Prediction of metals distribution in mill processes, Part 3 of 3: NPE management in kraft chemical recovery

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ABSTRACT: Most transition metals are precipitated in green liquor as dregs. Completely removing dregs from green liquor will control transition metals in chemical recovery systems. A regular, small purge of lime mud controls phosphorus in lime mud at acceptable levels.

The Samoa Pacific mill installed an X-filter and a pre-coat dregs filter to improve dregs removal. Mill measurements show significant improvements in lime mud quality, lime availability, and lower nonprocess element content in the white liquor. It took more than a year for the new system to purge the NPE accumulation in the recovery system.

Using equilibrium calculation tools, mill and laboratory measurements are interpreted and incorporated into metals equilibrium models. Combining the equilibrium models with a particular mill process configuration, process simulation successfully predicts metals content in kraft mill recovery systems. The metals distribution and concentrations are very process dependent. *(Part 1 of this study was published in* TAPPI JOURNAL *Vol. 3 No. 1, and Part 2 was published in* TAPPI JOURNAL *Vol. 3 No. 2.)*

Application: This study will help mills manage non-process element (NPE) on a mill-wide basis. In particular, better dregs removal achieves significantly drier lime mud to the kiln.

In an open kraft pulp mill, all nonprocess elements (NPE) are purged from the process in one way or another before they reach a level that would cause serious operational problems. Mill process closure concentrates more NPE, sometimes causing operating problems, such as scaling. Some new technologies, including peroxide bleaching, require control of transition metals, such as manganese, iron, and copper. Therefore, NPE management is important for the operation of a modern pulp mill.

About 50% of the original wood mass is dissolved during kraft cooking. A significant amount of NPE in wood dissolve into black liquor [1]. If the NPE in black liquor are not purged from the chemical recovery systems, they will accumulate in the chemical recovery system or cause high NPE content in white liquor. High NPE in recovery systems causes operating problems, such as recovery boiler plugging [2, 3], and low lime kiln energy efficiency. High NPE content in white liquor causes fiberline operation problems, such as scale on washers and high peroxide decomposition in bleach plants.

Phosphorus is precipitated as calcium phosphates in white liquor [4]. The solubility of calcium phosphates in green liquor is much higher than in white liquor [5]. Therefore, phosphorous accumulates in lime mud [6]. A small fraction of mud purge, such as applying lime mud as the pre-coat of the dregs filter, is a simple and effective way to control phosphorus in recovery systems.

The Samoa Pacific mill produces market totally chlorine free (TCF) bleached pulp [7]. In April 1996, an X-filter [8] and a pre-coat dregs filter were installed to improve dregs removal and control NPE in chemical recovery [9]. The mill measurements show significant improvements in lime mud quality and lime availability plus lower NPE content in the white liquor. However, it took more than a year for the new system to purge the NPE accumulation in the recovery system.

The data in this paper shows that magnesium and transition metals are effectively controlled by the complete removal of green liquor dregs. Relative to NPE inputs and outputs, a significant amount of NPE are circulating in the calcium cycle. A small change in NPE input or output results in a significant NPE change in the circulation. However, it takes a long time to reduce the NPE in the calcium circulation. In this study, detailed process simulation confirms this mill observation.

NPE IN KRAFT CHEMICAL RECOVERY SYSTEMS

The X-filter is designed to replace traditional green liquor clarifiers. In the Samoa Pacific mill, the existing green liquor clarifier was converted into a storage tank for clarified green liquor (see **Fig. 1** for flow diagram).

