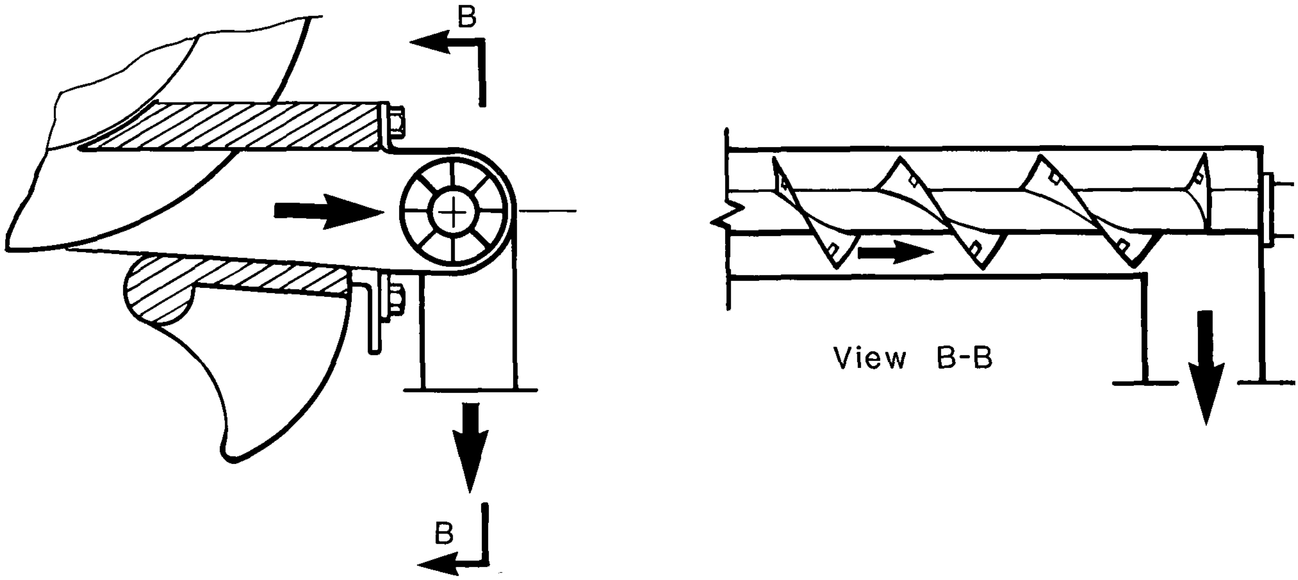

Figure 8 **Discharge Screw-Shredder**

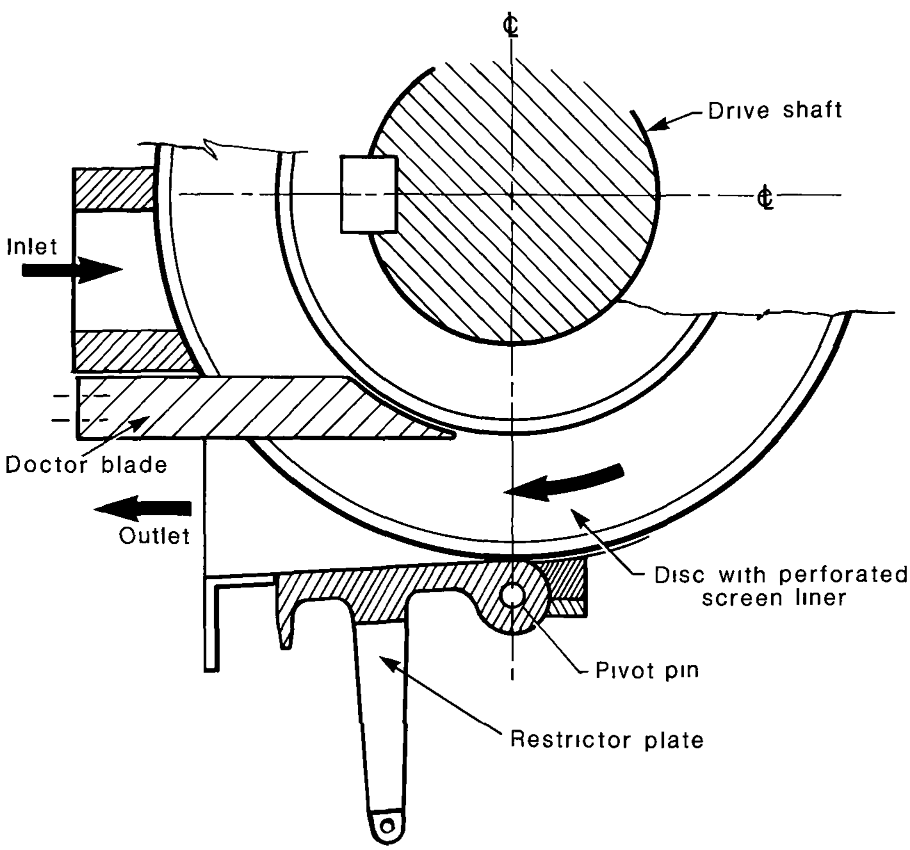

Figure 9 **Partial Cross Section Showing