TCF System Closure
The Kvaerner Vision

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Introduction

The pulp and paper industry has been, during the last years, under strong pressure from authorities, "green" organizations and consumers to reduce the environmental impact of the pulping processes.

Since the dioxin debate, the pulp industry has improved its operation and to a great extend, reduced the emissions of organo chlorides and other substances to the receiving waters, by the introduction of ECF (Elemental Chlorine Free) and TCF (Total Chlorine Free) pulps. About one third of the bleached kraft mills in the world produce today ECF pulp and at least 60 pulp mills produce TCF pulp.

Many companies around the world are working in the direction of recycling the bleach plant effluents in order to further decrease their water consumption and effluent discharges.

Driving forces for system closure

Environmental legislation in most countries are becoming more and more stringent. In some countries, there is taxation on use of water and effluent discharges to the environment and others are discussing to implement this system. There are also discussions about the environmental effects of chelating agents used in TCF pulp production. The natural path is then to recycle the bleach plant effluents reducing the water discharges from the pulp mill to a minimum.

The environmentally friendly products and production process are becoming an important marketing strategy. There is a lot of trade mark pulps like "Z-pulp™" from Mönsterås, "OD_{100}™" from Champion, "MoDo Balans™" from Husun, being introduced to the market with a clear "green" market appeal.

For some mill locations there are limitations on water supply or effluent discharges due to, for example, small rivers or sensitive agricultural uses of the water downstream the mill discharges. For green field mills, the "closed" concept with limited requirements of water and effluent disposal, would allow "site selections" criteria such as infrastructure, transportation distances for raw materials and products to be almost independent of water resources.

There is an increased public attention to water usage and contamination. Potable water resources in the world are limited and with population increase, more water will be needed for human and agricultural use. From the total amount of existing water on the earth, 97,3% is salted water in the oceans, 2,3% is frozen in the poles and only 0,4% is in the rivers and underground for human use.

Finally, a green field mill designed for system closure with TCF production will have lower investment and operational costs than a conventional ECF mill. There is a tendency among international financial institutions and commercial banks to require strict compliance with environmental standards before financing projects in the chemical pulp industry.

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Companies committed to closed cycle operation

The following companies have already announced commitment to closed cycle operation in the near future:

- Metsä-Rauma - Finland
- Metsä-Botnia - Finland
- Kemi Kymmene - Finland
- MoDo Paper AB - Sweden
- SCA Pulp AB - Sweden
- Södra Cell - Sweden
- Champion International Corporation - USA
- Weyerhaeuser Paper Company - USA
- Louisiana Pacific - USA
- Consolidated papers - USA
- Sappi - South Africa

Legislation

There is a clear tendency to put more stringent regulations on COD emissions once toxicity comes from both bleached and unbleached part of the mill. This means that spill collection systems and condensate cleaning will be very important to accomplish with the new regulations.

Also, there is an indication that as long as there is a liquid discharge from pulp mills, the environmental regulations and consumer demands will be tighter and tighter.

The table below shows estimated figures for discharges by year 2000.

Parameter	unit	Existing Mills	New Mills
AOX	kg/ADt	0,25-0,5	0,1-0,2
BOD	kg/ADt	2-3	0,5-2,0
COD	kg/ADt	20-30	10-20
Color	kg/ADt	70-100	40-60
TSS	kg/ADt	2-4	0,5-2,0