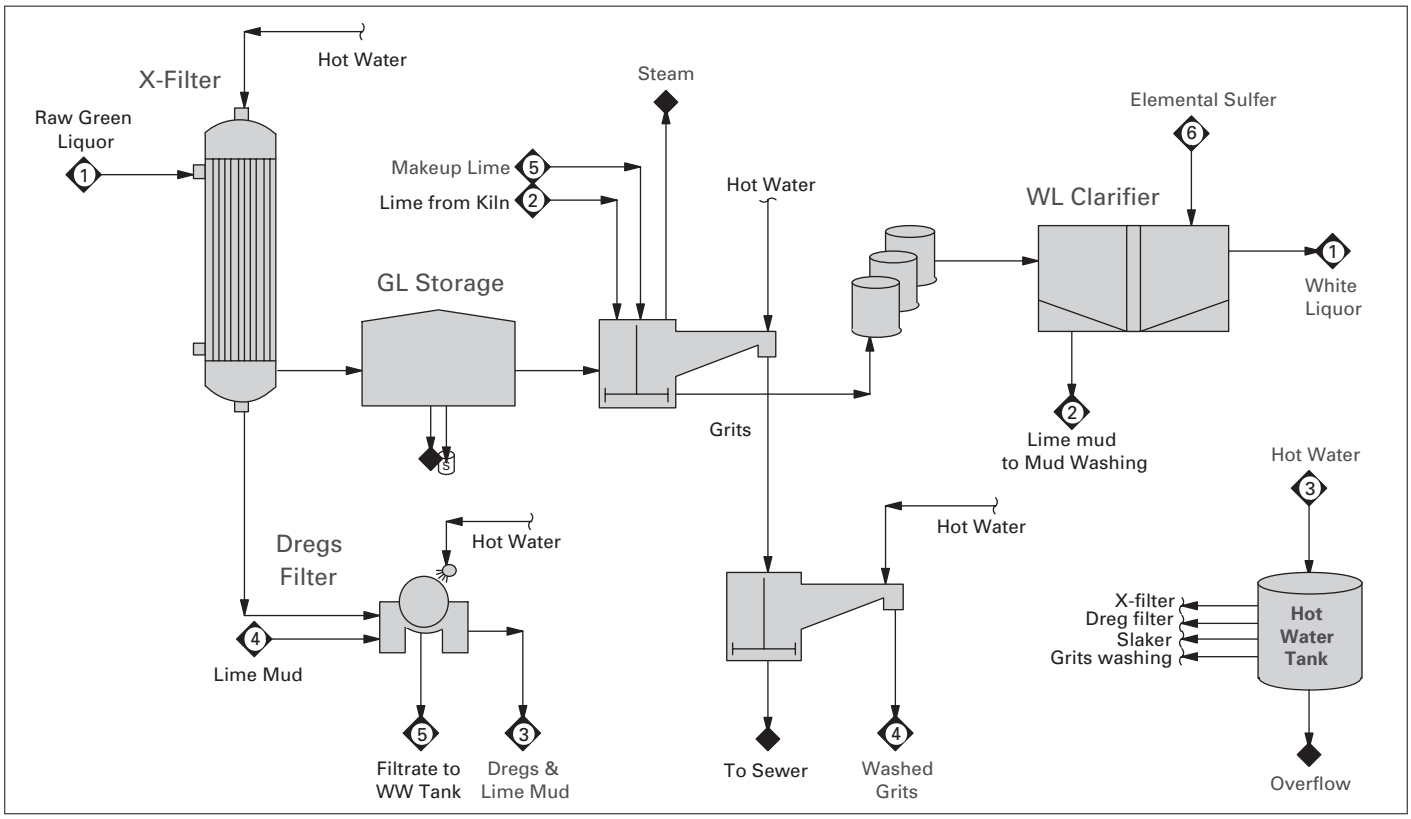
Kiln dead load/NPE accumulation in the calcium cycle

The accumulation of NPE in the calcium cycle of kraft chemical recovery systems increases lime kiln dead load with the following results:

- Lower lime availability
- Higher fuel consumption
- Lower kiln capacity.

Table I shows inductively coupled plasma (ICP) analysis for Samoa Pacific mill lime samples. The samples were taken during March, 1995. During and before the sampling, green liquor dregs were removed by a green liquor clarifier, which was performing poorly. Quite often, the dregs content in the clarified green liquor was more than 300 ppm. Lime mud was only purged from the process when there was a process upset. The mill also applied magnesium sulfate to the oxygen delignification process during TCF production, resulting in high magnesium levels in the black liquor. The data in Table I are the averages of five samples.

In Table I, NPE that exceed 0.5% in the reburned lime include magnesium,



1. Samoa Pacific mill recausticizing plant (simulation diagram).

Element	Reburned Lime		Makeup Lime	Reburned/Makeup
	mg/kg	%	mg/kg	ratio
Aluminum	3275	0.33	690	4.7
Arsenic	33.75		16	2.1
Barium	1102.5	0.11	7.6	145.1
Beryllium	0.4		0.48	0.8
Calcium	380000	38.00	440000	0.9
Cadmium	2.525		1.1	2.3
Chromium	79.5		8	9.9
Cobalt	17.5		5.1	3.4
Copper	98.25		21	4.7
Iron	5350	0.54	700	7.6
Lead	120		33	3.6
Magnesium	15750	1.58	1500	10.5
Manganese	3275	0.33	78	42.0
Molybdenum	7		5	1.4
Nickel	55.5		12	4.6
Phosphorus	11225	1.12	67	167.5
Potassium	1750	0.18	740	2.4
Silicon	1584	0.16	3932	0.4
Sodium	12075	1.21	310	39.0
Sulfur	7875	0.79	4900	1.6
Zinc	172.5		18	9.6

I. ICP analysis (Average of five samples, before X-filter start-up) of Samoa Pacific mill lime: kiln dead load /NPE accumulation.

phosphorus, iron, and sulfur. Phosphorus exists as tricalcium phosphate [$Ca_3(PO_4)_2$] in reburned lime [4]. Therefore, 1.12% of phosphorus accounts for 5.6% loss in lime availability. Also, 1.58% of magnesium causes a 2.63% (as magnesium oxide) loss in lime availability. The dead load from NPE was very significant during this period of operation in the Samoa Pacific mill. The mill was also experiencing a white liquor shortage.

