Heat Recovery Aspects of Sunds Defibrator's TPM/CTMP Systems

Engstrom Bengt*, Jackson Michael**

INTRODUCTION

In TMP and CTMP production a large portion of the elecrical energy input is dissipated as heat which in turn generates steam. This contaminated steam can be separated from the pulp at pressures in the range of 4 to 5 bar (55 to 70 psig) and used to generate clean steam suitable for use in pulp and paper machine dryers. Steam separation techniques and the full utilization of the generated steam have become important aspects of process technology and represent an integral part of many of the TMP and CTMP systems in operation today.

Development of energy recovery systems has played a major role in TMP and CTMP pulping during the past decade, a role in which Sunds Defibrator has played an active part.

REFINER HEAT BALANCE

It is generally accepted that about 90 percent of the refining energy used in a TMP or CTMP system is converted into steam. Some of this steam is required for presteaming, for preheating the chips prior to refining and for heating the dilution water. The remainder, which amounts to between 60 and 70 percent of the generated steam, is recoverable.

The total amount of heat available for recovery can be determined from a simple heat balance using the following nomenclature :

C_i— consistency (kg. dry fiber/kg stock) of raw material entering the refiner at temperature T_i.

C_o— consistency of raw material discharging from the refiner at temperature T_o.

T_d— temperature of the dilution water.

E_i— electrical energy consumption, kWh/BD tonne (1 kWh/BD tonne=860 calories/kg.).

Assuming a specific heat value of 0.34 for lignocellulosic material, the refiner heat balance per kilogram of dry fiber consists of the following components:

(a) Increase in heat content (cal) of entering water is given by :

$$\left(\frac{1-C_i}{C_i}\right)\left(H_{wo}-H_{wi}\right)$$

where H_{wi} and H_{wo} are the enthalpy values for water corresponding to the inlet and outlet temperatures Ti and T_o respectively.

(b) Increase in heat content (cal) of fiber material is given by :

$$0.34\left(H_{wo}-H_{wi}\right)$$

(c) Increase in heat content (cal) of that proportion of the dilution water which is not evaporated is given by :

$$\left(\frac{1-C_o}{C_o}-\frac{1-C_i}{C_i}\right)\left(H_{wo}-H_{wd}\right)$$

where H_{wd} is the enthalpy of the dilution water.

Thus the total heat (in calories) transferred to the pulp is given by :

$$H_{wo}\left[0\,34+\left(\frac{1-C_o}{C_o}\right)\right]-H_{wi}\left[0\,34+\left(\frac{1-C_i}{C_i}\right)\right]-H_{wd}\left[\left(\frac{1-C_o}{C_o}\right)-\left(\frac{1-C_i}{C_i}\right)\right]$$

The difference between this quantity and the heat equivalent of the electrical energy input (E_i) at the refiner represents the total recoverable heat, Q_r. This is given by the following expression :

*Sunds Defibrator, Inc., Minneapolis, Minnesota
**Sunds Defibrator Ltd., Vancouver, B.C.

REFINER HEAT BALANCE

$$Q_r = 860\,E_i - H_{wo}\left[0.34 + \left(\frac{1-C_o}{C_o}\right)\right] + H_{wi}\left[0.34 + \left(\frac{1-C_i}{C_i}\right)\right] + H_{wd}\left[\left(\frac{1-C_o}{C_o}\right) - \left(\frac{1-C_i}{C_i}\right)\right]$$

where Q_r = total recoverable heat, cal/kg
E_i = specific energy consumption, kWh/tonne
H_{wi} = enthalpy of water at refiner inlet temperature, T_i
H_{wo} = enthalpy of water at refiner outlet temperature, T_o
H_{wd} = enthalpy of refiner dilution water at temperature, T_d
C_i = consistency of raw material (kg fibre/kg stock) entering refiner at temperature, T_i
C_o = consistency of raw material (kg fibre/kg stock) discharging from refiner at temperature, T_o

$$Q_r = 860\,E_i - H_{wo}\left[0.34 + \left(\frac{1-C_o}{C_o}\right)\right] + H_{wi}\left[0.34 + \left(\frac{1-C_i}{C_i}\right)\right] + H_{wd}\left[\left(\frac{1-C_o}{C_o}\right) - \left(\frac{1-C_i}{C_i}\right)\right]$$

The term Q_r includes that heat necessary for the presteaming and preheating of chips as well as that required for the heating of dilution water.

