

Lime mud recycling improves the performance of kraft recausticizing

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Lime mud recycling increased the solids content of the white liquor clarifier and decreased the free lime content of the mud.

The recycling of lime mud to the slaker from the underflow of the white liquor clarifier has been advocated as a way to improve the performance of the recausticizing system (1, 2). Implementation of the concept requires only minor piping changes. If a higher target for causticity could be achieved, as expected, the dead load of inorganics in the liquor cycle would be decreased. There are several potential benefits to be gained from decreasing the dead load, the main one being a small increase in the productive capacity of the recovery boiler (3, 4).

Lime mud recycling also has the potential for extending the productivity of the lime kiln slightly. Furthermore, recycling should help to even out variability in the performance of the recausticizing system.

The concept was tested in the recausticizing system in the Weyerhaeuser Canada Ltd. mill at Prince Albert. The results of the trials were quite good.

The concept

Chemistry

The recausticizing reaction occurs at a solid-liquid interface within the solid particles (1). Liquor containing dissolved Na_2CO_3 reacts with solid $\text{Ca}(\text{OH})_2$, forming solid CaCO_3 and NaOH . The solid CaCO_3 remains at the interface, and NaOH leaves dissolved in the liquid. As the reaction proceeds, the reaction interface moves from the outside of the particle to its core, $\text{Ca}(\text{OH})_2$ being progressively replaced by CaCO_3 in the outer part of the particles.

When more than about half of the $\text{Ca}(\text{OH})_2$ in the particles is consumed, the rate of movement of Na_2CO_3 and NaOH through the CaCO_3 in the outer part of the particles completely dominates the reaction rate (1). At this time, diffusion restricts the necessary movement of Na_2CO_3 from the bulk liquid phase through the outer part of the particles to the reaction interface; it also restricts the travel of the product NaOH in the reverse direction.

With conventional co-current flow of the liquid and solid phases through the causticizers, the overall rate of the recausticizing reaction quickly becomes diffusion-limited and becomes progressively slower as the reaction proceeds. The concentration forces that move Na_2CO_3 to the reaction interface and take NaOH away are at their lowest toward the end of the reaction, when they are needed the most. Since the diffusion limitation is within the solid particles, the retention time of the solid particles in the reaction vessels is more important than the retention time of the liquid.

There are alternatives to conventional co-current flow (1), but they are not well developed and would be expensive. Therefore, practical considerations point to continued use of co-current flow. Nonetheless, it is appropriate to consider innovative changes within the confines of co-current flow. Lime mud recycling is such an innovative proposal. With lime mud recycling, some of the underflow from the white liquor clarifier is simply returned, undiluted, to the slaker.

Lime mud recycling allows the average retention time of the solid phase to be uncoupled from the average retention time of the liquid phase. The average retention time of the solid phase within a set of causticizers can be increased substantially, while the retention time of the liquid phase is decreased somewhat. An increase in the average retention time of the solid phase allows more time to compensate for the slow diffusion rates.