Comparing NPE content in the reburned lime and makeup lime, we found that some NPE accumulate in calcium cycle to high levels. In Table I, NPE whose ratio in reburned lime to makeup lime exceeded 7 include phosphorus, barium, manganese, magnesium, chromium, zinc, and iron. Phosphorus accumulates unless there is a regular lime purge. High magnesium intake from oxygen delignification and poor magnesium removal from green liquor dregs were responsible for the high magnesium accumulation. Controlling manganese and iron is important for successful peroxide bleaching.

NPE in green liquor and white liquor

Liquor samples were taken during the same period (March, 1995) as the lime samples for Table I. **Table II** lists total metals content (filterable and nonfilterable) in the liquor samples. The suspended

solids content in the clarified green liquor is 400 ppm, which is higher than usually found at most mills. We filtered the mill samples through 0.2 mm filter paper before analysis for dissolved NPE. **Table III** lists the metals content in the filtered liquor samples. Data in Tables II and III are the averages of five analyses conducted at room temperature.

In Table II, calcium and sodium content is the same for green liquor and white liquor, but zinc is lower in the green liquor and all other NPE are higher. NPE are removed after the green liquor clarifier. The white liquor suspended solids content (150 ppm) also is lower than in the green liquor (400 ppm). This means that part of the NPE from the green liquor settled in the lime mud in the mill white liquor clarifier. This is confirmed by the data in Table I.

Comparing Table II with Table III, we find that most of the transition metals were removed by the filtration before the analyses. Therefore, transition metals mainly exist as precipitants in white liquor and green liquor and can be well-controlled if the precipitants are removed. Except for barium and zinc, metals solubility in green liquor is lower than white liquor (Table III). Therefore, removing metals from green liquor is a better choice than from white liquor. Because only the precipitants removed from green liquor can be purged from the system without contaminating lime mud, purging nonprocess metals from green liquor (i.e. removing green liquor dregs) is the best strategy to control NPE.

NPE purge: mill X-filter data

An X-filter was installed at the Samoa Pacific mill in April 1996 to replace the existing green liquor clarifier [9]. At the same time, a pre-coat dregs filter was installed. The X-filter is designed to remove almost all dregs from raw green liquor [8]. Because most NPE exist as precipitants in green liquor, the removal of dregs by the X-filter controls NPE content in clarified green liquor. After the X-filter and dregs filter installation, both white liquor quality and lime mud quality improved significantly.

Figure 2 shows metals removal by the X-filter during the first 18 months after the installation. Except for calcium, silicon and lead, no decrease in metals removal efficiency was found during this period. At this level of removal efficiency, the recovery system purged most metals from black liquor and metals previously accumulated in the calcium cycle. Because most silicon is soluble in green liquor, the X-filter still cannot effectively control silicon content in clarified green liquor.

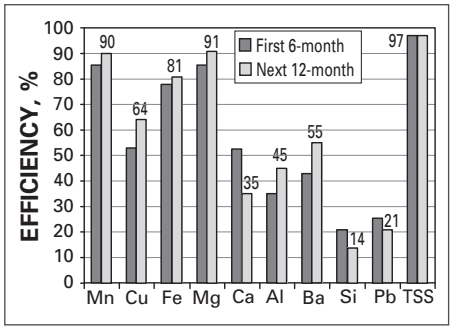
Figure 3 shows magnesium content in the lime before and after the X-filter installation. Six months after the X-filter went into operation, the magnesium content dropped about 80% (34,000 vs. 7500 mg/kg). Magnesium content in the lime

	White Liquor mg/L	Green Liquor mg/L	Raw GL mg/L	GL/WL Ratio
Barium	0.8	3.1	5.5	3.98
Beryllium	0.010	0.014	0.019	1.37
Cadmium	0.03	0.09	0.14	2.73
Calcium	71	71	418	1.00
Chromium	0.15	0.24	0.40	1.67
Cobalt	0.09	0.16	0.33	1.68
Copper	0.60	0.68	1.25	1.13
Iron	7	9	35	1.20
Magnesium	4	35	118	7.89
Manganese	4.2	8.2	24.8	1.95
Molybdenum	1.7	1.8	1.5	1.06
Nickel	0.4	0.6	1.0	1.63
Potassium	2000	2075	2100	1.04
Sodium	59000	59000	59250	1.00
Vanadium	1.8	2.2	2.4	1.24
Zinc	1.0	0.7	2.7	0.71
Non-Filterable Solids	239500	246500	251500	1.03
Filtrable Solids	153	400	1580	2.62

II. Total NPE content in mill clarified white liquor and green liquor before and after mill clarification (Average of 5 samples, room temperature).