Original Ring Press Discharge Arrangement**

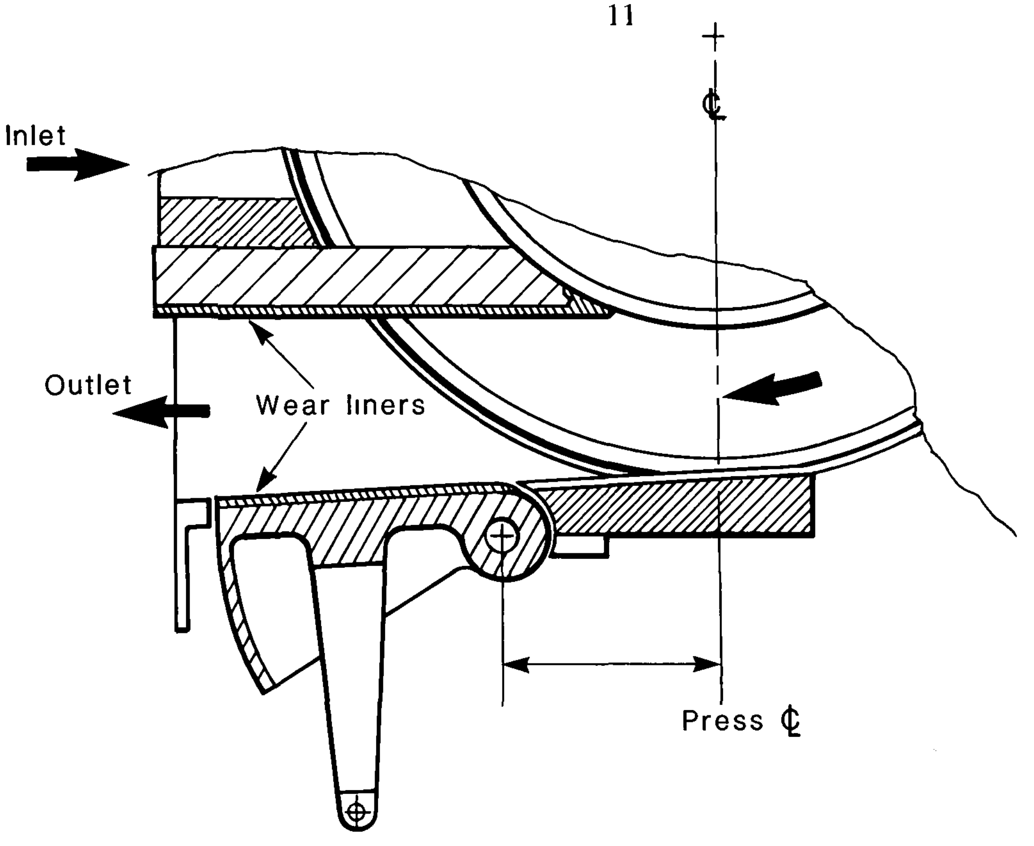

Figure 10 Partial Cross Section Showing Modified Ring Press Discharge Arrangement

