# RECAUSTICIZING - PRINCIPLES AND PRACTICE

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OVERVIEW

The recausticizing process produces cooking liquor for the digester from recycled inorganic chemicals generated in the recovery boiler and lime kiln. The process involves one very simple chemical reaction followed by process steps utilizing various types of liquid solid separation equipment.

Cooking liquor (white liquor) for the kraft process is produced from smelt generated in the recovery boiler. Quick lime is slaked in the smelt solution (green liquor) producing white liquor and calcium carbonate (lime mud). The calcium carbonate is calcined in a lime kiln to produce quick lime. The lime mud is washed to reduce it's chemical content before it is fed into the lime kiln and the wash liquor (weak wash) generated is recycled to dissolve the smelt to produce green liquor.

The chemical reaction can be described very simply as follows:

Green Liquor + Lime = Lime Mud + White Liquor

$Na_2CO_3 + H_2O + CaO = CaCO_3 + 2NaOH$

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sodium Carbonate | + | Water | + | Calcium Oxide | = | Calcium Carbonate | + | Sodium Hydroxide |

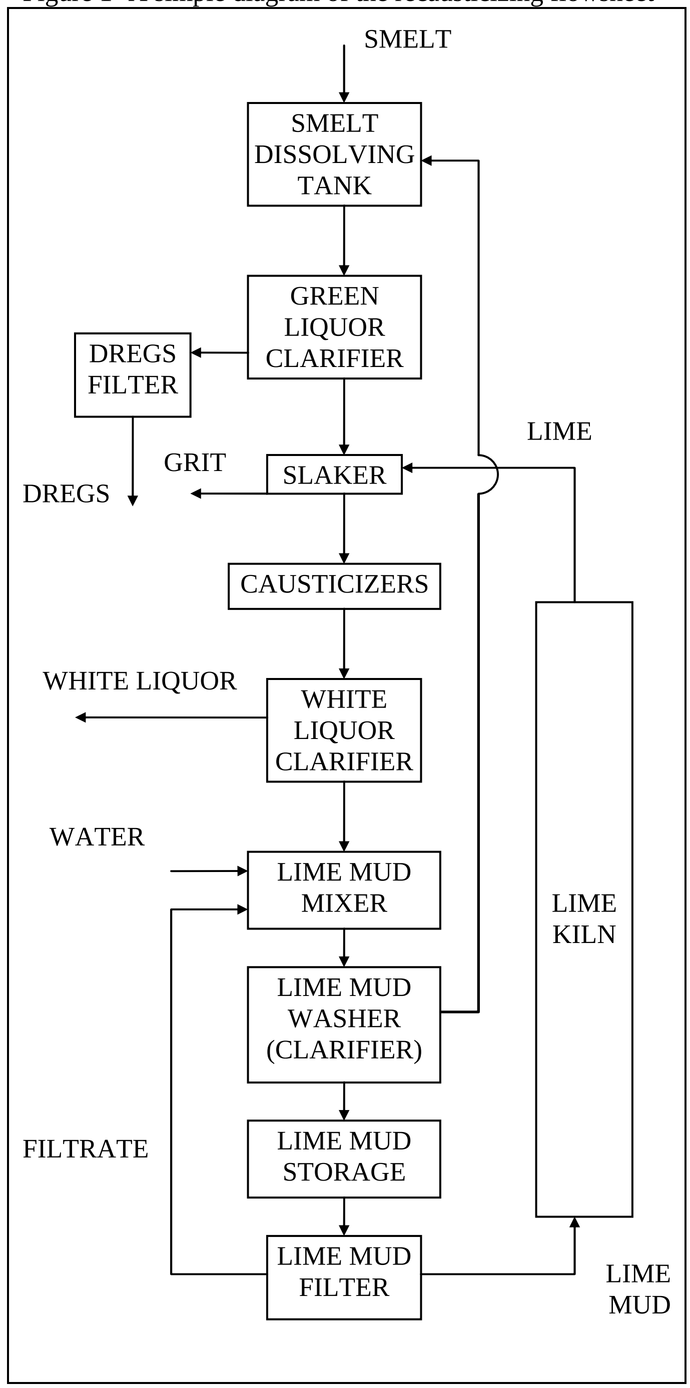
Figure 1 Shows the flowsheet in the form of a block diagram.

CHEMICALS IN THE RECAUSTICIZING PLANT

Sodium Carbonate ($Na_2CO_3$) - This is the main constituent of the smelt generated in the recovery boiler. Dissolving the smelt in water (weak wash) produces Green liquor

Calcium Carbonate ($CaCO_3$) (Lime Mud) - Produced by slaking Quick Lime in Green Liquor.

Figure 1- A simple diagram of the recausticizing flowsheet




Calcium Oxide (CaO) (Quick Lime) - Produced in a rotary lime kiln by calcining lime mud ($CaCO_3$)

$$CaCO_3 + Heat = CaO + CO_2$$

Sodium Hydroxide (NaOH) - This is the main constituent of white liquor (cooking liquor) used in the digester. At high temperature and pressure it dissolves the lignin bonding the wood fiber together. It is produced by slaking quicklime in green liquor.

Sodium Sulfide ($Na_2S$) - A major constituent of white liquor that helps reduce damage to the cell walls of the wood fibers during the cooking process in the digester.

Sodium Sulfate ($Na_2SO_4$) (Salt Cake) - This is a make-up chemical introduced in the recovery boiler and is carried through the recausticizing system and liquor cycle as dead load.

There are other chemicals such as sodium sulfite ($Na_2SO_3$), sodium thiosulphate ($Na_2S_2O_3$), iron, manganese, silica, and aluminum to name a few[1]. These generally are not troublesome unless the system is not designed with a means of purging. Mills in Asia that use bagasse, or straw pulps often have problems with high silica levels.