	White Liquor mg/L	Green Liquor mg/L	Raw GL mg/L	GL/WL Ratio
Aluminum	3.525	2.650	2.038	0.75
Barium	0.525	1.550	1.900	2.95
Beryllium	<0.022	<0.022	<0.022	
Cadmium	<0.009	<0.009	<0.009	
Calcium	3.125	1.850	1.475	0.59
Chromium	0.018	<0.015	<0.015	
Cobalt	<0.033	0.034	<0.033	
Copper	0.094	0.033	0.034	0.35
Iron	0.209	0.038	0.050	0.18
Magnesium	0.013	0.012	0.030	0.88
Manganese	0.673	0.022	0.027	0.03
Molybdenum	0.573	0.518	0.595	0.90
Nickel	0.100	0.083	0.070	0.83
Vanadium	0.603	0.558	0.643	0.93
Zinc	0.089	0.115	0.104	1.29

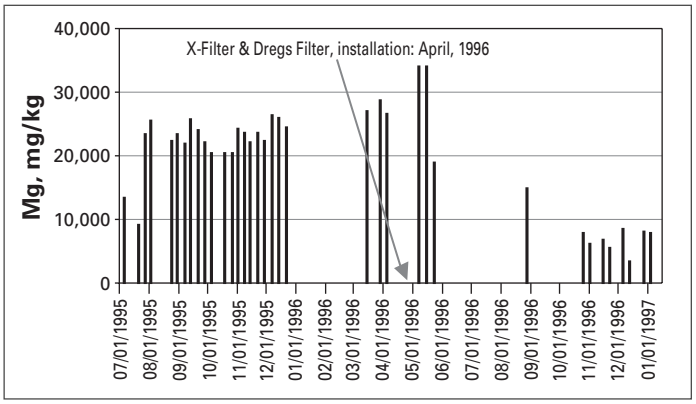
III. Dissolved NPE content in filtered white liquor and green liquor: NPE solubility (Average of 5 samples, room temperature).



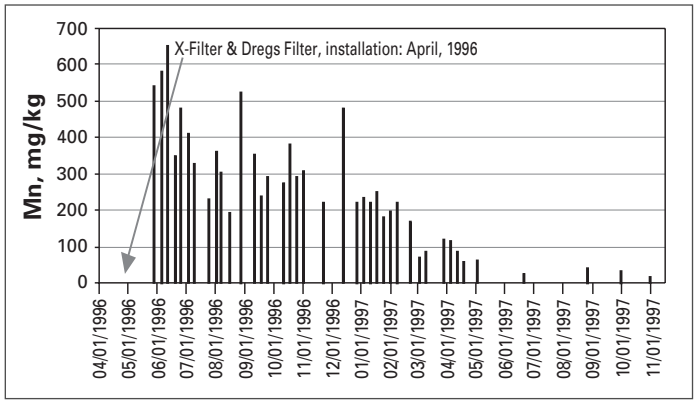
2. X-filter NPE removal efficiency from green liquor.

X-Filter Operation	Mn mg/L	Cu mg/L	Fe mg/L	Mg mg/L	Al mg/L	Ba mg/L	Si mg/L	Pb mg/L	TSS mg/L
Clarified Green Liquor									
1st 6-month	2.22	0.47	3.43	3.98	14.28	4.14	203.53	2.27	21.46
Next 12-month	1.36	0.36	3.52	3.43	13.98	4.12	268.16	2.16	35.32
Clarified White Liquor									
1st 6-month	8.93	0.62	6.40	4.02	14.61	1.99	214.14	2.78	80.38
Next 12-month	3.62	0.47	6.03	3.36	15.71	1.61	292.21	2.25	90.80

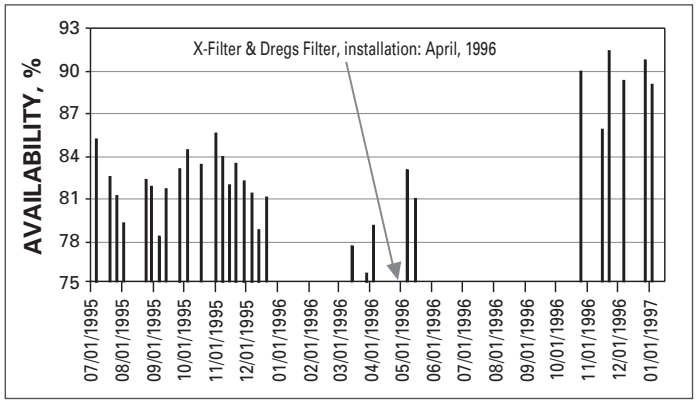
IV. Liquor NPE content after X-filter installation.