3.2 Problems Encountered/Solutions

3.2.1 Initial Start-up

The restrictor blades broke after only a few hours of operation due to a design defect (Figure 7). The problem was recognized and promptly corrected by Kamyr, Inc., who supplied new restrictor blades of much heavier construction

3.2.2 Operating Pressure

The consistency to which materials can be pressed depends, for the most part, on the compressibility of the fibers. Higher pressing pressures and higher temperatures result in closer compaction of the fibers, leaving less space for residual water.

It became immediately apparent that the mill air pressure of 80 psig was insufficient to apply enough force on the restrictor plates to achieve the expected degree of water removal. After studying various alternatives, Kamyr, Inc. supplied an air compressor capable of operating at 150 psig, which significantly improved the level of dewatering

The press was operated at a conservative pressure of 120 psig until August 1989, at which time the operating pressure was increased to 150 psig. Plans to modify the system to operate at a pressure of 200 psig are being considered.

3.2.3 Shredder Jamming

As shown in Figure 8, a shredder screw is attached directly to the outlet of the press, discharging in a rotary air lock. Because of a defective electrical interlock, the Ring Press did not stop after the discharge shredder stopped. Consequently, the shredder continued to fill with sludge until friction finally stalled the rotor. The 200 HP drive motor then tripped. The stresses imposed on the press at that time were enormous and were sufficient to shift the rotor assembly approximately 0.125 in. (3.2 mm) axially, causing the stainless steel disc surface to rub against the stainless steel doctor blade, galling it, sealing approximately 50% of the perforations. After undergoing a thorough inspection, the unit was restarted.

3.2.4 Doctor Blades

The original doctor blades, of stainless steel construction, deteriorated rapidly. To overcome the problem, Kamyr, Inc developed new doctor blades incorporating a cast wear plate. These were installed during a major overhaul at the end of 1988. An inspection in the summer of 1989 revealed that the rate of abrasion had been substantially reduced, but that the tip (3 in. (7.6 cm) long) of two of the doctor blade wear plates had broken off. This did not seem to affect the performance of the press, however.

In February 1990, new 316 stainless steel doctor blades with chrome plating were installed

The idea of the cast wear plate, however, was abandoned based upon cost and performance considerations.

3.2.5 Screen Plates

The side screens, which were damaged as a result of rubbing against the doctor blade, were replaced late in 1988 with chrome-plated screens for added resistance to abrasion. To date, these screens have performed as expected, the only concern being the apparent wear at the weld between the disc and the circumferential ring.

The press was opened for inspection and replacement of the doctor blades in February 1990

3.2.6 Modification of the Discharge Section

As shown in Figures 9 and 10, the restrictor plate was moved outward to increase friction in the outlet channel, retention time, pressure, and, therefore, water removal.

3.2.7 Feed Screws

The feed screws wear more frequently than other components of the press. For this reason, the screws are replaced and rebuilt on a routine basis.

3.2.8 Modification of Inlet

Modifying the inlet arrangement would allow for more equal distribution of the sludge among the three rings of the press. The three screws could discharge in one common discharge spout. Other Kamyr clients have tried various modifications; we are waiting for the results and will proceed according to their experience.

3.2.9 Press Reliability

In 1989, the press was shut down for 2 days when the tip of one of the doctor blades broke off and jammed the discharge screw This was the only unplanned downtime in 1989 directly attributed to the press. All other downtime was attributed to auxiliary equipment (e.g , feed conveyor system, discharge screw, rotary air lock).

When compared with the Reitz "Vee" presses used at the Gatineau mill in the past, the Kamyr Ring Press has proven to be exceptionally reliable and efficient.

3.2.10 Operator Intervention

The press operates at a constant rpm and with a constant pressure being applied to the restrictor plate. It is insensitive to reductions in throughput, the only limitation being that the inlet chute will eventually fill up if overfeeding occurs (in such a case, a photocell would detect the problem and interrupt the system). The press runs virtually unattended except when occasional plugging of the filtrate ports occurs. This problem is remedied through manual cleaning.