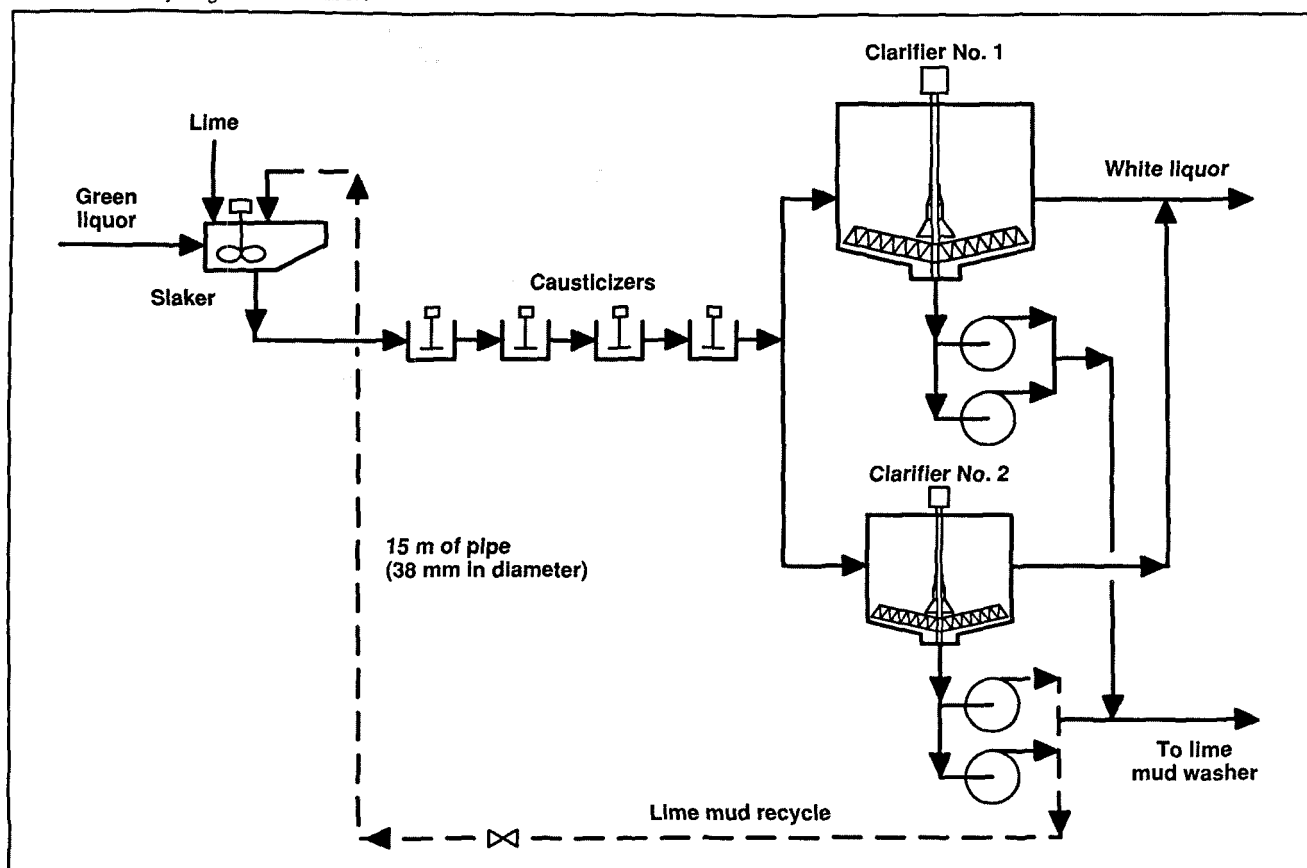
Lime mud recycling has the additional attraction that it places the recycled particles in an environment where the concentration forces are strong for causing Na_2CO_3 to diffuse into the particles and NaOH to diffuse out of the particles. That is, in the bulk liquid phase, the Na_2CO_3 concentration is high, and the NaOH concentration is low. This advantage enhances the utilization of the free $\text{Ca}(\text{OH})_2$ in the inner parts of the recycled particles.

With the combined effects of more time and stronger driving forces of concentration acting on the recycled particles, there are two possible improvements:

1. Less free lime in the lime mud leaving the causticizers, at a given causticity. This decrease in free lime leads to a slight decrease in reburned lime requirements, because the lime is more completely utilized.
2. A higher causticity at a given free lime content in

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1. Lime mud recycling at Prince Albert



the lime mud. In this case, the amount of excess lime is maintained, so there is no change in reburned lime requirements.

For lime mud recycling to have these improvements, there must be some residual free lime in the lime mud.