## CHEMISTRY OF COOKING LIQUOR PREPARATION

Digester operators are primarily concerned with the effective alkali (EA) of the white liquor. They use this value to calculate the volume of cooking liquor they will need to process wood chips in the digester. The active alkali (AA) is easily calculated from the EA. See Table I. for definitions.

$$EA = NaOH + \tfrac{1}{2}Na_2S$$
$$AA = NaOH + Na_2S$$

Generally all chemical concentrations (lbs./cu.ft. or $kg/m^3$) are expressed in terms of sodium oxide ($Na_2O$) in North America. In other parts of the world some mills express the concentration in terms of sodium hydroxide (NaOH). It is always good to check whether the basis is $Na_2O$ or NaOH when talking to mills outside North America.

The amount of AA required per day will determine the flow of white liquor required from the recausticizing plant. Target values of Total Titratable Alkali (TTA) and Active Alkali (AA) and Sulfidity (% $Na_2S$) are set by the digester design. Recausticizing system operators perform routine tests (ABC tests - See Tappi Test Methods for more details) to check that the plant is operating close to these design values.

The primary chemical reaction in the lime slaker is the hydrolysis of quick lime. This reaction is exothermic.

$$CaO + H_2O = Ca(OH)_2 + Heat$$

The reaction proceeds very fast and generates a lot of heat. Calcium hydroxide reacts instantaneously with the sodium carbonate in the green liquor to form sodium hydroxide and calcium carbonate.

$$Ca(OH)_2 + Na_2CO_3 = 2NaOH + CaCO_3$$

Table I - Definitions

Total Titratable Alkali - TTA* = $NaOH+Na_2CO_3+Na_2S$

Active Alkali AA = $NaOH + Na_2S$

Activity % = (AA/ TTA) x 100

Effective Alkali EA = $NaOH + \tfrac{1}{2} Na_2S$

Causticizing Efficiency % =
$$\frac{\text{NaOH (less NaOH in Green Liquor)} \times 100}{\text{NaOH (less NaOH in Green Liquor)} + Na_2CO_3}$$

Causticity = $(NaOH/ (NaOH + Na_2CO_3)) \times 100$

Sulfidity (AA Basis) = $(Na_2S/AA) \times 100$

Sulfidity (TTA Basis) = $(Na_2S/TTA) \times 100$

Total Chemical = all sodium salts

Reduction (in green liquor) = $Na_2S/ (Na_2S + Na_2SO_4)$

* TTA should include ½ $Na_2SO_3$ but it is generally ignored

This reaction is an equilibrium reaction and is therefore reversible and never actually reaches full conversion. Typically only about 80% of the $Na_2CO_3$ is converted to NaOH. This percentage will vary with the concentration (TTA) of the solution and the percentage sulfidity see Figure 2.[2] Since both $Ca(OH)_2$ and $CaCO_3$ are insoluble, this reaction takes place by the exchange of OH and $CO_3$ ions at the interface between the solid and liquid.

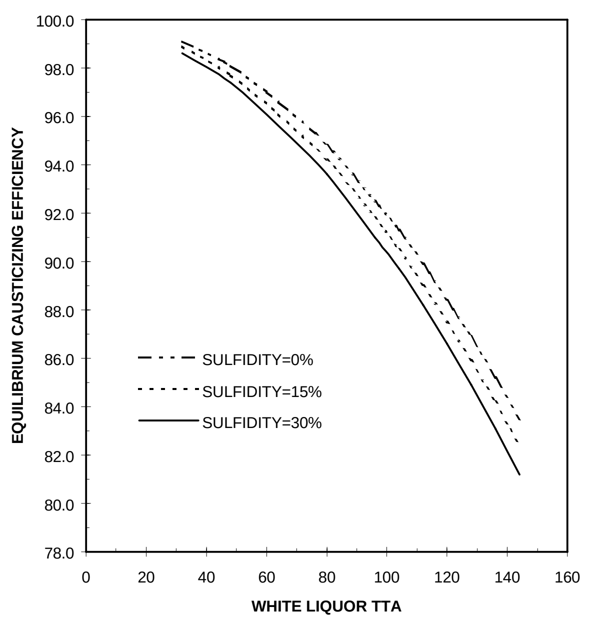
The reaction can be driven to the right by adding more lime but this has an adverse effect on the performance of process equipment due to the presence of 'free lime'. For any given white liquor there will be a threshold limit for the causticizing efficiency above which the free lime becomes a major operating problem, especially with pressure filter systems. Figure 3[3] was developed from mill data and illustrates the effect of trying to achieve a higher causticity. This problem will be discussed later in Trouble Shooting.

The above reactions occur in the lime slaker; therefore control of the lime slaker operation is critical to good recausticizing plant operation. Operators must be aware of the effects of various process changes such as,

- ⇒ Green liquor temperature and TTA
- ⇒ Lime quality
- ⇒ Slaker temperature

There are systems available today that will provide good control of a lime slaker with only routine check tests by the operator.