3. Impact of X-filter on lime NPE: magnesium.



4. Impact of X-filter on lime mud NPE: manganese.



5. Impact of X-filter on lime availability.

stabilized around 7500 mg/kg with the X-filter and oxygen delignification in operation.

Similar to magnesium, all other NPE in the lime and lime mud dropped after the X-filter installation. **Figure 4** shows manganese changes in the lime mud. It took about 12 months for manganese to reach a stable and very low level, compared to less than 6 months for magnesium.

Figure 5 shows that the decrease of NPE in lime also had a positive effect on lime availability (an increase of 9%). In the operation, less makeup lime was needed, although no accurate measurement was available. The wet lime mud to the kiln also dewatered better and was white, not green.

Table IV shows NPE content in the clarified white liquor and green liquor after the X-filter installation. After the X-filter installation, metals content in the clarified green liquor dropped immediately for most metals. **Figure 6** compares metals content in the clarified green liquor before and after the installation (data from Tables II and IV). However, it took longer to see the decrease of NPE in the white liquor. **Figure 7** shows the change of manganese in white liquor. NPE content in white liquor is determined by NPE in clarified green liquor and in the lime. After the X-filter installation, NPE inputs into the calcium cycle were reduced (lower NPE in the clarified green liquor). However, NPE in the lime and lime mud were still high. Those were leached out by the white liquor, which resulted in high NPE in white liquor. Over time, NPE content in lime and in white liquor decreased. NPE solubility differs between green liquor and white liquor. Therefore, the lime "cleaning" time is different for each NPE. After 18 months from the X-filter installation, all NPE in the calcium cycle were "cleaned." The "new" lime was white, with much lower NPE content (Figs. 3 and 4), producing white liquor with low NPE content. Mill measurements show that the X-filter installation had no effect on metals content in the raw green liquor (e.g. see **Fig. 8** for manganese).

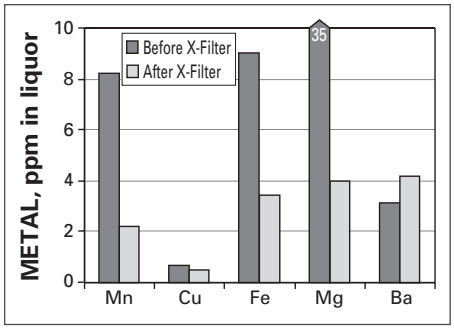
NPE SIMULATION FOR SAMOA PACIFIC MILL CHEMICAL RECOVERY

We have shown the dramatic effects of an equipment change on NPE in the Samoa Pacific mill chemical recovery system. The high NPE sensitivity to process configuration and equipment results because only a small fraction of NPE circulated in the process are purged. The amount of NPE circulated in the process is determined by the NPE input rates and purge rates. Any change that affects NPE purge will significantly affect NPE in the circulation. The installation of the X-filter greatly changed NPE purge in the dregs. Therefore, the X-filter significantly affected NPE in the calcium cycle. This example clearly shows that NPE mill measurements in chemical recovery are very process and equipment dependent. Thus, careful interpretation is needed when mill measurements from one mill are applied to another mill.

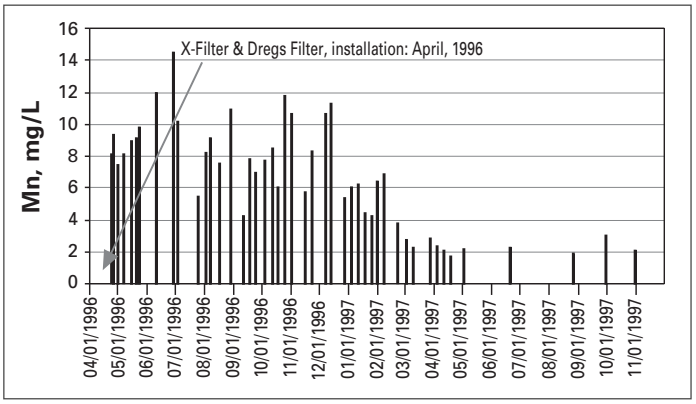
New process simulation with detailed chemistry models has been proven to be a successful approach to interpret mill measurements that are process and equipment dependent for bleaching as well as VOC air emissions [10-13]. The following section shows that the impacts of processes, equipment, and operating conditions on NPE can also be predicted by process simulation if NPE chemistry models, i.e. equilibrium, for chemical recovery are available.

There are various approaches to model NPE equilibrium [14-16]. Some are from more fundamental theories and others are

easier to use. In the end, measurements are always needed to determine model parameters. All of these models are useful if they are "adjusted" according to equilibrium measurements at mill conditions, such as ion strength and temperature.