Physical effects

Earlier, Blackwell described the results of some calculations of the effects of 100% recycle rate (1). At 100% recycle rate, the underflow from the white liquor clarifier is recycled back to the slaker in amounts equal to the amount of new mud being produced by the reaction of the lime added to the slaker. At steady state, then, the white liquor clarifier would receive twice the usual amount of solids. Half of the solids from the clarifier underflow would be recycled, and half would be forwarded to lime mud washing.

With a 100% recycle rate, the volumetric flow rate of the slurry through the causticizer would increase by 15%. In most cases, this small increase could be accommodated in the existing equipment. Despite an increase in the slurry solids concentration from 7% to 13% by weight, the increase in the power requirements for the mixers in the slaker and the causticizers would be only 4%. Therefore, the existing agitators would be adequate in most cases. A 100% recycling rate would increase the overall solids residence time by 75%. The usual solids residence time of 90 min, for example, would be increased to about 160 min. Though the average liquid residence time would decrease by 17%,

I. White liquor causticity

Period in 1989	Re- cycle	Solids contents, %		No. of data
		Avg.	Std. dev.	
1 Mar. 18-28	Off	86.4	1.55	252
2 Apr. 13-24	On	85.0	2.38	276
3 May 10 to June 16	On	86.3	1.70	848
4 June 19-23	Off	86.0	1.74	115
5 June 26-30	On	86.4	2.01	110
6 July 3-14	Off	86.3	2.63	257
7 July 18 to Aug. 1	On	86.1	2.26	336
8 Aug. 2 to Sept. 1	Off	85.0	2.39	683
9 Sept. 18 to Dec. 14	Off	85.2	2.07	1610
Means	Off	85.4	2.2 ^a	2917
	On	86.0	2.0 ^a	1570
95% confidence limits ^b				
	Off	85.4 ± 0.04		
	On	86.0 ± 0.05		

^aPooled standard deviation for a single sample.

^bDetermined as twice the pooled standard deviation, divided by the square root of the total number of samples in all tests.

this decrease is not considered important at the long retention times typical of conventional recausticizing systems.

Since white liquor clarification involves hindered settling of lime mud, the increased slurry concentration in the clarifier feed would tend to decrease the settling rate of the lime mud particles, for a set amount of free lime in the mud (1). On the other hand, a decrease in the free lime content would tend to increase the settling rate of the lime mud particles. Even if the net result were a decrease in the settling rate, no change would be expected in the suspended solids concentration of the clarified white liquor, in most situations.

This result is almost always the case, because under normal mill conditions, the settling rate of lime mud particles is considerably higher than the upflow rate in white liquor clarifiers—by a factor of 4 at one mill, for example (5). White liquor clarifiers are designed on the basis of being thickeners to compact the mud, so the resulting horizontal cross-sectional area is more than adequate to properly settle the solids and provide clear white liquor (6).

The impact of the increased slurry concentration on the settling rate would not be expected to detract from the advantages of the increased solids residence time.

Prince Albert recausticizing system

The mill produces an average of 950 a.d. tons/day of kraft pulp with nominal running rates of 1170 a.d. tons/day on hardwood and 1080 a.d. tons/day on softwood. At the running rate, the green liquor flow to the slaker is about 750 gal/min. The green liquor is reacted with reburned lime from a lime kiln in a No. 12 Dorr Oliver slaker that provides a retention time of about 7 min.

The slurry from the slaker flows through four causticizers in series, as the figure shows, for a total retention time of about 90 min. White liquor is separated from the lime mud in two clarifiers, in parallel. The first clarifier is 65 ft in diameter, and the second is 50 ft in diameter. The slurry from the causticizers is split so that about 65% goes to the first clarifier and 35% goes to the second. There are two underflow pumps for each clarifier, but under normal circumstances only one pump is operating on each clarifier. The underflows from the two white liquor clarifiers are combined and sent to one lime mud washer.

Trial procedures

Trials were conducted several times, for periods of a few days to several weeks. Between trials, the system was operated conventionally. There was a common causticity target of 86%, for both conventional operation and operation with lime mud recycling.