Figure 2 - Equilibrium causticizing efficiency versus white liquor TTA[2]




Equilibrium Causticizing Efficiency =

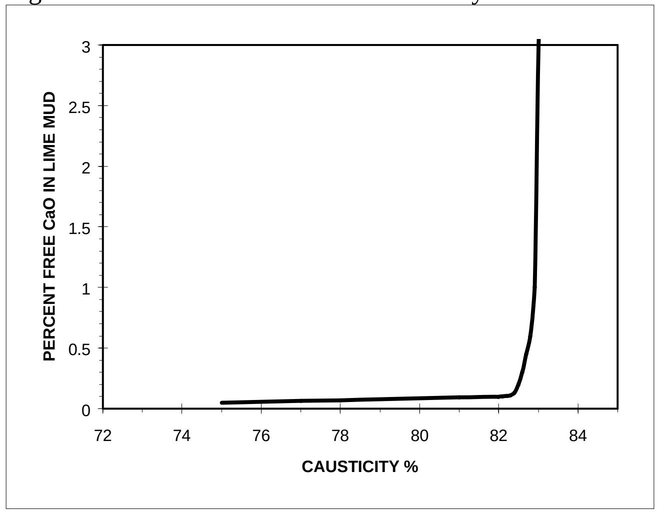
$$NaOH \ /(NaOH + Na_2CO_3)$$

TTA (Total Titratable Alkali) expressed in g/l as $Na_2O$

Sulfidity = $Na_2S / (NaOH + Na_2S + Na_2CO_3)$

A vast majority of the chemical conversion takes place in the slaker, however with time this reaction can continue to a causticizing efficiency approximately 4 - 5 percentage points below the theoretical equilibrium curve (See Figure 2). In a recausticizing plant additional retention time is provided in agitated tanks called causticizers. It is at this point that the chemistry ends and the following process steps involve liquid/solid separation and washing of lime mud by dilution and displacement washing. Displacement washing is accomplished on a filter.

Figure 3 - Percent free lime versus causticity




SYSTEM DESCRIPTION

You will notice up to now this chapter has only discussed the chemical reaction taking place in the lime slaker. Before we try to make any process calculations it is good to have an understanding of the process flowsheet of a typical recausticizing plant as shown in Figure 1.

From a control stand point recausticizing plant operation generally starts at the inlet of the green liquor clarifier or green liquor stabilization tank if one is installed. Operation and control of the smelt dissolving tank is usually by the recovery boiler operators, however the smelt dissolving tank is an important part of the overall recausticizing flowsheet.

The following is a brief description of each process step starting from the smelt dissolving tank.

Smelt Dissolving Tank

Molten smelt from the floor of the recovery boiler is dissolved in weak wash to produce green liquor. This agitated tank is equipped with a gas scrubber on the exhaust vent using weak wash to knock down particulates and condense steam.

Raw Green Liquor Stabilization Tank

This is an agitated tank designed to have sufficient retention time to even out fluctuations in green liquor temperature and density. Including this tank in the flow sheet can improve the operation of the green liquor clarifier.

Green Liquor Clarifier

Suspended particles in the green liquor are called dregs and are typically removed in a sedimentation clarifier. The dregs settle to the bottom and are moved to the center sludge outlet by a rake mechanism. Clarified green liquor from the top of the clarifier is used in the lime slaker. Green liquor can also be clarified in pressure filters of various configurations.

Dregs Filter

The dregs removed from the bottom of the green liquor clarifier are generally filtered and washed on a precoat filter to remove residual chemical and increase solids content of discharged cake for ease of disposal. The dregs can also be filtered and washed in a filter press generally without the use of a precoat.

Lime Slaker

In the slaker lime and green liquor are mixed together to produce white liquor. The lime slaker is equipped with a sedimentation type classification device to remove unreacted lime and other reject material called grit from the system.

Causticizers

Three or more agitated tanks are used in series to ensure that the reaction proceeds as far as possible to completion before the white liquor is separated from the lime mud.

White Liquor Clarification

A sedimentation clarifier or pressure filter is used to separate lime mud from the white liquor. The clarified white liquor is pumped to the digester.

Lime Mud Mixer

Lime mud from the white liquor clarifier is diluted with water and lime mud filter filtrate to wash the lime mud.

Lime Mud Washer

Sedimentation clarifier or pressure filter is used to separate washed lime mud from weak wash. The weak wash is used to make green liquor in the smelt dissolving tank.

Lime Mud Storage Tank

This tank is used to store thickened lime mud from the lime mud washer prior to filtration on the lime mud filter.

Lime Mud Filter

A vacuum precoat type filter washes and dewaters the lime mud prior to feeding into the lime kiln.

Lime Kiln

The lime kiln calcines the recovered lime mud into quicklime for use in the lime slaker.

PROCESS CALCULATIONS AND EQUIPMENT SIZING

Appendix A gives simple calculations for determining the mass balance around a typical flowsheet for producing one oven dry tonne of pulp.

The calculations start at the outlet of the white liquor clarifier by determining the flow of white liquor needed at the digester plus any white liquor required by the pulp mill bleach plant and then calculating the lime required to make that quantity of white liquor. The quantity of lime mud solids is determined next so that the underflow from the white liquor clarifier can be calculated.

The calculations use the molecular weights of the compounds to make the conversions, for example calcium oxide to calcium carbonate. The reaction can be written as follows:

$$\begin{array}{lllllllll} CaO & + & Na_2CO_3 & + & H_2O & = & 2NaOH & + & CaCO_3 \\ 56 & & 106 & & 18 & & 80 & & 100 \end{array}$$

Simplified this can be written in terms of sodium oxide by removing the water from the equation.

$$\begin{array}{lllllll} CaO & + & Na_2CO_3 & = & Na_2O & + & CaCO_3 \\ 56 & & 106 & & 62 & & 100 \end{array}$$

1 kg of $Na_2O$ will require 56/62 kg of CaO and 1kg of CaO will be converted to 100/56 kg of $CaCO_3$

Given the two flows out of the clarifier, the flow from the causticizers can be determined. The green liquor flow to the slaker can also be calculated now. We now have sufficient information to size the following equipment.