6. Metals content in the clarified green liquor: before and six months after X-filter installation (Total Suspended Solids: 400 ppm before X-filter, 21 ppm after X-filter).



7. Impact of X-filter on white liquor NPE: manganese.

Simplified metals equilibrium models

The purpose of our model is to predict metals solubility in green and white liquor at mill operating conditions (pH, concentration, ion strength, temperature, etc). For other purposes, more sophisticated, detailed, and complicated models [17] may be needed. We simplified our model by including only major species at mill conditions. We also directly tuned formation constants to match mill solubility measurements.

Table V lists all species included in the current equilibrium model and their adjusted formation constants. We used SOLGASWATER [14], a general multicomponent and multiphase equilibrium program, to calculate equilibrium concentrations. When equilibrium system information (species and formation constants, Table V) and total component concentrations are supplied as inputs, SOLGASWATER calculates equilibrium concentrations for all species based on free-energy minimization. The equilibrium engine has been integrated into the industry's most widely used process simulator, WinGEMS. This approach has been used for metals profile prediction in fiberlines [1, 18]. More details about adapting SOLGASWATER to the pulp and paper industry are available in Part 1 of this series [18].

The model-predicted metals solubilities in white liquor and green liquor are listed in **Table VI**. Metals solubility in green liquor is lower than in white liquor. The difference results because carbonate is the dominant anion species in green liquor while hydroxide is the dominant anion species in white liquor.

Samoa Pacific mill chemical recovery simulation

NPE content in chemical recovery is closely related to NPE inputs, the recovery process and equipment, and the operation conditions of the process. As the mill measurements in this paper have shown, process and equipment changes can cause significant changes in NPE during a very long transition (over a year, Fig. 4). Therefore, to compare simulation with mill measurements, we must include the detailed process and process dynamics. A process simulation was conducted for the full chemical recovery system in the Samoa Pacific mill (from weak black liquor to white liquor). Figure 1 shows the recausticizing area simulation. The full simulation includes the mud washer and lime kiln. Before the chemical recovery plant modernization, the mill used a green liquor clarifier to remove dregs and directly purged the underflow. The normal operation did not include a regular lime purge, but some mud was purged during process upsets.

Two metals equilibrium calculation blocks—MetEQs—are included in the WinGEMS simulation (Fig. 1). One is before dregs separation from green liquor in the X-filter, the other is before lime mud separation from white liquor in the white liquor clarifier. The equilibrium calculation divides metals content between liquor and suspended solids according to the equilibrium model.

The simplified dynamic simulation includes three tanks: green liquor storage, white liquor clarifier, and lime mud storage. The operation status before the

Components

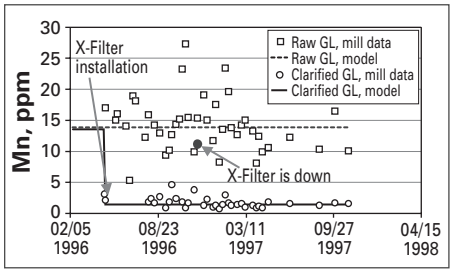
Serial No.	Component	Description	Serial No.	Component	Description
1	H^+	Proton	5	Mn^{2+}	Manganese
2	Na^+	Sodium	6	HS^-	Hydrosulfide
3	Ca^{2+}	Calcium	7	PO_4^{3-}	Phosphate
4	Mg^{2+}	Magnesium	8	CO_3^{2-}	Carbonate

Formed Species

Serial No.	Species	Formation Reaction	Constant[1]	Serial No.	Species	Formation Reaction	Constant[1]
1	$Ca(OH)^+$	$Ca^{2+} + OH^- === Ca(OH)^+$	10.50	7	$Ca(OH)_2(s)$	$Ca^{2+} + 2OH^- === Ca(OH)_2(s)$	0.80
2	$Mg(OH)^+$	$Mg^{2+} + OH^- === Mg(OH)^+$	8.00	8	$Mg(OH)_2(s)$	$Mg^{2+} + 2OH^- === Mg(OH)_2(s)$	0.10
3	$Mn(OH)_3^-$	$Mn^{2+} + 3OH^- === Mn(OH)_3^-$	-19.00	9	$Mn(OH)_2(s)$	$Mn^{2+} + 2OH^- === Mn(OH)_2(s)$	0.95
4	HPO_4^{2-}	$H^+ + PO_4^{3-} === HPO_4^{2-}$	3.40	10	$CaCO_3(s)$	$Ca^{2+} + CO_3^{2-} === CaCO_3(s)$	8.06
5	HCO_3^-	$H^+ + CO_3^{2-} === HCO_3^-$	10.34	11	$MgCO_3(s)$	$Mg^{2+} + CO_3^{2-} === MgCO_3(s)$	3.70
6	H_2CO_3	$2H^+ + CO_3^{2-} === H_2CO_3$	16.64	12	$MnCO_3(s)$	$Mn^{2+} + CO_3^{2-} === MnCO_3(s)$	8.70