REFINER SYSTEM DEVELOPMENTS

During the past two to three years, Sunds Defibrator's TMP/CTMP systems have undergone development towards single-stage refining systems and towards pressurized two-stage systems including pressurized reject refining. These developments have further improved the potential for the improved recovery of steam at high pressure. Sunds Defibrator has thoroughly investigated the consequences of running the TMP and CTMP refiners at higher refiner casing pressure and trials have been conducted in systems containing both single-disc and double-disc refiners.

The single-stage refining unit at the Hallsta papermill (Fig. 1) can be described as a reference installation for these developments

The TMP plant consists of two single-stage pressurized refiners, the RLP 58 and the CD 70 units, which have a connected power of 7.0 MW (9,500 HP) and 13.5 MW (18,300 HP) respectively. After atmospheric presteaming and chip washing, the chips are fed to one of two preheaters where they are treated in a steam atmosphere at a pressure of 2.0 to 2.3 bar for two to three minutes. Each preheater feeds to its own pressurized refiner where the preheated chips are converted to thermomechanical pulp in a single refining stage. The refined pulp from each refiner is blown to a pressure cyclone and, after steam separation, the pulp discharges to a common latency chest prior to screening, cleaning and reject refining.

The restriction formed between the opposing working surfaces of the refining segments acts as a pressure seal between the refiner housing and the refiner inlet as described in Fig. 2. The refiner inlet pressure and the refiner housing pressure can thus be controlled at different levels independent of each other.

In a two-stage refining system, the primary pressure cyclone is connected directly to the side feed screw of the secondary refiner. The secondary refiner will operate under the same conditions as a primary refiner and thus the TMP steam can be collected at the same pressure from both the primary and the secondary cyclone.

Figure 1. Schematic Diagram of Single-Stage TMP Plant during Trial Period.

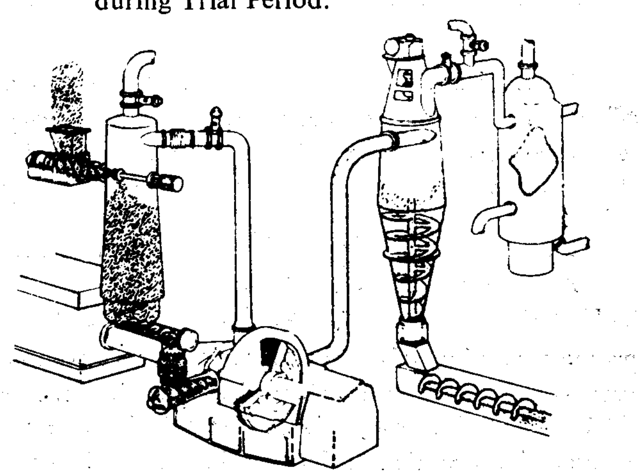
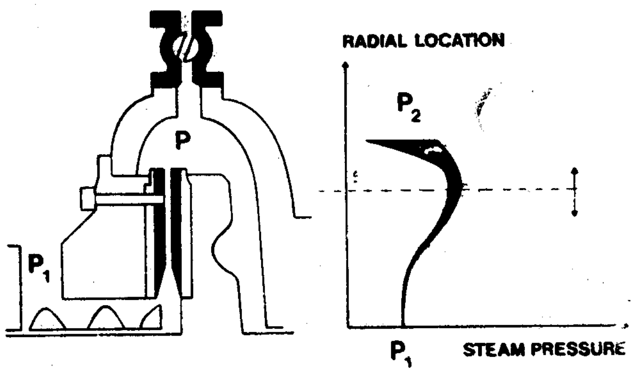


Figure 2. Schematic Diagram indicating Change in Steam Pressure through the Refining Zone.



Detailed data from some of these trials conducted at Hallsta in January 1982 were outlined in a recent paper presented at the Mechanical Pulping Conference in Washington (1). The main questions on refiner operation at high steam pressures (or high temperatures) concerned the effect of high temperature steam on pulp brightness and strength properties. As clearly indicated in Table 1, operating at high refiner casing pressure has no detrimental effect on brightness. It was essentially the same for pulps produced at normal and elevated pressure.

TABLE—1

Effect of preheating and refiner housing pressure on optical properties (average figures from six days of trials).