- Lime slaker from green liquor feed flow
- Causticizers from green liquor feed flow
- White liquor clarifier from mud solids

Table II Equipment loading rates

| **Equipment** | **English Units** | | **Metric units** | |
|---|---|---|---|---|
| Raw Green Liquor Stabilization | hrs | 2 - 4 | hrs | 2 - 4 |
| Green Liquor Clarifier | ft/hr | 1.3-1.8 | m/hr | 0.4-0.55 |
| Dregs washer (sedimentation) | $ft^2$/Ton/d | 100 | $m^2$/tonne/d | 10.3 |
| Dregs filter (precoat) | lb/hr/$ft^2$ | 2.5-3.5 | kg/hr/$m^2$ | 12-17 |
| Slaker (clarifiers) | min. | 10-15 | min. | 10-15 |
| Slaker (pressure filters) | min. | 15-25 | min. | 15-25 |
| Causticizers (clarifiers) | min. | 90 | min. | 90 |
| Causticizers (pressure filters) | min. | 150-180 | min. | 150-180 |
| White Liquor (WL) Clarifier | | | | |
| Unit type | $ft^2$/Ton/d | 9 – 10 | $m^2$/tonne/d | 0.92-1.0 |
| Tray type | $ft^2$/Ton/d | 14 – 16 | $m^2$/tonne/d | 1.43-1.64 |
| WL Pressure filter (tube type) | usgpm/$ft^2$ | 0.6 | L/min/$m^2$ | 25 |
| WL Pressure disc filter | usgpm/$ft^2$ | 1.0 | L/min/$m^2$ | 40 |
| Lime Mud Washer | | | | |
| Unit type | $ft^2$/Ton/d | 7 – 8 | $m^2$/tonne/d | 0.72-0.82 |
| Tray type | $ft^2$/Ton/d | 12 – 14 | $m^2$/tonne/d | 1.23-1.43 |
| LMW Pressure filter (tube type) | usgpm/$ft^2$ | 0.73 | L/min/$m^2$ | 30 |
| LM Filter | Ton/d/$ft^2$ | 0.6 – 0.75 | tonne/d/$m^2$ | 5.9-7.3 |
| Note: Above loading rates should be used in conjunction with an analysis of the existing or proposed system making allowance for future changes in the plant capacity. The above loading rates are only a guide. Please check with your equipment supplier for the recommended loading rates. | | | | |

Lime kilns with wet scrubbing systems recirculate collected dust back to the kiln via the lime mud washer. This additional recycled mud load can vary from 10% of the kiln feed in newer installations to 25% of the feed in older overloaded installations. Systems with a dry electrostatic precipitator most often return the dust directly to the kiln.

The mud load to the lime mud washer is calculated next using the mud from the white liquor clarifier and the kiln scrubber dust recycle. This same mud load is used to determine the following equipment sizes.

- Lime mud washer from mud solids
- Lime mud storage agitator from mud flow
- Lime mud precoat filter from mud solids

The balance around the green liquor clarifier will allow sizing of the clarifier from the hydraulic flow of green liquor. The dregs load will determine the size of the dregs filter.

For pressure filter systems the filters are sized on hydraulic flow per unit of filtration area.

Calculation of the equipment sizes can be carried out starting at the beginning of the flow sheet at the green liquor clarifier. Table II gives typical loading rates for sizing a recausticizing system.

Referring to Appendix A the green liquor flow calculated in Item 7 is used to determine the area of clarifier required. Determine the flow of green liquor per hour and divide it by the loading rate in the Table II. This will provide the area of the clarifier and hence the diameter. Here it is a good idea to be conservative and select the next size of clarifier larger than that calculated.

The lime slaker is sized on the green liquor flow based on the retention time in the mixing section of the slaker ignoring any bypass of flow to the classifier. Check with the equipment supplier for the volumes of the various size slakers.

Causticizers are sized on the green liquor flow. For new systems assume four tanks unless there are space limitations which may dictate that fewer tall multi-compartment tanks are installed.

White liquor clarifiers are sized using the mud flow calculated in Item 4 of Appendix A. The mud solids are used to calculate the area and hence the diameter of the clarifier. In the case of pressure filters used for white liquor the flow of white liquor to the digester calculated in Item 2 plus any liquor required by the bleach plant is used to size the filters.

The lime mud washer is sized using the mud flow from Item 6 to determine the area of clarifier needed. The kiln scrubber recycle is included in the flows to this step in the process. Modern mills have dry electrostatic precipitators that collect the dust and return it directly to the kiln without having to pass it through the lime mud washer and over the lime mud filter. In the case of dry precipitators additional mill water has to be used at the lime mud mixer to make up for the lack of scrubber water.

The lime mud washer underflow is used to size the lime mud storage tank and the lime mud filter. Lime mud storage volume is generally calculated using 24 hours of storage time based on a consistency of 40% solids by weight.

The lime mud filter is sized based on the mud solids in the feed flow. The loading in Table II is conservative so that oxidation of the sodium sulfide is achieved prior to feeding the kiln. Excess reduced sulfur ($Na_2S$) in the kiln feed will result in TRS emissions from the kiln exhaust stack. Current practice is to oversize the lime mud filter so as to achieve greater oxidation of the sulfides in the lime mud being fed to the kiln.

This chapter has so far covered the basic chemistry and discussed the process steps necessary to achieve a balanced recovery cycle. We will next discuss the implementation of the various process steps and the different types of equipment available.

The recausticizing plant flowsheet is divided into three sections:

Green liquor processing
White liquor preparation
Lime mud washing

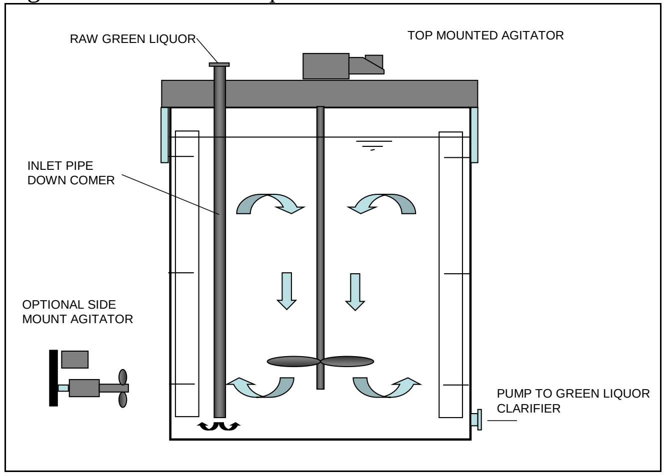
GREEN LIQUOR PROCESSING

Green liquor is prepared by dissolving smelt in weak wash in the smelt dissolving tank located underneath the recovery boiler. The raw green liquor, as it is called, is sent to a stabilization tank and from there to a green liquor clarification device before processing in the lime slaker.