During each recycling trial, most of the underflow from the No. 2 white liquor clarifier was recycled to the bowl of the slaker, as shown in Fig. 1. To do this, it was necessary to install about 15 m of 38-mm-diameter pipe, including a hand-operated valve. This piping was connected to the discharge piping on the underflow pumps of the No. 2 clarifier.

The usual temperature of the slurry in the slaker was maintained during the trials. Though recycled lime mud

was added to the slaker, there was no need to change the temperature setpoint on the green liquor cooler. At Prince Albert, no dilution water is added to the underflow from the white liquor clarifiers. Dilution water is relatively cool, so the underflow would be cooled if dilution water were added to it. Hence, at a mill where dilution water is added to the white liquor clarifier underflow, the temperature setpoint on the green liquor cooler would have to be increased to compensate.

The underflow solids are withdrawn from the bottom of the clarifiers based on the indicated torque on the clarifier rake. The underflow pumps are operated in an on-off mode by the operator, as required to control the rake torque in the desired range. This is normal procedure at Prince Albert and is common industry practice. During the trials, both underflow pumps were operated most of the time on both of the clarifiers.

The free lime content was determined for the slurry from the causticizers, the clarifier underflow, and the washer underflow. The analytical procedure was based on a modification of the test method commonly used at kraft mills to measure the availability of reburned lime. In all cases, a volume of sample was taken, filtered, and washed twice, each time with 100-mL of warm CO₂-free water. After drying the washed mud in an oven, 2 g of material was taken, and the standard sugar test was used to determine the free lime content.

In this test, sugar is added to tie up the Mg(OH)₂, and hydrochloric acid is used to titrate to pH = 8.2. It is assumed that the CaCO₃ does not react with the acid at pH values above 8.2. This assumption is consistent with observations made when lime mud samples were titrated with hydrochloric acid as part of effluent neutralization work (7). For the slurry from the causticizers, a 25-mL sample was used, whereas a 10-mL sample was used for the underflows from the white liquor clarifiers and the underflow from the lime mud washer clarifier. Consequently, for 1 g of lime mud solids, the causticizer slurry sample received 1.5–2.0 times as much washing as the clarifier underflow samples. As we will discuss shortly, the extra wash water caused a lower result for the indicated free lime content.

The samples of clarifier feed and overflow were taken from the combined flow from the clarifiers. The clarifier underflow samples were taken from one clarifier, mostly from the No. 2 system. Simultaneous sampling of both No. 1 and No. 2 white liquor clarifiers indicated comparable results.

Results

Tables I–III summarize the data for four separate periods when lime mud recycling was in practice and for five other periods when the recycling system was shut off. The results exhibit considerable variability. However, by taking the results from all the trials, we find that some differences are apparent.

The increase in the solids content in the slurry feed to the clarifier can be used to calculate the degree of recycle during the trials. On average, the amount of solids being recycled was equal to about half of the new solids being produced by the reaction of the lime being added to the slaker—i.e., a 50% recycle rate. Under these conditions,

II. Slurry solids concentrations for white liquor clarifier flows

Period	Recycle	Common feed, g/L		No. 2 underflow, g/L		Common overflow, g/L		No. of data
		Avg.	Std. dev.	Avg.	Std. dev.	Avg.	Std. dev.	
1	Off	104	17	467	28	101	2	3
2	On	123	26	539	43	114	44	8
3	On	151	53	538	51	131	38	10
4	Off	102	5	510	11	79	19	5
5	On	143	14	565	12	200	59	4
6	Off	101	8	474	46	101	62	9
7	On	141	20	546	19	189	112	12
8	Off	101	8	438	77	165	128	12
9	Off	102	7	522	76	176	116	17
Means	Off	102 ^a	9 ^b	482 ^c	65 ^b	124	101 ^b	47
	On	140	34 ^b	547 ^c	37 ^b	159	81 ^b	34
95% confidence limits ^d								
	Off	102 ± 3		482 ± 19		124 ± 26		
	On	140 ± 12		547 ± 13		159 ± 28		

^a102 g/L = 8.7% by weight.
^bPooled standard deviation for a single sample.
^c482 g/L = 34.7% by weight. 544 g/L = 38.4% by weight.
^dDetermined as twice the pooled standard deviation, divided by the square root of the total number of samples in all tests.

about one third of the total underflow solids from the two clarifiers was being recycled, and two-thirds was being sent to lime mud washing.