1. Formation constants, pKf

V. Simplified metals equilibrium model for green and white liquor.

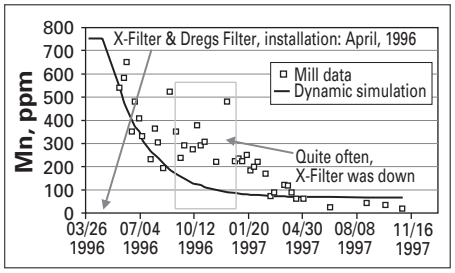


8. Comparison of dynamic simulation with mill measurements: manganese in raw and X-filtered green liquor.

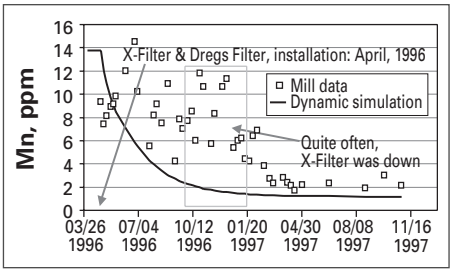
			Green Liquor, mg/L	White Liquor, mg/L
Solubility	Ca	Lab Data (a)	1.85	3.13
		Model	2.95	1.09
	Mg	Lab Data (a)	0.012	0.013
		Model	0.028	0.010
	Mn	Lab Data (a)	0.022	0.673
		Model	0.047	0.137
Clarified Liquors	Ca	Mill Data (b)	—	469
		Model	11.2	331
	Mg	Mill Data (b)	3.72	2.58
		Model	3.09	0.60
	Mn	Mill Data (b)	1.33	2.44
		Model	1.42	1.17

a. Non-filtrable metals at room temperature by ICP (Table 3)
b. Steady state after the X-Filter installation, by AA

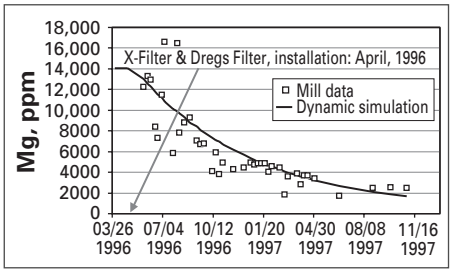
VI. Model-predicted solubility in green liquor and white liquor.



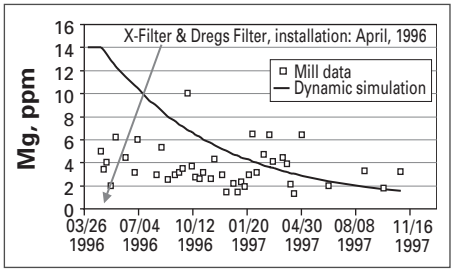
9. Comparison of dynamic simulation with mill measurements: manganese in lime mud.



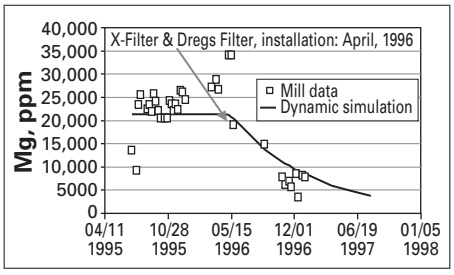
10. Comparison of dynamic simulation with mill measurements: manganese in white liquor.



11. Comparison of dynamic simulation with mill measurements: magnesium in lime mud.



12. Comparison of dynamic simulation with mill measurements: magnesium in white liquor.



13. Comparison of dynamic simulation with mill measurements: magnesium in reburned lime.

X-filter and dregs filter installation is used as the starting point (initial steady state) for the dynamic simulation. The installation of the X-filter resulted in significantly lower nonprocess metals in the clarified green liquor. The operation of the pre-coat dregs filter results in a regular lime mud purge. These two items are the only changes for the dynamic simulation.

Figure 8 shows the change of manganese in the raw green liquor and clarified green liquor. Manganese in the clarified green liquor immediately dropped from around 13.5 ppm to 1.4 ppm after the X-filter installation. The decrease is the result of much better dregs removal by the X-filter (30 ppm total suspended solids in the clarified green liquor after the X-filter compared to 400 ppm previously). Mill measurements indicate that manganese in the raw green liquor did not change during a period of 1-1/2 years.