3.3 Test Results

Tests were conducted on two occasions:
(1) January 22-28, 1988 (Table 3), and
(2) August 29-30, 1989 (Table 4).

Figure 11 shows that the press input torque remains relatively constant regardless of changes in the feed rate. It also indicates that

Table 3 Ring Press Test Data, January 22-28, 1988

Test No	Eimco Filter Speed (% of maximum speed)	Filter Consistency (%)(bone-dry basis)	Freeness (CSF)	Inlet Screw (% of full amperage) 1	2	3	Cylinder Pressure (psig) 1	2	3	Press Torque (in -lb)	Cake Consistency (%) (bone-dry basis)	Press Filtrate Consistency (%)(bone-dry basis)	Production (t/d) (bone-dry basis)
1	40	21 1	--	53	52	49	80	80	80	1600	33 3	0 83	44
2	39 5	--	130	52	52	49	100	100	100	1700	34 8	0 96	44
3	39 5	20 2	--	51	51	49	125	125	125	2000	36 6	0 91	44
4	40	--	--	52	52	49	150	150	150	2200	37 3	0 97	44
5	50 5	18 5	--	51	51	48	80	80	80	1650	32 8	0 82	44
6	51	--	--	52	52	48	100	100	100	1875	33 8	1 01	44
7	51	--	--	51	51	49	125	125	125	2150	36 2	1 01	44
8	51	19 7	--	53	53	50	150	150	150	2350	36 8	1 01	44
9	61	19 4	--	54	54	50	80	80	80	1700	30 4	0 94	47
10	61	--	118	54	55	51	100	100	100	2000	31 7	0 93	47
11	61	--	--	54	56	52	125	125	125	2500	34 8	0 95	47
12	61	18 9	--	53	55	51	150	150	150	2600	36 3	0 98	47
13	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	--
15	70	--	--	52	53	49	125	125	125	2300	31 0	1 22	57
16	70	18 6	--	53	54	49	150	150	150	2750	36 5	1 18	57
17	80	16 7	--	52	57	48	150	150	150	2900	33 0	1 10	61
18	80	--	111	52	57	50	125	125	125	2700	30 5	1 11	61

Note The side screen on the tending side of each ring channel had been scored and plugged prior to this test The Ring Press, therefore, was not operating at its full potential In spite of being heavily damaged, however, these data indicate that the performance of the Ring Press was acceptable

Table 4 Ring Press Test Data, August 29-30, 1989*

Test No	Eimco Filter Speed (% of maximum speed)	Filter Consistency (%)(bone-dry basis)	Inlet Screw (% of full amperage) 1	2	3	Cylinder Pressure (psig) 1	2	3	Press Torque (in -lb)	Press Motor amperage	Cake Consistency (%) (bone-dry basis)	Production (t/d) (bone-dry basis)
1	40	19 7	50	45	45	100	100	100	2200-2300	54	38 2	42 1
2	40	--	50	45	45	125	125	125	2600-2900	60	39 2	42 1
3	40	--	50	45	45	150	150	150	2800-3200	63	40 7	42 1
4	50	18 9	50	45	45	100	100	100	2300-2400	55	36 8	37 7
5	50	--	50	48	47	125	125	125	2800-2950	62	38 8	37 7
6	50	--	50	48	47	150	150	150	3000-3200	64	40 1	37 7
7	60	17 6	50	49	47	100	100	100	2300-2450	56	35 7	38 2**
8	60	--	48	48	46	125	125	125	2750-2950	60	37 3	38 2**
9	60	--	51	51	48	150	150	150	3000-3200	64	40 6	38 2**
10	70	18 7	48	46	45	100	100	100	2500-2700	56	37 7	40 9
11	70	--	48	47	45	125	125	125	3000-3100	62	39 8	40 9
12	70	--	48	47	45	150	150	150	3100-3300	64	40 9	40 9
13	80	18 4	48	47	45	100	100	100	2400-2600	56	37 2	48 2
14	80	--	48	47	45	125	125	125	2900-3100	61	39 0	48 2
15	80	--	48	47	45	150	150	150	3150-3350	64	39 3	48 2
16	100	16 7	50	50	47	100	100	100	2600-2700	58	36 8	59 6
17	100	--	50	51	47	125	125	125	3050-3250	63	40 0	59 6
18	100	--	50	51	47	150	150	150	3200-3450	67	42 1	59 6