Source: Duoplan Report, Nov. 1994

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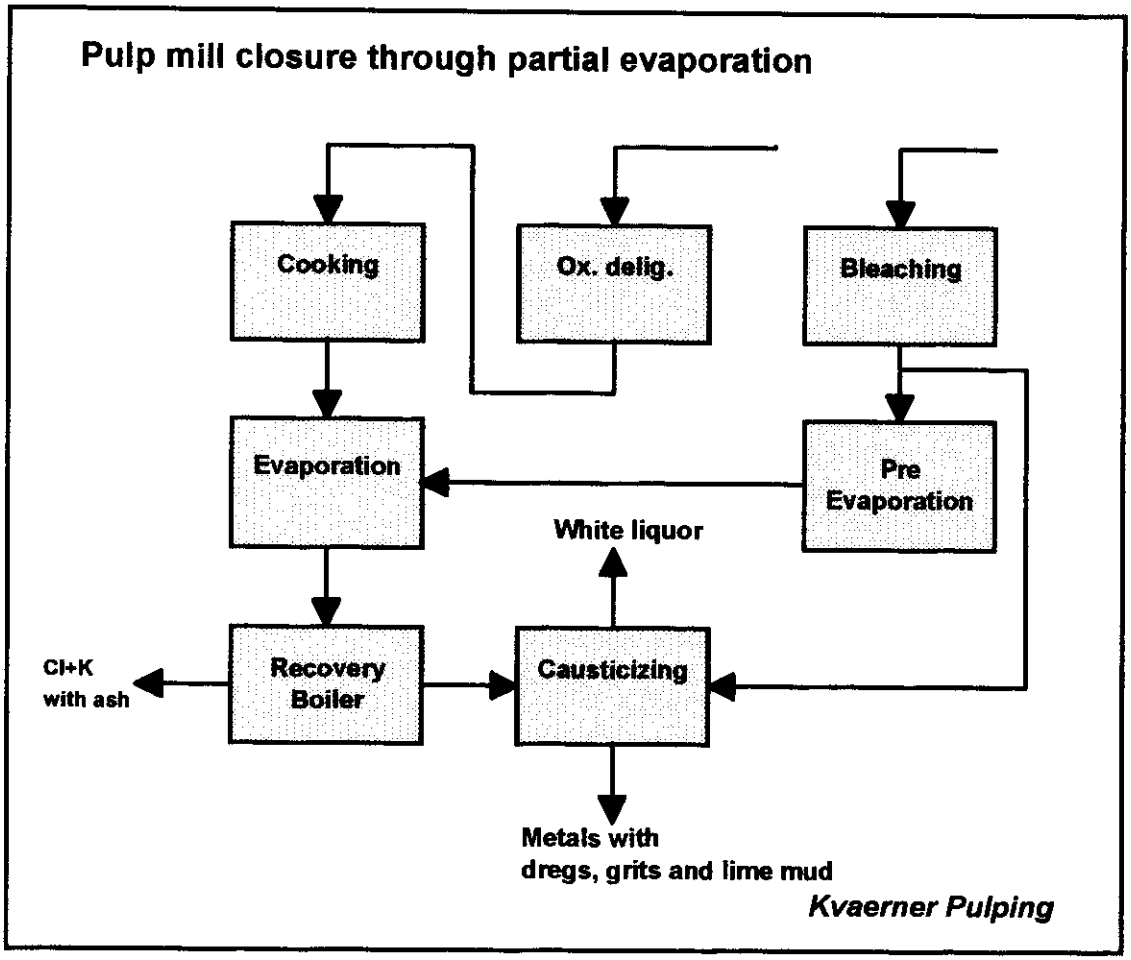
Main approach for TCF system closure

The following diagram illustrates the system for a pulp mill with closure through partial evaporation of effluents.



This process is the approach to be utilized by the mills with TCF bleaching.

The main process requirements are:

- TCF bleaching plant with low effluent flow (~5m3/ADt)
- Pre-evaporation integrated to the normal black liquor evaporation plant
- Green liquor filter for removal of non process elements like Mn, Mg and Fe
- Purge of precipitator ash to control Na/S balance and removal of chlorides and potassium that enter the mill with wood. Depending on the Na/S balance there can be also a leaching process to remove Cl and K.
- Utilization of part of the bleach plant effluent in the dissolving tank
- Steam stripper integrated to the evaporation plant with capacity to treat most of the condensates.

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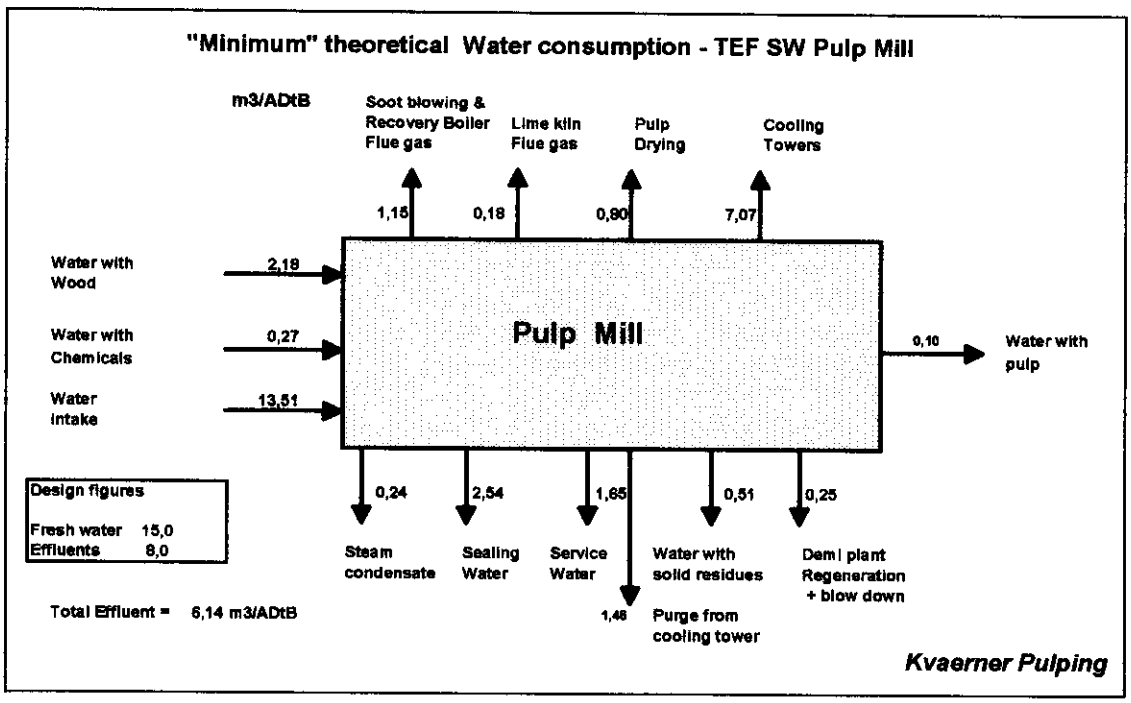
Water and heat balance