As shown in Table I, the average causticity of the white liquor was 86.0% when lime mud was being recycled, as opposed to 85.4% for conventional operation. The variability in the causticity was similar between the two.

Recycling resulted in a 65% decrease in the free lime content of the lime mud leaving the white liquor clarifier—from 3.3% by weight CaO for conventional operation to 1.2% by weight CaO. Lime mud recycling also increased the slurry solids content of the clarifier underflow to 38.4% by weight from the normal 34.7%. Statistically, the suspended solids content of the overflow from the clarifier was unaffected by recycling; its variability was unaffected as well. Recycling decreased the variability in the free lime content of the mud and the variability of the slurry solids content of the clarifier underflow, both by about 50%.

No operational problems were experienced during the trials. The causticizer mixers functioned normally, and there were no irregularities in the flow of the slurry through the causticizers. The 38-mm-diameter recycle piping did not plug any more readily than other mud lines. Generally, the recycling system was simple to operate.

For the trial conditions, the overall residence time of the lime mud in the causticizers increased by 37%, while the volumetric flow rate of the slurry through the slaker and causticizers increased by 9%. On average, one third of the solids going to lime mud washing would have been recycled one or more times. About two-thirds of the solids would have experienced no recycling and would have been in the causticizers for 9% less residence time than normal. Therefore, it is somewhat surprising that the free lime content of the solids decreased by considerably more than one-third. The decrease in the free lime content of the mud of 65% indicates that there must be an additional

mechanism at work, beyond the stronger driving forces for diffusion acting on the recycled material and an average 37% increase in residence time of the solid phase.

This additional mechanism is related to the lime mud slurry concentration. Laboratory work by Bonsu of Domtar sheds some light on this (8). Lime was added to white liquor with a causticity of about 79%, containing varying amounts of lime mud. When the white liquor contained no lime mud, the causticity increased by 1.3% in 60 min. By adding 20 g/L of lime mud to the white liquor prior to the lime, the causticity after 60 min of reaction with the lime increased by 4.5%. For 40 g/L, 60 g/L, and 80 g/L additions of lime mud, the causticity increases in 60 min were 5.3%, 5.8%, and 5.0%, respectively. Bonsu concluded that the presence of extra lime mud accelerated the rate of the recausticizing reaction.

At the higher slurry concentrations created by lime mud recycling, there may be more abrasive action of lime mud particles, one on the other, resulting in a clearing of the pores within the particles. Such action would facilitate the internal diffusion of Na_2CO_3 and NaOH , both for the particles that are recycled and the particles that go through the system without recycling.

After the trials summarized in Tables I–III, we studied the performance of the lime mud filter. With lime mud recycling on, the filter cake had a solids content of 65.7%, with a standard deviation of 1.9% based on 7 samples. The soda content was 0.2% as Na_2O , with a standard deviation of 0.1%. With lime mud recycling off, the solids content was 63.4%, with a standard deviation of 2.9% based on 10 samples. The soda content was 0.4% as Na_2O , with a standard deviation of 0.3%. Apparently, lime mud recycling improved the performance of the lime mud filter and made the operation more consistent.