* The Ring Press has been equipped with chrome-plated screens
** Production rate taken from production plot

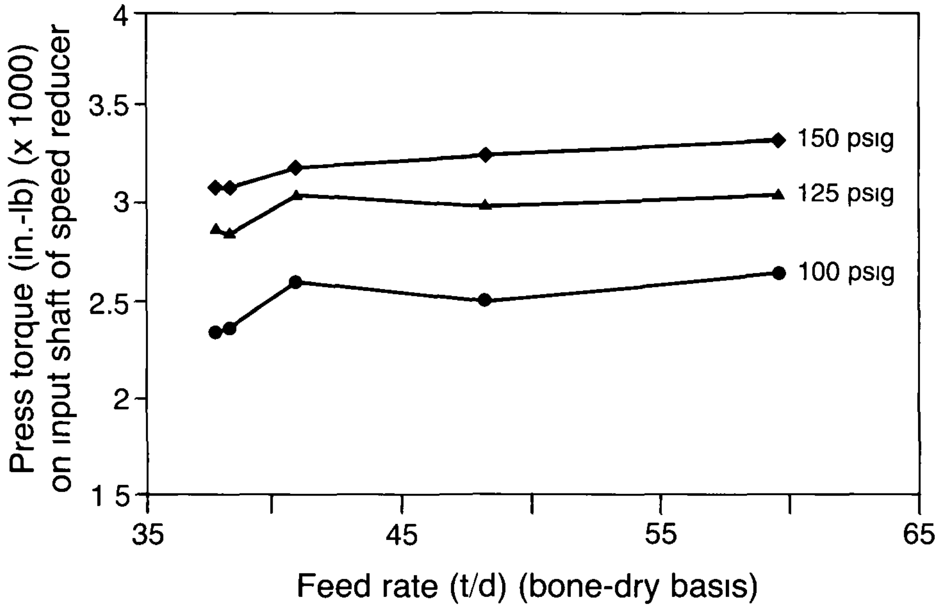

Figure 11 **Ring Press Operation with New Chromed Screens and Discharge Arrangement: Press Torque Versus Feed Rate**

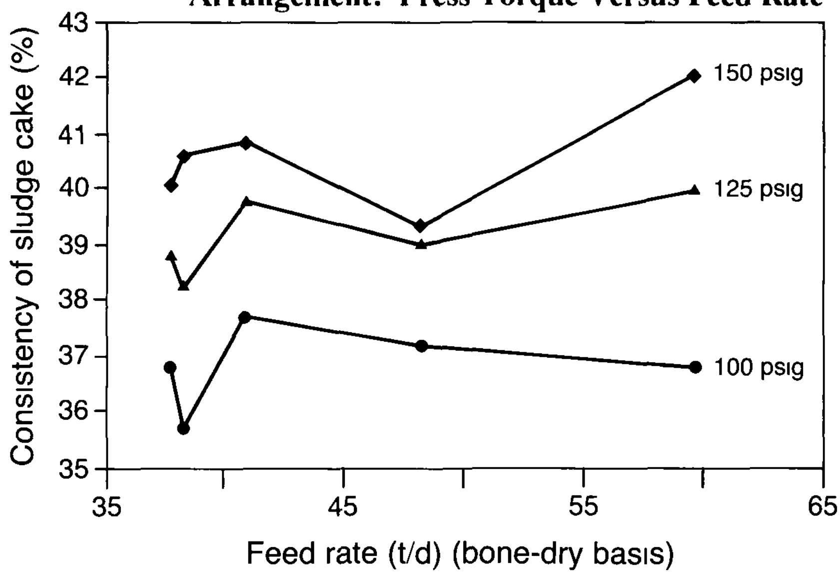

Figure 12 **Ring Press Operation with New Chromed Screens and Discharge Arrangement: Consistency Versus Feed Rate**

the press torque increases as pressure on the restrictor plate increases. Both of these observations characterize the operation of the Ring Press versus other types of machines where, for example, the torque would be proportional to the feed rate.