Table VI shows the metals content in the clarified green liquor and white liquor. The suspended solids in the clarified liquor are responsible for the metals content differences between the solubility and the clarified liquors. For manganese and magnesium, almost all of the content in clarified green liquor is from the suspended solids. This suggests that the nearly complete purge of manganese and magnesium from kraft chemical recovery systems can be achieved by removing the suspended solids in green liquor. For simulation, it is important to match the suspended solids content in clarified green liquor with mill measurements; there are no good tools to predict that content. The simulation also suggests that the ratios of nonprocess metals to calcium in the suspended solids of clarified white liquor are much higher than in white liquor clarifiers. In other words, it is much more difficult for nonprocess metal precipitants to settle in the white liquor clarifier than calcium carbonate. Experimental measurements are needed to directly confirm this finding from mill process simulation.

Figures 9 and 10 show the simulated effects of the X-filter and dregs filter on manganese in the lime mud and white liquor. The simulation can generally represent the trends of manganese decrease in both the lime mud and white liquor. During the last few months of 1996, the X-filter was down quite often because of clothing plugging problems. The lime mud purged from previous process upsets (containing high levels of NPE) also was reclaimed after the X-filter installation. These two events were not well documented and were not included in the simulation. If these events had been included in the simulation, the model-predicted manganese decreases would be slower than the current prediction. Mill situations are always more complicated than simulation can represent, especially for dynamics. The complexity of mill situations is reflected in scattered mill measurements, such as data in Figs. 8-13. Nevertheless, the simulation of simplified mill operations gives realistic trends.

Figures 11 and 12 show the simulated effects of the X-filter and dregs filter on magnesium in the lime mud and white liquor. Because of the high magnesium concentration in the lime mud, the regular lime mud pre-coat purge at the dregs filter made a significant contribution to the decrease of magnesium in the lime mud and reburned lime. The change of magnesium in the reburned lime, (Fig. 13), further confirms the change of magnesium in the lime mud (Fig. 11). However, the mill-measured change of magnesium in the white liquor (Fig. 12) is not as significant as the model predicted change.

In **Table VII**, the importance of green liquor dregs removal on metals control in kraft chemical recovery systems is shown. Table VII is the simulated results for the Samoa Pacific mill before and after the installation of the X-filter and pre-coat dregs filter. The same chemistry model (solubility) is used for both cases. The differences are caused by the reduction of total suspended solids in clarified green liquor from 300 ppm to 30 ppm. In the Samoa Pacific mill, the reduction of the total suspended solids is achieved by the new X-filter. The effectiveness of green liquor clarification equipment on metals control can be solely judged by the total suspended solids content in the clarified green liquor. Any equipment with good dregs removal will be effective for metals control.

The above example shows that process simulation can calculate NPE

contents and their dynamics in a kraft mill chemical recovery system. The simulation is the result of combining a general metals equilibrium model for white liquor and green liquor with a specific mill process model. Because the NPE equilibrium model is common to all kraft mills, the current equilibrium model, which has been validated by Samoa Pacific mill measurements, can be applied to other mills. Simulation also demonstrates the importance of matching the suspended solids content in clarified green liquor and white liquor. Through process simulation and modeling, the understanding from one mill can be quantitatively and reliably transferred to another mill. This is an effective approach to interpret mill measurements that are process dependent.

CONCLUSIONS

Removing metals precipitants (i.e. green liquor dregs) from green liquor effectively purges transition metals from kraft chemical recovery systems because transition metals have lower solubility in green liquor than white liquor and dregs are removed from the process.

After installing a green liquor X-filter and pre-coat dregs filter, the Samoa Pacific mill has experienced significant improvements in lime quality, kiln efficiency, and white liquor quality. This mill experience has demonstrated that the full purge of green liquor dregs is an effective way to control transition metals contents in kraft chemical recovery systems. No special "kidney" is necessary for transition metals control.

Although NPE content in a mill is very dependent on its process configuration and operations, the underlying chemistry is the same for all kraft mills. An equilibrium model for metals solubility in green liquor and white liquor has been developed. Combining the equilibrium model with detailed process models, process simulation is able to successfully predict NPE behaviors in kraft chemical recovery systems. **TJ**

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	Mn, ppm		Mg, ppm	
	Total	Soluble	Total	Soluble
Before X-Filter (poor clarifier performance)				
TSS in Clarified Green Liquor	300 ppm			
Raw Green Liquor	13.94	0.06	33.41	0.02
Clarified Green Liquor	13.46	0.04	32.24	0.03
Clarified White Liquor	13.73	0.11	13.93	0.01
Lime Mud	751		14070	
Lime	1148		21459	
Stabilized after X-Filter installed				
TSS in Clarified Green Liquor	30 ppm			
Raw Green Liquor	13.94	0.06	33.41	0.02
Clarified Green Liquor	1.42	0.04	3.09	0.03
Clarified White Liquor	1.17	0.11	0.60	0.01
Lime Mud	66		685	
Lime	109		1125	

VII. Importance of dregs removal on metals control (simulation).

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