Preheater Pressure, Bar	2.2	2.2	1.0
Refiner Housing Pressure, Bar	2.5	5.0	5.0
Light Absorption Coefficient, m^2/kg	10.7	11.4	10.1
Brightness, ISO%	54.5	53 5	55.2

These trials also proved that there were no adverse effects on pulp strength properties. On the contrary, it was discovered that long fiber content increased and that tear index and tensile index improved.

Data referring to the tear index are given in Fig. 3.

As a result of these trials, Sunds Defibrator's latest TMP and CTMP systems have been designed for high pressure refining after atmospheric or conventional preheating. The latest system, incorporating the new RGP 60 sixty-inch singledisc refiner unit, is currently in commercial operation at the Braviken mill (Fig. 4).

Figure 3. Relationship between Pulp Drainage Characteristics and Tear Strength for Different Preheating and Refining Conditions.

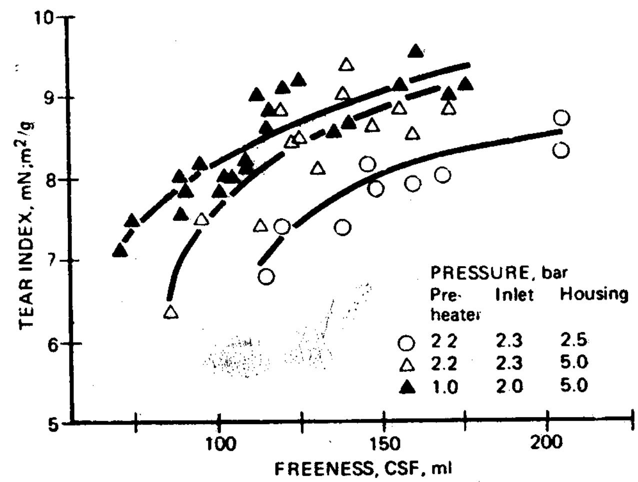
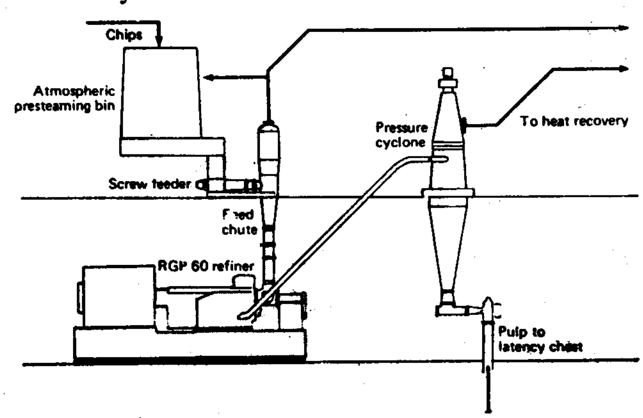


Figure 4. Schematic Diagram of Single-Stage TMP System at Braviken Mill.



This RGP 60 refiner, which is equipped with an 8 MW (10,800 HP) motor for a production of 100 ADMT/D, incorporates a new design that provides exceptional stability at the very high steam pressure operations that can be of interest in TMP and CTMP manufacture in the future. The RGP 60 refiner is designed for a maximum steam pressure of 9 bar (133 psig.)

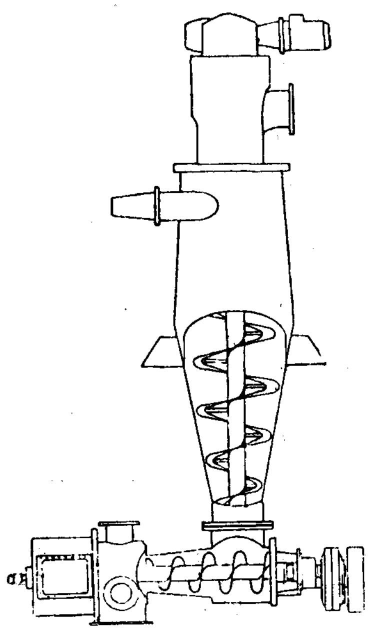
Trials conducted with pressurized double-disc refiners have yielded similar positive results. The TMP single-stage line at the Ortviken mill consists of an atmospheric preheater connected to a new RSA 1500 sixty-inch pressurized double-disc refiner. This refiner, which has been in operation for more than a year, is equipped with a 12 MW (16,300 HP) motor for a production of 150 ADMT/D TMP at a refiner casing pressure of 5 bar (70 psig).

The Ortviken mill has recently ordered a 900 T/D single-stage TMP system censisting of 5 doubledisc refiners each with 12.8 MW (17,400 HP) total installed power.