Figure 12 illustrates that the consistency of the sludge cake increases as pressure on the restrictor plate increases. It also reveals that consistency remains relatively constant even at 50% of the maximum throughput. This is an important advantage of the Ring Press compared with other presses where the consistency will drop drastically if the press is running below its rated feed rate. Other presses require complicated control systems (variable speed control or back pressure control, for example) to retain cake dryness with varying feed rates. The Ring Press, on the other hand, operates at constant speed and back pressure at any feed rate.

Section 4

Economic Evaluation

The time frame for this comparison is the last 4 months of 1986 and 1989.

Table 5 indicates that the average feed rate to the boiler in 1986 was 37.4 t/d on a bone-dry basis, whereas the average feed rate in 1989 was 53.7 t/d, an increase of 16.3 t/d. The moisture content of the sludge fed to the Reitz Press and the Kamyr Ring Press was essentially the same (Table 6). However, average moisture levels of sludge leaving the Reitz and Kamyr presses for the corresponding periods in 1986 and 1989 were 76.8 and 60.2%, respectively, representing percentage reductions in moisture content of 5.5 and 27.6 for the Reitz and Kamyr presses (Table 6). Thus, sludge leaving the Kamyr Press contained 21.6% less moisture than that leaving the Reitz Press

The high moisture content of the product (sludge) fed to the boiler in 1986 limited the input rate to 35 to 40 t/d. At rates higher than 40 t/d, the input rate exceeded the combustion rate, causing sludge buildup in the furnace When this occurred, it was necessary to discontinue feeding bark and sludge to the boiler

The Kamyr Ring Press is capable of operating at a feed rate of 50 t/d and producing a product with a moisture content in the 55 to 60% range. In the tests conducted, the average sludge feeding rate achieved (53.7 t/d) falls within the operating specifications of the press. As well, the moisture content of the product (60.2%) is at the upper end of the design range. At this moisture content, the boiler is capable of combusting sludge at a rate of 50 to 56 t/d. Sludge feeding rates greater than 55 t/d, however, exceed the design specifications of the press and the capacity of the dewatering filter ahead of the press.

Table 5 Sludge Feed Rate to Boiler No. 6

Year	Month	Feed Rate (t/d) (bone-dry basis)
1986	September	38 2
	October	36.4
	November	38.3
	December	36.7
	Average	37.4
1989	September	55.2
	October	49.6
	November	53.3
	December	56.6
	Average	53.7

Table 6 Sludge Moisture Levels

Reitz Press

Date (1986)		Moisture (%) After Press	Moisture (%) Before Press
Aug.	31-Sept. 6	79.1	82.2
Sept	7-13	76.7	81.3
	14-20	--	82.4
	21-27	74.8	83.3
	28-Oct.4	76.9	81.3
Oct.	5-11	78.1	82.8
	12-18	76.6	82.8
	19-25	--	79.9
	26-Nov 1	76.9	81.3
Nov.	2-8	78.1	82.8
	9-15	76.6	82.8
	23-29	--	79.9
	30-Dec. 6	75.5	80.0
Dec.	7-13	--	77.4
	14-20	74.8	80.9
	21-27	77.4	78.9
Average		76.8	81.3

Kamyr Press

Date (1989)		Moisture (%) After Press	Moisture (%) Before Press
Sept.	3-9	--	--
	10-16	58.5	82.9
	17-23	59.6	83.6
	24-30	61.2	82.8
Oct	1-7	60.0	83.7
	8-14	61.5	84.3
	15-21	60.1	83.5
	22-28	60.2	82.5
	29-Nov. 4	62.0	80.9
Nov.	5-11	59.9	83.6
	12-18	61.1	83.3
	19-25	59.6	83.6
	26-Dec. 2	61.2	83.5
Dec	3-9	60.5	82.9
	10-16	60.4	84.0
	17-23	57.4	81.8
Average		60.2	83.1