Smelt Dissolving Tank

The recovery boiler has a series of spouts that discharge the molten smelt from the bottom of the boiler into the smelt dissolving tank. Weak wash is pumped into the tank to dissolve the smelt. The tank is equipped with a gas scrubbing system because a tremendous amount of steam is generated as this molten smelt contacts the weak wash inside the tank. The scrubber uses weak wash for scrubbing the steam and this scrubbing liquor is discharged into the smelt dissolving tank. The tank is often equipped with side mounted propeller-type agitators to keep the tank well

Figure 4- Raw Green Liquor Stabilization Tank




mixed, and some mills use a pump to recirculate the raw green liquor inside the tank. The raw green liquor is then pumped to the raw green liquor stabilization tank.

The density of the raw green liquor is controlled by the addition of weak wash to the smelt dissolving tank. Density is measured by bubble tubes in the tank or nuclear density gauges on the discharge line from the pumps. Even with this control, density can still fluctuate due to erratic flow of smelt and it may be necessary to add additional control of density after the raw green liquor stabilization tank.

Raw Green Liquor Stabilization Tank

This tank has approximately two to four hours retention time and should be operated as full as possible to maximize the available tank volume. The tank is equipped with either side-mounted propeller agitators or a top-mounted turbine-type agitator. See Figure 4. The agitation provided should be sufficient to turn the contents of the tank over fairly quickly but not enough to shear any dregs flocs that have formed. The mixing in the tank evens out temperature and density fluctuations that may occur from irregular flow of smelt from the recovery boiler. It is a good idea to locate the raw green liquor stabilization tank close to the green liquor clarification device.

Some of the problems experienced with green liquor clarification can be attributed to the way the raw green liquor stabilization tank has been designed. Any flow going into the tank should be introduced with down-comers rather than a free discharging pipe at the top of the tank. The free discharge tends to introduce air into the raw green liquor