III. Free lime content of the lime mud for white liquor clarifier flows

Period	Recycle	Common feed, wt. % as CaO		No. 2 underflow, wt. % as CaO		No. of data
		Avg.	Std. dev.	Avg.	Std. dev.	
1	Off	...	...	3.1	1.0	5
2	On	...	...	1.0	0.5	8
3	On	0.6	0.4	1.2	0.7	10
4	Off	1.2	1.0	2.1	0.8	5
5	On	1.0	0.9	2.2	1.4	4
6	Off	2.3	2.4	4.5	4.1	9
7	On	0.6	0.5	0.8	0.4	12
8	Off	2.2	1.5	4.4	4.1	12
9	Off	1.3	1.0	2.4	1.7	17
Means	Off	1.8	1.5 ^a	3.3	3.1 ^a	48/53
	On	0.7	0.5 ^a	1.2	0.7 ^a	26/34
95% confidence limits ^b	Off	1.8 ± 0.45		3.3 ± 0.94		
	On	0.7 ± 0.20		1.2 ± 0.27		

^aPooled standard deviation for a single sample.

^bDetermined as twice the pooled standard deviation, divided by the square root of the total number of samples in all tests.

Comparison with the Cariboo trial

A two-week lime mud recycling trial was conducted at Cariboo Pulp and Paper Co. in Quesnel, B.C. (1). No change in performance was observed in these trials, because the lime mud contained only about 0.20% free lime under normal circumstances, so there was minimal scope for increasing causticity or lowering the free lime content of the mud. In that trial, the amount of lime mud recycled was about 60% of the normal clarifier underflow, much like the 50% for the Prince Albert trials.

At Quesnel, the suspended solids content in the overflow from the white liquor clarifiers was unaffected by lime mud recycling. This result is consistent with the Prince Albert results. At Quesnel, the initial settling rate of the lime mud particles, over the first 5 min, was decreased by 50% with recycling. Settling rates were not measured at Prince Albert.

Table IV summarizes the data on the slurry solids concentration of the underflow from the white liquor clarifier at Quesnel. Superficially, the averages indicate a decrease in the slurry solids. However, considering the variability of the results and the small number of samples, a reliable conclusion cannot be made about the change in the underflow solids. In contrast to observations at Prince Albert, the variability in the solids concentration appeared to increase with lime mud recycling. At Prince Albert, enough samples were taken to reliably illustrate that there was an increase in the slurry solids concentration.

Thickening performance is determined by the solids flux, which is the product of the settling rate of the particles and the suspended solids concentration of the feed. It appears that the solids flux increased at Prince Albert, but the free lime content of the lime mud was higher than at Quesnel, which may be the reason. With the substantial decrease of 65% in the free lime content at Prince Albert, there would have been a tendency for

the settling rate of the lime mud particles to increase, counteracting the tendency for the settling rate to decrease at the higher slurry concentrations. Based on the two mill trials, when there is a reasonable free lime residual in the clarifier underflow solids under normal conditions, lime mud recycling provides an increase in the solids flux, which leads to an increase in the underflow solids concentration.

The absolute value of the slurry solids concentration in the clarifier underflow may be a factor in determining the increase in slurry solids achievable with recycling. At Prince Albert, the slurry solids concentration was low by industry experience, at 35–38% by weight. At Quesnel, the concentration was high by industry experience, at 45–48%. Lime mud recycling may have a greater impact on the underflow solids in situations in which the concentration is low. In general, progressively lower slurry solids can be expected in the clarifier underflow as the loading on the clarifier increases and as the free lime content of the lime mud increases.

Free lime test

A knowledge of the free lime content of the lime mud leaving the white liquor clarifier is important in establishing the potential improvements achievable with recycling. Accordingly, it is good to understand the factors that affect the reliability of the procedure commonly used at kraft mills to measure the free lime content. In examining this test procedure, we discovered an important limitation. If too much wash water is used in processing the sample, some of the $\text{Ca}(\text{OH})_2$ is washed out of the mud, leading to a result lower than the actual amount.