The efficiency of the boiler when combusting sludge from the Kamyr Ring Press, with a moisture content of 60.2%, is calculated to be 57.8% (Table 7). The efficiency of the boiler when combusting sludge from the Reitz "Vee" Press, with a moisture content of 76.8%, on the other hand, is calculated to be 32.5%. The potential savings resulting from using the Kamyr Ring Press (with its increased combustion efficiency and lower moisture levels of the sludge) are estimated to be $515 540 per year (Appendix A).

Indications are that the return on capital investment is approximately 2.5 years.

The combustion of sludge (recovered fibre) represents approximately 30% of the total wood residue combusted. The steam generated from this supplies 10% of the total energy required by the Gatineau facility. Translated into equivalent oil savings, the combustion of waste wood products currently saves about 7000 barrels of oil per month (Table 8, Appendix B).

Table 7 Boiler Operation

Parameter		Unit	Value
Boiler drum pressure		psig	500
Feedwater temperature		°F*	224
Excess air		%	40
Flue gas temperature		°F	500
Enthalpy of steam		Btu/lb**	1 204
Fuel efficiency:	Bunker C	%	84.5
	Natural gas	%	82
Fuel			
Bunker C: heat value		Btu/gal***	180 000
Natural gas		Btu/ft³+	1 000
Bark and sludge		Btu/lb	8 700
Cost (Bunker C)		$ Cdn/bbl	21.35
Sludge burning			
Input:	1989	t/d (bone-dry basis)	53.7
	1986	t/d (bone-dry basis)	37.4
Moisture:	1989	%	60.2
	1986	%	76.8
Efficiency:++	1989	%	57.8
	1986	%	32.5

* $°C = \frac{°F-32}{1.8}$
** 1 Btu/lb = 2 326 kJ/kg
*** 1 Btu/gal = 0 232 kJ/L
\+ 1 Btu/ft^3 = 37 3 kJ/m^3
++ The combustion efficiency of burning sludge was taken from published graphs (author unknown) of combustion efficiency versus moisture content for various flue gas temperatures at fixed percent excess air, radiation loss, and unknown losses

Table 8 Fossil Fuel Consumption, 1989

	Total Gas Consumption ($m^3 \times 10^3$)	No. 6 Boiler* Gas Consumption ($m^3 \times 10^3$)	Gas Consumption of Other Boilers ($m^3 \times 10^3$)	Oil Consumption of Other Boilers (bbl)
Sept.	9 176	1 052	8 124	2 703
Oct	9 489	1 401	8 088	13 586
Nov.	8 071	1 482	6 589	27 614
Dec.	4 878	968	3 910	38 306

	Total Steam Generated (lb x 10^3)	No. 6 Boiler Steam Generation (lb x 10^3)	Other Steam Generation (lb x 10^3)	Mill Days of Operation
Sept.	313 074	67 862	245 212	29
Oct.	372 248	77 304	294 944	31
Nov	401 007	79 287	321 720	30
Dec.	332 745	45 911	286 834	23

	No 6 Boiler Steam Generation (lb x 10^3)	Steam Generation Using Gas (lb x 10^3)	Steam Generation Using Bark and Sludge (lb x 10^3)	%	Oil Saved** (bbl)	No. 6 Boiler Days of Operation
Sept.	67 862	30 105	37 757	55 6	7 177	29
Oct.	77 304	40 083	37 221	48.1	7 075	31
Nov.	79 287	42 406	36 881	46.5	7 010	30
Dec.	45 911	27 693	18 218	39.7	3 463	16

* No 6 boiler is the hog fuel boiler at the Gatineau mill
** Refer to Appendix B for detailed calculations

Section 5

Conclusions

Overall, the experience with the Kamyr Ring Press at the Canadian Pacific Forest Products Limited mill in Gatineau, Quebec, was positive.