Figure 5 - Typical flowsheet with sedimentation clarifiers

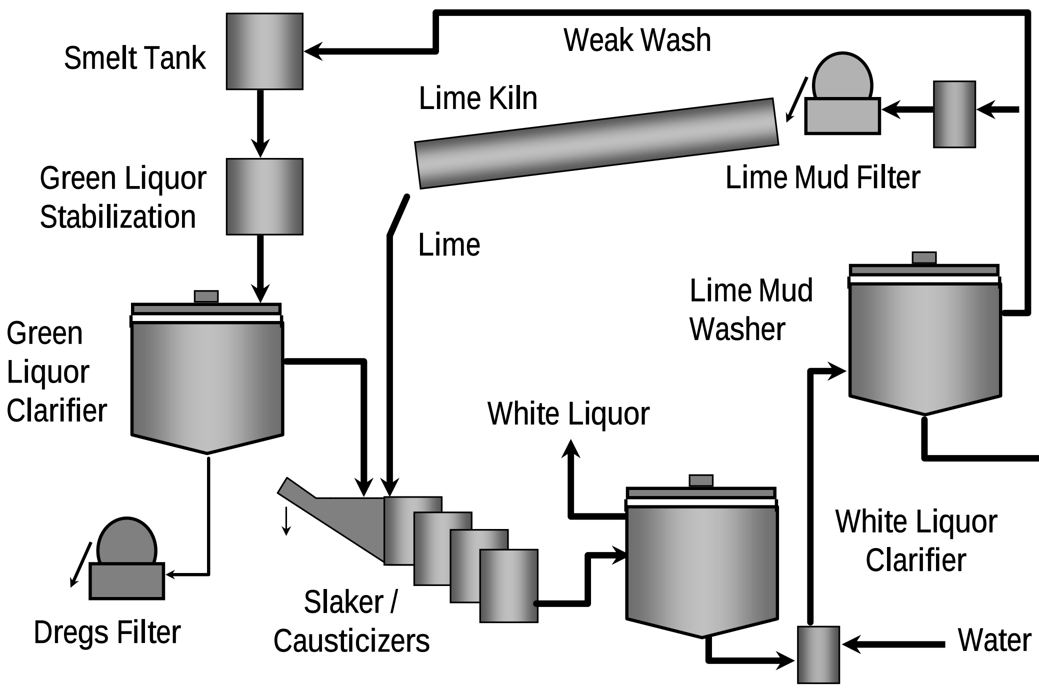



Figure 6 - Tray type clarifier

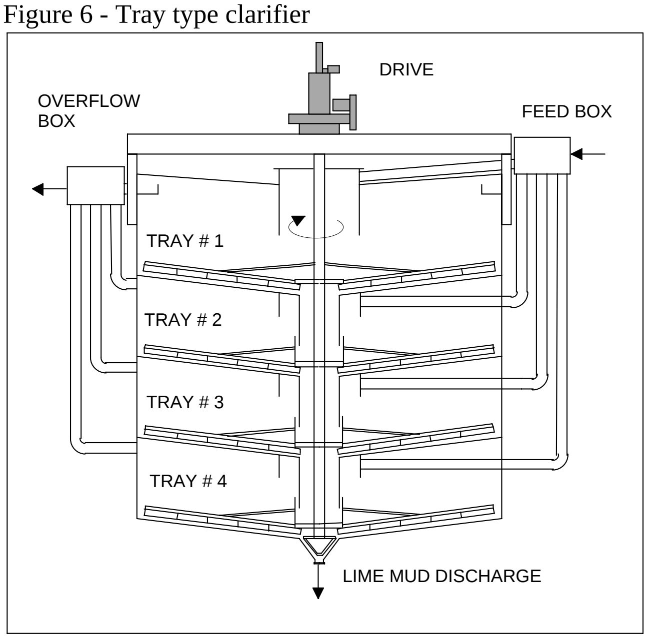
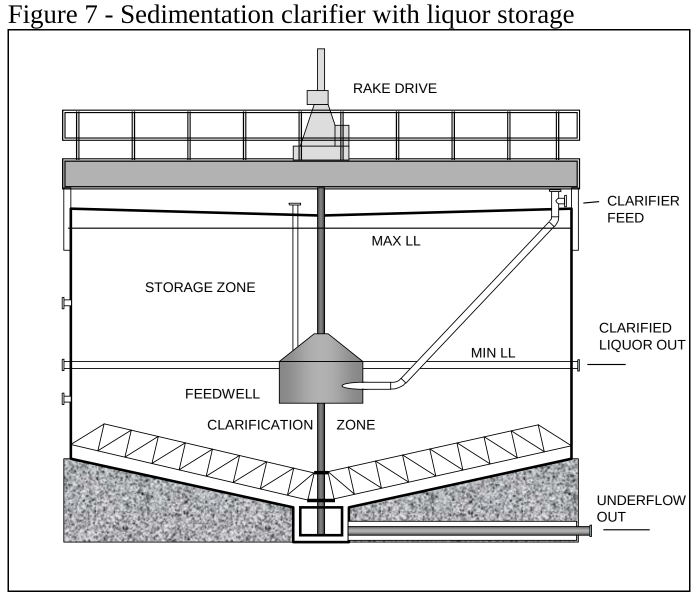



Figure 7 - Sedimentation clarifier with liquor storage



and can cause the green liquor dregs to float, which will cause clarity problems in the green liquor clarifier storage zone.

Green Liquor Piping

It is normal in most kraft mills to arrange duplication of the green liquor piping from the smelt dissolving tank to the green liquor clarifier. One pipe is maintained in operation as a green liquor line while the stand-by green liquor line carries weak wash back to the smelt dissolving tank. The lines are switched regularly to minimize build up. The flow of weak wash will dissolve any scale that has formed in the line while it was carrying green liquor.

In a mill with a number of recovery boilers, the piping approaching the raw green stabilization tank can become quite complicated and the same applies to a mill having more than one green liquor clarifier, however the extra piping and valves reduces maintenance costs associated with manually cleaning the lines.

Green Liquor Clarifier

The most common type of green liquor clarification device in the industry today is a sedimentation clarifier incorporating a raking device that moves the settled solids toward the center of the tank into a sludge pit. The feed flow is introduced into a feedwell, which helps to dissipate energy and provide the right conditions for separation of the dregs from the green liquor. Feedwell design is important for proper operation of the clarifier.

Older mills may have tray-type clarifiers, as illustrated in Figure 6. These are multiple compartment type clarifiers with a series of rakes and compartment trays mounted above one another in one tank.

There may be up to four compartments in one tank and the flow into each compartment is adjusted using a weir box with adjustable gates.

The unit-type clarifier has now replaced the tray type clarifier; this is a single compartment clarifier most commonly incorporating a storage zone inside the tank above a submerged overflow bustle pipe arrangement. The advantage of the unit storage type clarifier is that storage and clarification are provided in the same footprint, thereby saving space on what might be valuable mill real estate. The older tray-type clarifier required a separate storage tank for the clarified green liquor. In most cases today, the only reason a mill might consider a tray or multi-compartment type clarifier instead of a unit type clarifier is space constraints within an existing recausticizing plant.

The multiple compartment type clarifiers are inherently susceptible to corrosion because of the many components of the tanks submerged under green liquor inside the tank.

Unit-type clarifiers are loaded at a rise rate of 0.40-0.55 meter per hour to give the optimum green liquor clarity for use in the lime slaker. Any mill today contemplating a green liquor clarifier should put in the largest unit that can be installed in the space available even if the loading rate goes below 0.40 meter per hour. Using a very conservative loading rate will result in good green liquor clarity and produce fewer problems in operating the clarification equipment downstream of the lime slaker. A mill operating pressure filters for white liquor clarification will tell you that dregs carryover in the green liquor is one of the major problems in operating these filters. A green liquor clarifier should be able to produce green liquor clarities of less than 100 mg/L. It is therefore important to insure that the optimum clarification equipment is installed ahead of a pressure filter system. The installation of various types of pressure filters for white liquor clarification will be discussed later on in this chapter.

The green liquor clarifier has a raking device that is driven by a drivehead mounted on the top of the tank on a bridge-type structure. The rake should have a lifting device of at least 24 inches to allow the rakes to be raised should a high load situation occur in the clarifier. The use of a rake lifting device in mills that operate sedimentation clarifiers is of great importance because there is a greater likelihood of lime mud solids carryover in the weak wash which end up in the green liquor clarifier. These recirculated lime mud solids can cause problems with high torque.

Generally the feed pipe to the green liquor clarifier enters the tank from the roof level and is directed down to the feedwell at an angle of approximately 45 degrees. A vertical feed pipe tends to generate a vacuum (barometric leg) and causes more problems with pipeline scaling. The advantage of feed entry from the top of the tank is that the feed pipe can be cleaned without draining the tank. Feed pipes that enter through the sidewall of the tank horizontally are very difficult to clean and the tank has to be emptied before any cleaning equipment can be inserted into the line from outside the tank.