The data in Table III indicate a lower free lime result for the feed to the white liquor clarifier than for the clarifier underflow at Prince Albert. This finding runs contrary to expectations. With the apparent anomaly in

IV. Quesnel trial: slurry solids content in white liquor clarifier underflow

Recycle	Solids content, %		No. of data
	Avg.	Std. dev.	
Off	48.1	5.3	8
On	45.3	8.5	17

VI. Impact of the amount of wash water in the free lime test

Volume of wash water, mL	Free lime content, wt. % as CaO	Filtrate loss, mole/L of sample	
		Ca	Na
100	2.9	0.10	1.3
200	2.1	0.34	1.3
500	0.9	0.46	1.7
1000	0.4	0.52	1.5

10-mL sample taken from the white liquor clarifier underflow.

V. Sampling profiles at Prince Albert, free lime content of mud, wt. % as CaO

White liquor clarifier				
Profile	Feed	Underflow		Mud washer underflow
		No. 1	No. 2	
1	1.13	3.58	2.58	1.28
2	0.31	0.90	0.81	1.52
3	0.56	...	1.09	0.99
4	1.08	...	2.01	3.01

VII. Optimizing wash water use in the free lime test

Volume of wash water, mL	Free lime content, wt. % as CaO	Filtrate loss, mole/L of sample	
		Ca	Na
0	4.8	0.0000	0.4
25	3.0	0.0017	1.8
50	3.0	0.0061	2.2
100	2.6	0.042	2.2
200	1.9	0.12	2.2

10-mL sample taken from the white liquor clarifier underflow.

the results, we initiated some investigative sampling and analytical work.

The results of some sample profiles are summarized in **Table V**. Generally, the results for the No. 1 white liquor clarifier are similar to those for the No. 2 clarifier. The mud washer underflow results are more like those for the white liquor clarifier underflows than for the white liquor clarifier feed.

The analytical procedure for washing the lime mud samples resulted in more wash water being used per gram of dry mud solids for the clarifier inlet sample than for the clarifier underflow samples. When we realized this, we conducted a test in which the amount of wash water was varied. The results, summarized in the first two columns of **Table VI**, show that the free lime content is affected by the amount of wash water, particularly in the range of wash water used in the analytical procedure.

In the procedure, the washing is done with the intent of removing residual Na_2CO_3 and NaOH before titration with hydrochloric acid. If the NaOH and Ca_2CO_3 are not properly removed, the titration result for free lime would be falsely high. However, in washing the mud with excessive amounts of water, there is the possibility of leaching $\text{Ca}(\text{OH})_2$ from the solids, because $\text{Ca}(\text{OH})_2$ is reasonably soluble in water—about 0.015 g moles $\text{Ca}(\text{OH})_2$ per liter at 50–75°C (9).

According to one hypothesis of the mechanism for the recausticizing reaction (1), the residual $\text{Ca}(\text{OH})_2$ should be at the center of the lime mud particles, where it would be difficult to leach out during the short interval of the water wash. Nonetheless, it was apparent that some basic material was being washed out of the lime mud prior to

the titration, but it was not clear whether it was Na_2CO_3 and NaOH , or $\text{Ca}(\text{OH})_2$.

To investigate the leaching, we washed a sample with varying amounts of wash water and analyzed the filtrates for calcium and sodium. The results are shown in **Table VI**. With large amounts of wash water, $\text{Ca}(\text{OH})_2$ is leached from the lime mud particles.

Further work was done to see if the amount of wash water could be reduced to that necessary to remove most of the sodium compounds, while limiting the removal of $\text{Ca}(\text{OH})_2$. The results are presented in **Table VII**. If the wash water volume is restricted to 5 times the volume of the original sample, basically all of the sodium compounds are washed out, but essentially all of the free lime remains.