The key advantages of the Kamyr Ring Press are its compact design, simplicity of operation, and reliability. The press operates at a constant rpm and constant back pressure; it can accept load reductions without resulting in subsequent increases in the moisture content of the sludge cake exiting the discharge outlet; the absence of a fixed pinch point eliminates plugging; and the addition of polymers is not required. In short, the Kamyr Ring Press is capable of operating virtually unattended.

In addition to these physical/mechanical advantages, the sludge cake discharged from the Kamyr Ring Press has associated environmental benefits.

The reduced moisture content of the sludge allows it to burn more efficiently in the bark boiler. Therefore, the sludge feed rate to the boiler can be increased, which increases the amount of steam/energy generated while reducing fossil fuel consumption and the amount of waste requiring disposal at a landfill site. This, in turn, translates to financial savings.

Appendix A

Calculation of Potential Energy Savings and Environmental Benefits

Fuel Reduction

Increased heat transfer to steam resulting from the increased combustion efficiency of the boiler:

$$8700 \frac{Btu}{lb} \times 2000 \frac{lb}{t} \times 1.1023 \times \left[(53.7 \frac{t}{d} \times 0.578) - (37.4 \frac{t}{d} \times 0.325) \right]$$

$$= 3.621 \times 10^{8} \, Btu/d$$

Bunker C fuel required to produce an equivalent amount of energy:

$$\frac{3.621 \times 10^{8} \, Btu/d}{180000 \frac{Btu}{gal} \times 0.845 \times 35 \frac{gal}{bbl}}$$

$$= 68.02 \, bbl/d$$

Potential annual savings:

$$68.02 \frac{bbl}{d} \times \frac{\$21.35}{bbl} \times 355 \, d$$

$$= \$515\,540.59$$

Waste Reduction

The increase in the sludge feeding rate to the boiler results in a decrease in the amount of waste being transported to a dump site.

Annual reduction in waste.

$$16.3 \frac{t}{d} \times 355 \, d$$

$$= 5786.5 \, t$$

Waste is normally transported to a municipal dump site in boxes capable of holding 18 t of waste. The cost of disposing of these boxes at the dump site is $145 per box. Thus, annual savings amounting to

$$\frac{5786.5 \, t}{18 \frac{t}{box}} \times \frac{\$145}{box}$$

$$= \$46\,613.47$$

can be realized as a result of this reduction in waste

Operating Costs

Electricity:

$$100\ HP \times 24\ \frac{h}{d} \times 350\ \frac{d}{year} \times 0.7457\ \frac{kW}{HP} \times \frac{\$0\ 0145}{kW\ hour}$$

= $9082 63/year

Maintenance: MTL and labour

= $100 000/year

Total operating costs, therefore, are $109 082 63/year.

Net Annual Savings

$515 540.59 + $46 613.47 - $109 082.63

= $453 071.43

Appendix B

No. 6 Boiler - Oil Saved

The total steam generated (measured, a) minus the steam generated from gas (calculated, b) equals the steam generated from bark and sludge converted to equivalent barrels of oil (c).

Example calculation for September 1989 (refer to Table 8):

(a) Total steam generated. $67\,862 \times 10^3\ lb$

(b) Steam generated from gas: $1\,052\,498\ m^3 \times \dfrac{1\,000 ft^3}{28.328\ m^3} \times 1\,000\ \dfrac{Btu}{ft^3} \times \dfrac{1}{1\,012}\ \dfrac{lb}{Btu} \times 0.82$

$= 30\,105 \times 10^3\ lb$

(c) Steam generated from bark and sludge, a - b: $37\,757 \times 10^3\ lb$

Equivalent oil savings:

$37\,757 \times 10^3\ lb \times 1\,012\ \dfrac{Btu}{lb} \times \dfrac{1}{180\,000}\ \dfrac{gal}{Btu} \times \dfrac{1}{0.845} \times \dfrac{1}{35}\ \dfrac{bbl}{gal}$

$= 7\,177\ bbl$