The following figures were extracted from a study made by Kvaerner for a mill that intends to implement a TEF SW bleach line with TCF bleaching technology..

The water balance for a TEF mill is site specific, mainly regarding the cooling water system.

The following diagram shows the simplified water balance for the mill.



The main specific characteristics for the mill are:

- Dry debarking in the wood handling
- BLITC™ cooking system (ITC™ with black liquor impregnation)
- TCF bleaching line with the sequence OQ(OP)(ZQ)(PO) for effluent flow of 5 m3/ADtB
- Pre-evaporation for part of the bleach plant effluents with condensate stripping
- Causticizing plant with Cassette™ green liquor filter and pressurized disc filter for white liquor
- Recovery boiler for 85bar and 480°C steam temperature
- Extraction, backpressure and condensing turbine
- No bark boiler (bark sent to existing mill)
- Additional storage tanks for bleaching effluents, white water and contaminated condensate.

We can see that the biggest amount of the water intake is due to losses in the cooling towers by evaporation. In this particular case, we have two cooling systems: one for the condensing turbine and cooling waters from equipment, with a capacity of approx. ~100 m3/ADtB, and the other for evaporation, condensates from stripping and process

coolers, with a capacity of approx. 140 m3/ADtB. We can conclude that there is still room for optimization in the cooling systems for a closed cycle mill due to the great cooling requirement (240 m3/ADtB).

On the effluent side, the discharge of 6 m3/ADtB is mainly clean water. For safety reasons and in order to guarantee a high availability of the plant in case of uncontrollable spills, the installation of a compact Kvaerner HCR™ (High-efficiency Compact Reactor) waste water treatment. was considered for this mill.

The power balance for the mill is shown in the following table:

- Woodhandling	kWh/ADtB	50
- Fiber line	kWh/ADtB	310
- Bl. stock scr. & drying	kWh/ADtB	130
- Recovery area	kWh/ADtB	170
- Ozone & oxygen generation	kWh/ADtB	110
- Others	kWh/ADtB	80
- Total	kWh/ADtB	850
- Power generation	kWh/ADtB	1100
- Excess power	kWh/ADtB	250

The green field TEF mill would be self sufficient in steam and power only by burning black liquor. In this case there was no bark boiler, but all bark could be utilized for additional power generation in a different site for external use.

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Non process elements and solid waste generation

The main concerns when designing a TEF mill is the introduction of NPE's (Non Process Elements) from wood and chemicals. Most of these NPE's are purged from the system through the bleach plant effluents in an ECF mill. Those compounds will accumulate in the liquor circuit impairing the mill operations in a mill with system closure. Elements present in very small amounts with no negative effect in today's modern mill can, due to accumulation become a problem in a closed cycle mill.

The following table shows an estimation of the amount of inorganics coming with the wood into the mill, for different woods.

Inorganics in wood into the pulp mill

	Unit	P. Taeda Brazil	P. Elliotis Brazil	Pine Scandinavia	Birch Scandinavia
Cooking yield	%	44	46	46	50
Wood	t/ADtB	2,21	2,11	2,18	2,07
Al	g/BDt	31,2	21,3	16	11
Ca	g/BDt	652	667	998	1190
Fe	g/BDt	17,4	10,7	24	21
K	g/BDt	477	538	465	616
Cl	g/BDt	750	850	162	283
Mg	g/BDt	194	165	182	213
Mn	g/BDt	84	64	76	76
Na	g/BDt	5,3	16,2	35	96
P	g/BDt	89	115	20	80
Si	g/BDt	10	24	390	320
Total inorganics	kg/ADtB	5,1	5,2	5,2	6,0

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The inorganic content of the wood depends to a great extend on the soil characteristics where the tree has grown, age and wood species.