The feedwell should be equipped with a vent to make sure that any entrained air in the feed is vented above the level of the liquor in the storage zone at the top of the clarifier. The dregs and green liquor exit the feedwell and the dregs settle to the bottom of the tank and the clear green liquor is collected above the overflow bustle pipe arrangement. See Figure 7 for a cross section through a typical unit type green liquor clarifier.

Above the bustle pipe it is a good idea to install a second draw-off for clarified green liquor approximately halfway up the storage zone of the tank. This enables the mill to obtain clearer green liquor should there be a process upset causing poor green liquor clarity at the normal draw-off level. It is also a good idea to install a green liquor draw-off nozzle just below the overflow bustle pipe. This lower nozzle will enable the mill to obtain green liquor to start the mill if the storage zone is depleted.

The dregs underflow is drawn out of the sludge pit in the bottom of the tank through a pipe that extends to the outer edge of the tank. This pipe is quite often duplicated so that if one line becomes plugged, the mill can switch to the stand-by line, which allows time to unplug the other line.

Typically, clarifier mechanisms and feedwells are type 304 stainless steel; however, the tanks are generally manufactured from carbon steel preferably of the low silica variety since silica is soluble in caustic.

Tanks are generally insulated on the vertical sidewalls; however, it is most common to leave the roofs uninsulated.

Alternative technology - pressure filtration of green liquor is carried out at a number of mills. There has been a reasonable amount of success with this technology and a number of suppliers are now offering various types of green liquor pressure filters. Although this technology is proven in various forms, the industry is approaching this technology cautiously, as was the case with white liquor pressure filtration twenty years ago. The dregs generated by different recovery boilers provides varied filtration characteristics and experience has shown that although direct filtration will work well at one mill, it may not work as well at another mill without some modifications of the filtration process such as using a precoat bed on the filter media.

<u>Dregs Filter</u>

The green liquor dregs from the bottom of the green liquor clarifier are generally dewatered and washed on a vacuum precoat-type filter. The filter is precoated with a sacrificial filter material and in the case of a pulp mill, the precoat used is lime mud. The lime mud precoat is formed on the drum under vacuum to a depth of approximately 4-6 inches and the green liquor dregs are filtered out of the clarifier underflow on to the precoat. An advancing type scraper blade scrapes off a very thin layer of the lime mud and the dregs as it advances.

The precoat will last anywhere between 8 and 16 hours depending on the load on the filter and the drum operating speed. At the end of the precoat cycle, the filter has to be washed down and a fresh layer of precoat built up on the drum before more dregs can be filtered.

A dregs holding tank is recommend between the green liquor clarifier and the dregs precoat filter. This holding tank will act as a sump for the dregs pump feeding the precoat filter and also act as a sump for receiving the wash-down water and overflow from the precoat filter. The underflow pumps from the green liquor clarifier control the level of dregs in the holding tank. This holding tank prevents dregs from ending up in the drain system in the recausticizing plant and the possible contamination of lime mud with green liquor dregs via a reclaim system.

Figure 8 - Dregs precoat filter

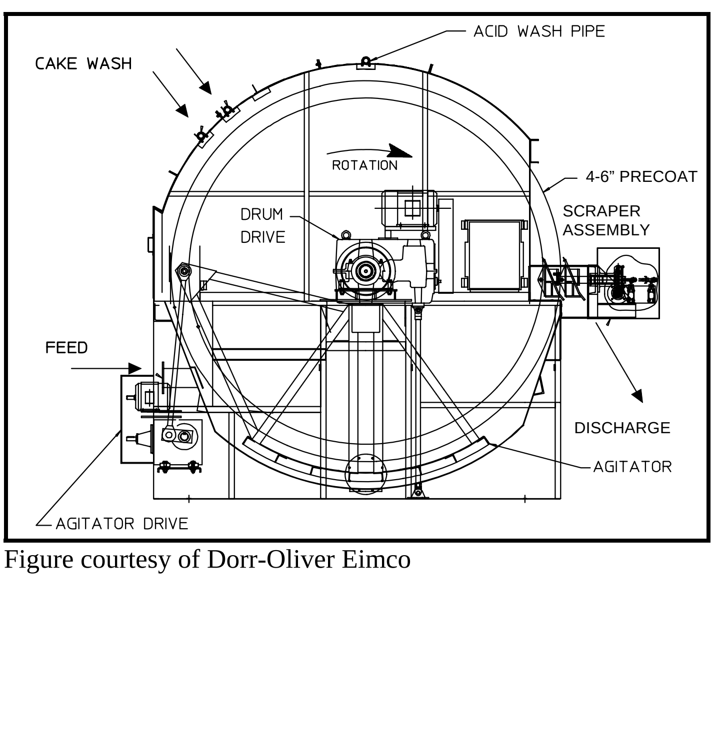



Figure courtesy of Dorr-Oliver Eimco

Figure 9 - View of a dregs precoat filter

Photo: courtesy of Dorr-Oliver Eimco

Dregs precoat filters are generally loaded at a rate of 17 to 22 $kg/hr/m^2$ of filter area. However, recent EPA requirements for a pH of less than 12.5 for dregs being discharged to landfill may require a more conservative loading rate so that more washwater can be applied to the cake before it is discharged.

Wash water is applied to the cake on the rising side of the drum. Usually 2.5 displacements of wash water are provided, which is equivalent to 2.5 times the weight of liquor in the cake. With a dry cake solids of 50% by weight the weight of shower water approximates the weight of dregs discharged from the filter. Soda removal is typically 90-95%.

Figure 8 shows a typical end elevation of a dregs precoat filter showing the scraper blade advance system and the location of the cake wash pipes. The cake wash pipes will apply a small quantity of hot water for a displacement wash on the very thin layer of dregs built-up on the precoat.