PRESSURIZED CYCLONE DEVELOPMENTS

As an integral pa·t of the development work towards high stεm p·essure systems, Sunds Defibrator has redesigned the pressure cyclone is presented in Fig. 5.

Figure 5
Schematic Diagram of
Prnssurized Cyclone.



In order to achieve a vapor-tight outlet even at very high steam pressure, the cyclone has been equipped with with a compacting screw and a specially-designed blow-out protection device The compacting screw can either be an integral part of the vertical cyclone or a separate horizontal compacting screw connected to the bottom of the cyclone. The size of the cyclone has been reduced due to the higher operating pcessures and correspondingly lower steam volumes A special feature in Sunds Defibrator's cyclone design is the slowspeed wiping screw, which prevents fiber build-up at the walls and fiber-bridging in the cyclone. This results in smooth and stable operation, ensuring that the steam leaving the cyclone has a low degree of fiber contamination.

ENERGY RECOVERY SYSTEMS, REFERENCE INSTALLATIONS

To date, Sunds Defibrator has delivered or has on order equipment for energy recovery systems to more than fifteen TMP and CTMP mills. This equipment includes 52 pressurized cyclones. Some of these installations are described in the following review (Table 2).

The first CTMP system in Canada with a heat recovery system including reboiler is the Consolidated Bathurst mill in Bathurst, New Brunswick.

NORSKE SKOGSINDUSTRIER, NORDENFJELSKE MILL, SKOGN, NORWAY

The TMP plant has a capacity of 600 ADMT/D and is equipped with four single-disc RLP 58 refiners with 8 MW (10,800 HP) motors in the primary stage and three RL 58 units with 8 MW (10,800 HP) motors in the secondary stage. An RGP 70 CD refiner has recently been ordered to be installed as a primary refiner. The capacity of the plant will then be increased to 820 ADMT/D. The main components of the steam recovery plant are four pressurized cyclones, a lamella falling-film type reboiler supplied by Rosenblads Patenter, and a thermocompressor supplied by Sultzer (Fig.6).

Basic data for the installation are supplied in Table 3.

The increased amount of steam after the compressor results from the fact that the electrical energy used to drive the comressor is converted into heat.

FOLLUM FABRIKKER, HGNEFOSS, NORWAY

The TMP plant has a cepacity of 250 ADMT/D and is equipped with two single-disc RLP 58 refiners in the primary stage and one RLP 58 in the secondary stage. All these refiners are equipped with 7.5 MW 10,200 HP) motors.

The main components in the steam recovery plant are two pressurized cyclones, a lamella falling-film reboiler supplied by Ahlstrom, Finland, and steam ejectors. The system is described in Fig 7.

The ejectors are normally operated fully open. The set point for the control valve for the motive steam is 3.2 bar (47 psig). To maintain clean-steam pressure in the reboiler during shut down of the TMP plant, there is a valve for recirculation of the steam from the 3 bar (44 psig) system.

Basic data concerning this intallation are given in Table 4.

TABLE—2. Sunds Defibrator TMP heat recovrey systems.

Mill	ADMT/D	Clean steam lbs/hour	Pressure psig	Heat recovery system
Billerud-Uddeholm Skoghall Mill Sweden	530	46,200	37	Folbex
Consolidated-Bathurst Bathurst, N.B. Canada	480	76,100	30	Aqua-Chem
Follum Fabrikker Honefoss Norway	300	37,400	25	Ahlstrom
Holmens Bruk Hallsta Paper Mill Sweden	260 350	39,800 34,300	40 35	Celleco Celleco
Holmens Bruk Braviken Paper Mill Sweden	600	68,000	40	Celleco
No·ske Skogsindustrier Nordenfjelski Mill Norway	600	66,000	42	Celleco
Stora Kopparberg Kvarnsveden Paper Mill Sweden	335	52,800	38	Celleco
SCA Ortviken Sweden	900	99,000	39	Rintekno
Donohue Inc. Clermont, Quebec	880	125,000	45	CE Bauer 3R

Table 3. Basic data, Nordenfjelske Mill.