The main elements of concern are:

Chloride and potassium

The chloride and potassium decrease the melting point of the ash in the recovery boiler. This causes a decrease in the sticky temperature (temperature when 15% and less then 70% of the carryover become melted) which increases the risk of boiler plugging and corrosion. Some of the design considerations to be taken are lower steam temperature and pressure, increased spacing and corrosion resistant materials in the superheater.

The chloride concentration in white liquor is a good indication for potential problems. The chloride and potassium concentration should not exceed ~7 g Cl/l and ~16g K/l.

Chloride and potassium are concentrating in the ESP ash and, for a TCF mill, part of the ash has to be purged from the system in order to control the sodium and sulfur balances, due to the addition of sodium hydroxide and sulfuric acid at the bleach plant.

The need for purge ESP ash can be balanced with the Na and S make-up requirements depending on the chemical charges in the bleach plant and the chlorides, potassium content in wood, steam temperature in the boiler and the enrichment factors of Cl and K in the ESP ash.

The table below shows an example calculation of the necessary bleeding of ESP ash in order to control the concentration of K and Cl. This calculation was made based on the steam temperature in the boiler (480 °C), the maximum molar ratios of Cl and K allowed in the ash in order to avoid the sticky temperature region and the Cl and K in wood.

Bleeding of precipitator ash

		Potassium	Chloride
wood consumption	t/ADtB	2,15	2,15
K(Cl) content in wood	g K(Cl)/t BD	500	800
total inlet	kg/ADtB	0,97	1,55
K(Cl) loss	%	10	10
maximum ratio K(Cl)/Na+K	mol %	8	4
enrichment factor in ESP ash	-	2,3	3,0
ratio K(Cl)/Na+K in ESP ash	mol %	18,4	12
Total ash Bleeding	kg Na2SO4/ADtB	9,6	25,3

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In this specific case, as the K and Cl content in wood is very high it is needed to purge considerable amounts of ESP ash. The necessary amount to purge due to the sulfur balance would be around 16 kg Na2SO4/ADtB. It is normally possible to balance the system by the utilization of oxidized white liquor in the OP stage when the K and Cl contents in wood are low.

Fe, Mg, and Mn

The green liquor filtration is another key point to control NPE's. In order to remove alkali insoluble elements from the liquor cycle, it is necessary a very efficient green liquor filtration. Any dregs contamination in the causticizing can cause accumulation of NPE's in the lime cycle. Kvaerner has developed a very efficient Cassette™ filter for green liquor. The following table shows results from mill trials with our pilot unit.

Removal of metals elements with Cassette Filter

	Mill "A" %	Mill "B" %	Mill "C" %
Fe	93	89	94
Mg	>99	>96	97
Mn	>92	93	94
Al	55	-	69
Ba	21	12	21
Zn	-	>92	91

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Si and P

These metals tend to accumulate in the lime cycle and precipitate in causticizing forming calcium silicates and phosphates, reducing the available CaO. In order to control the amounts of Si and P in the lime cycle it is needed to purge lime mud from the circuit. This is easily done in the lime kiln ESP.

The lime used as make-up shall have a low amount of Si and P.

Solid waste

As everything that comes in must go out, the solid waste generation in an TEF pulp mill is much higher than the amounts generated in a modern ECF mill.

The table below shows the estimated solid waste generation in a TEF pulp mill (excluding any wood material in excess). The normal figure for a modern ECF mill would be in the order of 30 kg/ADt.

Solid waste generation in a TEF pulp mill

	TEF Mill kg/ADtB
Lime from Lime kiln ESP	15
Dregs (45% conc.)	22
Grits (65% conc.)	5
Ash from boiler ESP	22
Screening rejects (40% conc.)	13
Total	77

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The pulp mill in the future

It's clear that the "closed" mill will be a reality within a few years. There are already some mills in the world testing progressive closing and recycle of bleach plant effluents in mill scale.

Recycling the bleach plant effluents gives some interesting possibilities to recover sodium and sulfur for conversion to sodium hydroxide and sulfuric acid. It's possible to split sodium and sulfur for this purpose by utilizing a Kvaerner pressurized Chemrec™.

All chemicals required in a TCF bleach plant can be produced basically from air. The future pulp mill will produce carbon dioxide (from biofuel), water and fertilizer for the forest, and pulp and electricity for community use.