Energy consequences in minimum effluent market kraft pulp mills

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NOTE: This is a condensed version of the original paper. The longer, unedited text is available in the *TAPPI JOURNAL* section of TAPPI's web site www.tappi.org.

Application: This information can help mills when condsidering water reuse, in order to not increase their energy demand while doing so.

Many pulp and paper mills are closing their water loops and/or building effluent treatment plants in order to satisfy environmental regulations. When closing the water loops, non-process elements (NPE) accumulate. These NPE can cause problems such as scaling in the system. In order to stop the accumulation of NPE, different removal processes, or "kidneys," need to be introduced to the system. Many kidneys for NPE involve evaporation, which is an energy intensive process. This paper considers options to integrate kidneys involving evaporation without significantly affecting the live steam demand.

Pulp mills produce warm and hot water as part of cooling operations; modern mills usually have a surplus of warm and hot water. Earlier work shows that excess heat can be made available if the secondary heat system is designed so that it only produces necessary warm and hot water [1]. Using that excess heat for evaporation can reduce the steam demand for the mill and reduce the cooling need. We evaluated this in our related study, "Usable excess heat in future kraft pulp mills," for two different model mills, one reference model mill referred to as the base case, and one model mill with a new type of dryer [2]. For the base case, which consists of "best available technology" built and run in the Nordic countries, the total steam demand can be reduced by 14% compared to a mill having a conventional secondary heat system. This is of special interest if evaporation is used as a kidney; the extra evaporation needed could then be obtained without increasing the total heat demand for the mill. Therefore, the same method has been applied here for four different minimum effluent kraft pulp model mills.

We simulated material and energy balances for the four different model mills. The result from these simulations is the base for a process integration study, for which we used Pinch Analysis [3]. This is a well-established tool used for improving energy efficiency, mainly in the petrochemical and chemical industries. Its use in the pulp and paper industry has been less frequent, but the interest in this tool has increased [4-8]. We used Pro Pi [9], an Excel based program, as a Pinch Analysis tool. In this study, we did not evaluate how to execute the actual process integration; rather, we discuss how to make excess heat available and use it, after process integration is completed, to reach even further energy savings. We evaluate the grand composite curves (GCCs) from the process integration study and identify the potential for process modification through those curves. Our other paper presents the process integration study more thoroughly [2].

The secondary heat system is designed to make the excess heat identified in the process integration study available. This excess heat is suitable for evaporation; it should be at the highest possible temperature in order to save the most live steam [1, 10].

A new evaporation plant design is needed to make use of the excess heat. Excess heat used in the evaporation plant is introduced at one or more intermediate temperature levels and cascaded through the effects below this temperature. This method is described more thoroughly by Algehed et al. [9, 10]. Depending on the temperature of the excess heat and the design of the evaporation plant, the excess heat can be used in one or more effects.

The minimum effluent mills

The bleach plant is the largest contributor to wastewater in a pulp mill. There are several different water reuse models for reducing wastewater from a bleach plant. One method is to reuse the filtrate in the upstream stages. The problem with reusing filtrate is that NPE accumulate. The main source for NPE is the wood entering the mill, and NPE differ depending on the origin of the wood [11]. Several different kidneys to remove NPE are in use today and even more are under development. We investigated pre-evaporation of bleach plant effluent, pretreatment of the chips entering the plant, a chloride kidney for the solution of recovery boiler ashes, and combinations of the kidneys from an energy perspective, since they have a significant impact on the steam demand. We did not study the capacity or efficiency of the kidneys, but merely took the results from the Swedish National Research Program "The Eco Cyclic Pulp Mill," and assumed the quantity and quality of the pulp can be maintained. The main alternatives we investigated are the following:

- **Mill A** 7 m^3/a.d., metric tons bleach filtrate to pre-evaporation
- **Mill B** 7 m^3/a.d., metric tons bleach filtrate to chip pretreatment and 5.8 m^3/a.d., metric tons from the chip pretreatment to pre-evaporation
- **Mill C** 4.7 m^3/a.d., metric tons bleach filtrate to chip pretreatment and 3.5 m^3/a.d., metric tons from the chip pretreatment to pre-evaporation
- **Mill D** 3.7 m^3/a.d., metric tons bleach filtrate to chip pretreatment and 2.5 m^3/a.d., metric tons from the chip pretreatment to pre-evaporation.