Type of Plant	Two-Stage TMP for Newsprsnt
Pulp Production	600 ADMT/D
Installed Motors	1 Stage 4×8 MW (10,800 HP) 2 Stage 3×8 MW (10,800 HP)
Generated Steam:	
TMP Steam Flow	30 t/h (66,000 Lbs/h)
TMP Steam Pressure	3.5 bar (51 psig)
TMP Steam Temperature	138°C
Clean Steam After Reboiler·	
Generated Steam Flow	28 t/h (61,600 Lbs/h)
Generated Steam Pressure	2.8 bar (41 psig)
Generated Steam Temperature	130°C
Clean Steam After Compression:	
Flow	33 t/h (72,600 Lbs/h)
Pressure	4 bar (59 psig)
Temperature	143°C

Table 4. Basic data, Follum Mill

Type of Plant	Two-Stage TMP for Newsprint
Pulp Production	300 ADMT/D
Installed Motors	1 Stage 2×7.5 MW (10,200 HP) 2 Stage 1×7.5 MW (10,200 HP)
Generated Steam:	
TMP Steam Flow	14 t/h (30,800 Lbs/h)
TMP Steam Pressure	3.9 bar (57 psig)
TMP Steam Temperature	142°C
Generated Steam After Reboiler:	
Generated Steam Flow	13 t/h (28,600 Lbs/h)
Generated Steam Pressure	2.8 bar (41 psig)
Generated Steam Temperature	130°C
Clean Steam after Ejectors:	
Flow	22 t/h (48,000 Lbs/h)
Pressure	3.7 bar (54 psig)
Temperature	140°C

Figure 6. The Nordenfjelske Mill, Steam Recovery System.

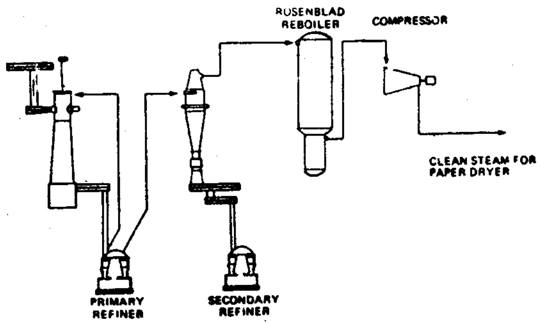
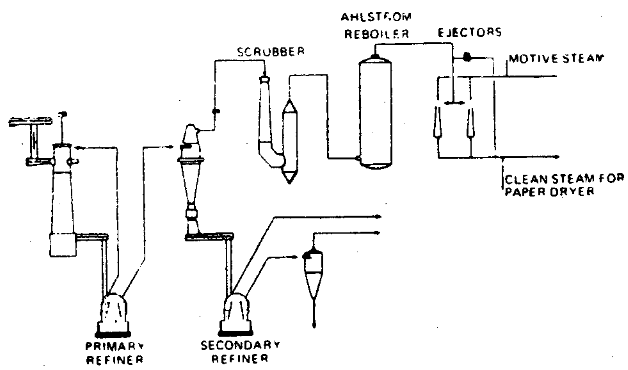


Figure 7. The Follum Mill, Steam Recovery System



The energy recovery plant in Follum is situated at some distance from the papermill. For this reason, a higher steam pressure is required.

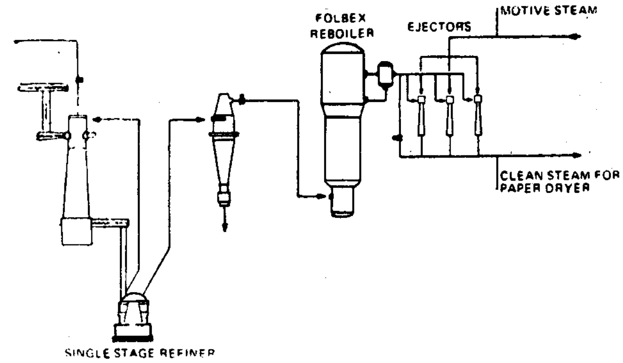
Since high pressure steam is available from a boiler, it is used in an ejector system to increase the pressure of the recovered steam for the TMP plant. This is probably the best and most economical way to increase the pressure of the generated steam.

BILLERUD-UDDEHOLM, SKOGHALL MILL, SWEDEN

The CTMP plant has a capacity of 530 ADMT/D and consist of three single-disc RLP 58 refiners equipped with 7.5 MW (10,200 HP) motors for single-stage refining.

The main components in the steam recovery plant (Fig. 8), are three pressurized cyclones, a lamella rising-film reboiler supplied by Unozon-Folbex, and steam ejectors.