Implications for other mills

Higher causticities are of interest in the effort to decrease the liquor cycle dead load, mainly for the purpose of increasing recovery boiler productivity. The common causticity target of 80% leaves considerable scope for improvement (1). At Prince Albert, a causticity target of 86% is regularly achieved by practicing an acceptable degree of overliming. The disadvantage of this practice is that the overliming infringes on the capacity of the lime kiln. The results of the trials at Prince Albert illustrate that lime mud recycling can be used to decrease the necessary degree of overliming. Alternatively, although not tested at Prince Albert, it should be possible with recycling to increase the causticity target somewhat, for the same degree of overliming. Either way, lime mud recycling is a simple technique to complement efforts to

achieve a higher causticity, while getting the most use out of the lime kiln.

Under circumstances of moderate overliming, lime mud recycling can be expected to increase the slurry solids concentration of the white liquor clarifier underflow. This increase has important implications for lime mud washing. For example, in the trials at Prince Albert, the slurry solids concentration of the clarifier underflow increased from 34.7% by weight to 38.4%. The amount of residual white liquor accompanying the lime mud in the underflow was decreased by 15%. Lime mud washing requirements were decreased accordingly. Consequently, lime mud recycling has potential for contending with lime mud washing limitations and for allowing more operating flexibility in adding wash water to the recausticizing system.

The benefits of lime mud recycling extend to the lime mud filter operation. Recycling provides a drier cake containing less sodium compounds.

Apparently, lime mud recycling would help to provide more consistent performance throughout the recausticizing system. In the trials, the variability of the slurry solids concentration in the white liquor clarifier underflow was cut in half by lime mud recycling. The variability in the free lime content of the mud was also decreased by 50%; therefore, the recycling should minimize overliming upsets. The variability in the sodium content of the lime mud filter cake was decreased by 50%, and the variability in the moisture content was decreased by 30%, which helps to improve the performance of the kiln.

To implement lime mud recycling, all that is required is a pump and some piping. In most cases, the length of the piping would be in the range of 15-75 m. A pipe diameter somewhat larger than 38 mm is recommended, to increase the degree of recycling beyond that in the trials at Prince Albert and Quesnel. In some cases, the pump may not be required.

Conclusions

Lime mud recycling is simple and inexpensive to implement, and it is easy to operate. It provides more time for the recausticizing reaction to continue, without the need of additional causticizers. Also, the recycled material is placed in an environment where there are strong concentration driving forces to consume the residual free lime in the center of the lime mud particles.

Although there was a common causticity target of 86%, lime mud recycling provided a slightly higher causticity—86.0% for lime mud recycling vs. 85.4% for conventional operation. The variability in the causticity was similar between the two modes.

Lime mud recycling decreased the free lime content of the lime mud in the white liquor clarifier underflow by 65%. With the more complete utilization of the lime, the requirement for reburned lime would have been decreased by about 4%. Also, the variability in the free lime content of the mud was decreased by 50%; this improvement in stability would help to moderate upsets from overliming.

Lime mud recycling increased the slurry solids concentration of the white liquor clarifier underflow by 3.7% by weight on an absolute basis, thereby decreasing the amount of white liquor accompanying the lime mud

by 15%. Also, the variability of the solids concentration was decreased by 43%. Both of these factors simplify lime mud washing.

Statistically, the clarity of the white liquor was unaffected by lime mud recycling. The variability in clarity was unaffected as well.

Results from limited sampling indicate that the benefits of lime mud recycling carry through to the lime mud filter, providing more consistent performance, with a drier cake that contains less sodium compounds.

The standard analytical procedure for measuring the amount of free lime in lime mud suffers from the limitation that some of the Ca(OH)_2 is washed out of the mud along with the residual white liquor. This can be moderated by restricting the amount of wash water to that necessary to get rid of most of the residual white liquor.

Finally, lime mud recycling is a simple technique to complement efforts at achieving a higher causticity to decrease the liquor cycle dead load, while getting the most use out of the capacity of the lime kiln. It may also be a simple solution to overcoming lime mud washing limitations. With lime mud recycling, the performance of the recausticizing system should be more consistent, and upsets from overliming should be more moderated. □

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