Secondary heat system and economic conditions

For each novel secondary heat system, we also designed a distribution system

Annuity factor	0.1
Cost for electricity	US$ 20-US$ 30/MWh
Boiler efficiency	0.80 based on LHV
Power to heat ratio	0.28
Value of biomass	US$ 7/MWh

I. Conditions for the economic evaluation.

and a reference system where all the heat below the pinch temperature is cooled. The distribution system transforms the excess heat made available into usable steam, by use of heat exchangers and a steam reformer.

Included in the investment cost for the new system are the following:

- The novel secondary heat system
- The collection of excess heat
- Transformation of the excess heat to usable heat
- The evaporation plant

This is compared to the investment cost for the reference secondary heat system and the reference evaporation plant. When calculating the costs for the novel designs as well as the reference designs, we used the conditions listed in **Table I**.

Results

Table II shows the results of this study, where the numbers in parenthesis represent the values corresponding to a higher electricity price. Since the cost for the chip pretreatment is not included in this study, we did not estimate the payback period for Mills B, C, and D. Even without the chip pretreatment, the payback period would be about the same as for Mill A or significantly larger.

With the economic conditions discussed above, there is an economic gain in designing the secondary heat system differently from today and using the excess heat made available in the evaporation plant (**see Table III**).

Discussion and conclusions

The payback period for Mill A is lower compared to the base case, presented more thoroughly in our other paper [2]. For the base case it is 6.7 years and for Mill A it is 3.6 years. This is mainly because the base case has more heat exchanger units in the distribution system, thus a larger investment cost. For Mills B, C, and D, the cost for the actual chip pretreatment is not included in the cost, which is why the profit for these cases will be lower if included. For that reason, the most profitable solution is to pre-evaporate without a chip pretreatment, not considering the positive effects the chip pretreatment might have on the running of the plant. **TJ**

	REDUCTION OF TOTAL LIVE STEAM DEMAND	REVENUE FOR SOLD BIOMASS (M$/year)	INVESTMENT COST FOR THE NEW SYSTEM (M$/year)	COST[1] FOR BUYING ELECTRICITY (M$/year)	NET PROFIT (M$/year)	PAY-BACK PERIOD[2] (years)
Mill A	12%	2.8	0.5	1.3 (1.9)	1.0 (0.4)	3.6 (7.3)
Mill B						
Configuration I	16%	3.7	0.8	1.8 (2.8)	1.1 (0.1)	—
Configuration II	12%	2.8	0.5	1.4 (2.0)	0.9 (0.3)	—
Mill C						
Configuration I	18%	3.7	0.9	1.9 (2.8)	0.9 (0)	—
Configuration II	12%	2.7	0.5	1.3 (2.0)	0.9 (0.2)	—
Mill D						
Configuration I	18%	3.6	1.0	1.8 (2.6)	0.8 (0)	—
Configuration II	13%	2.6	0.5	1.3 (2.0)	0.8 (0.1)	—

[1] Cost or reduction in revenue
[2] A payback period is not calculated for Mills B, C, and D since not all costs are included
M$ = US$ million

II. Reduction of live steam demand for the four model mills compared to the reference system.

	BEFORE PROCESS INTEGRATION (GJ/a.d. metric tons)	AFTER PROCESS INTEGRATION (GJ/a.d. metric tons)	AFTER REDESIGN OF THE SECONDARY HEAT SYSTEM (GJ/a.d. metric tons)	SAVED HEAT DEMAND (GJ/a.d. metric tons)
Base case	10.4	9.3	7.8	2.6
Mill A	11.9	10.4	9.2	2.7
Mill B				
Configuration I	11.9	10.7	9.1	2.8
Configuration II	11.7	10.9	9.6	2.1
Mill C				
Configuration I	10.9	9.7	8.0	2.9
Configuration II	10.7	9.9	8.6	2.1
Mill D				
Configuration I	10.6	9.4	7.8	2.8
Configuration II	10.4	9.6	8.4	2.0

III. Total heat demand before and after process integration and redesign of secondary heat system.

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