Figure 8. The Skoghal Mill, Steam Recovery System.



Basic data for the installation are given in Table 5.

The recovery plant at Skoghall is the first installation using a rising-film evaporator. The pressure after the ejectors is relatively high (66 psig), a necessity for the paper-board machine at the mill.

Table 5. Basic data, Skoghall Mill.

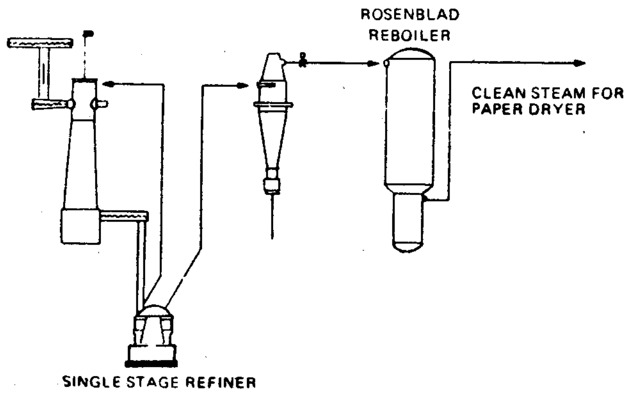
Type of Plant	Single-Stage CTMP fluff & Paperboard
Pulp Production	530 ADMT/D
Installed Motors	3×7.5 MW (10,200 HP)
Generated Steam :	
CTMP Steam Flow	22 t/h (48,400 Lbs/h)
CTMP Steam Pressure	4.2 bar (62 psig)
CTMP Steam Temperature	145°C
Clean Steam After Reboiler:	
Generated Steam Flow	21 t/h (46,200 Lbs/h)
Generated Steam Pressure	3.6 bar (53 psig)
Generated Steam Temperature	139°C
Clean Steam After Ejectors:	
Flow	40 t/h (88,000 Lbs/h)
Pressure	4.5 bar (66 psig)
Temperature	147°C

STORA KOPPARBERG'S KVARNSVEDEN PAPERMILL, SWEDEN

The TMP plant has a capacity of 335 ADMT/D and is equipped with to single-disc RLP 70 CD refiners with 13 MW (18,000 HP) motors for single-stage refining.

The steam recovery plant (Fig. 9) comprises the following main components : two pressurized cyclones and a lamella falling-film reboiler supplied by Rosenblads Patenter.

Figure 9. The Kvarnsveden Mill, Steam Recovery System.



Basic data for the installation are given in Table 6.

TABLE—6

Basic data, Kvarnsveden Papermill.

Type of Plant	Singie-Stage TMP for Newsprint
Pulp Production	335 ADMT/D
Installed Motors	2×13 MW (18,000 HP)
Generated Steam :	
TMP Steam Flow	27t/h (59,400 Lbs/h)
TMP Steam Pressure	4 2 bar (62 psig)
TMP Steam Temperature	145°C
Clean Steam :	
Generated Steam Flow	24 t/h (52,800 Lbs/h)
Generated Steam Pressure	3.7 bar (54 (psig)
Generated Steam Temperature	140°C

The Kvarnsveden installation is one of the most modern, efficient and least complicated steam recovery plants in the world.

The most recent TMP plant order for Sunds Defibrator was the 880 T/D installation for the Clermont mill of Donohue Inc. This plant will have eight RGP 70 CD refiners, each equipped with an 11 MW (15,000 HP) motor and fully pressurized primary and secondary refiners. The two RGP 60 rejects refiners, each connected to 11 MW (15,000 HP) motors, will also be pressurized.

Approximately 125,000 lbs/hour of clean steam at a pressure of 45 psig will be recovered at the Clermont mill. The steam will be used for paper drying.

CONCLUDING REMARKS

Rapid developments in heat recovery systems, along the lines indicated in this paper, will have a significant influence on the economics and development of future TMP and CTMP systems. Integrated mills will be built with a bark boiler as the main source of fresh steam, supplemented by a stand - by eleciric boiler for steam generation during periods of imbalance between pulping plant and paper mill operations. For market pulp mills, steam separated from pulp at high pressure will be used in the pulp dryer, thereby reducing fuel costs for drying.

REFERENCE

1. Jackson, M., Akerlund, G. The Effects of Preheating and Refiner Housing Pressure on the Quality Characteristics of TMP and CTMP. Paper prescnted at the International Mechanical Pulping Conference, Washington, D.C., 1983.