The filtrate that exits the vacuum end of the filter is collected in a vacuum receiver and then pumped to the raw green stabilization tank so that any recovered green liquor stays in the circuit. During the precoating of the filter, there will be a fairly high flow of weak wash since diluted lime mud from the lime mud storage is used for precoating. In this case, the filtrate should be directed to lime mud washing or weak wash storage, depending on the type of plant and white liquor clarification devices installed. It is important to design the filtrate pump with sufficient capacity to pump the filtrate during the precoating operation. This will avoid flooding out the vacuum pump causing the situation where the precoat being built up on the drum suddenly drops off the drum into the filter vat because of vacuum pump failure.

Dregs filter vacuum pumps are sized for 1.5 $m^3$/minute of air per $m^2$ of filter area at 560 mm of Hg vacuum

Dregs filters are typically mounted above a large bunker where the discharged dregs and lime mud precoat material can be collected. This is also commonly located close to the lime slaker grits discharge point so that both materials can be collected together. The filter is also generally equipped with a vapor hood to exhaust fumes from the filter to the outside of a building. If the filter is installed outside, the hood helps to keep rainwater from falling on the filter and re-wetting the discharged cake.

Plate type filter presses are now being offered by a number of suppliers to dewater and wash dregs without the use of lime mud precoat. This can be a benefit to mills with restricted landfill capacity.

The filter press is made up of plates stacked together. Each plate is essentially a slab of polypropylene or other material that has a large recess on each side. As the plates are placed together the recesses form a chamber for collection of the cake. One side of the recess can be fitted with a membrane which when pressurized squeezes the cake thereby giving a greater degree of dryness to the discharge cake.

The operation is a batch process but can be automated requiring little operator attention except when the press is discharging. The cake can be washed during the filter cycle reducing the soda loss from the mill and providing a cake that is environmentally acceptable for landfill.

<u>Green Liquor Heater/Cooler</u>

It is quite common for mills to install a heater/cooler in the pipeline between the green liquor storage and the lime slaker. Green liquors that are too hot or too cold make it very difficult to control the slaker temperature.

In older recausticizing plants with lime kilns that are not equipped with lime coolers, the hot lime entering the slaker combined with hot green liquor can result in boil over of the slaker when trying to achieve the optimum causticizing efficiency. It is therefore necessary to cool the green liquor to maintain the slaker temperature below boiling point (100°C to 104°C) while optimizing the process parameters.
In mills that have green liquor at a lower than desired temperature combined with a lime kiln equipped with coolers, it may be necessary to heat up the green liquor to maintain slaker temperature.

There are two types of green liquor heaters generally used in the recausticizing plant, depending on the problem encountered. In some mills, a heater/cooler is installed (generally of the shell and tube type) that can serve to either heat or cool the liquor depending on the circumstances. The shell and tube type heat exchanger, when operating in the cooling mode, is susceptible to scaling on the liquor side of the heat exchanger. Therefore, the heat exchanger should be designed to be easily cleaned including facilities for acid washing if necessary or a stand-by heat exchanger should be installed that it can be flushed by pumping weak wash or mill water through it to dissolve scale deposits while the other unit is operating with green liquor.

Some mills have had success in controlling the green liquor temperature by cooling the weak wash before it reaches the smelt dissolving tank. This helps eliminate the scaling problem associated with green liquor coolers.

To solve the problem of low green liquor temperature, a live steam injection-type heater is often installed. This type of heater slightly dilutes the green liquor and some allowance should be taken into account for the steam condensate in the green liquor flow. This type of direct steam heater should also be installed well ahead of the lime slaker and the line downstream of the heater should be maintained flooded at all times to avoid flashing of steam in the green liquor line prior to the lime slaker.

## WHITE LIQUOR PREPARATION

### Lime Slaker

The lime slaker is the heart or nerve center of the recausticizing plant. The chemical reaction that takes place in the slaker determines the chemical composition of the white liquor used in the digester. The size of the lime mud particles is also determined by the way the slaker is operated. Proper control of the lime and green liquor entering the lime slaker is important for correct operation of the recausticizing plant.

The lime slaker consists of two separate compartments. The mixing compartment where the lime and green liquor are introduced is equipped with an agitator to keep the lime particles in suspension while they are in the slaking process.

Figure 11 – Condensing type slaker scrubber

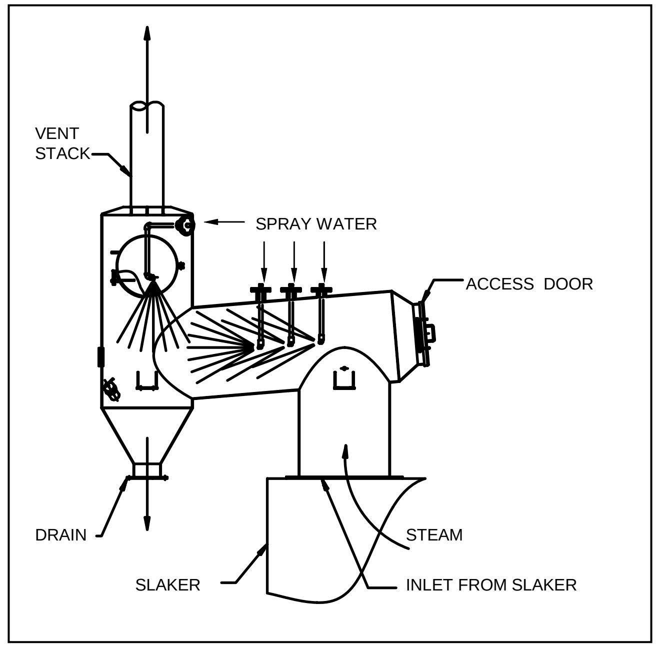



Figure courtesy of Dorr-Oliver Eimco

Figure 10 - Eductor type slaker scrubber

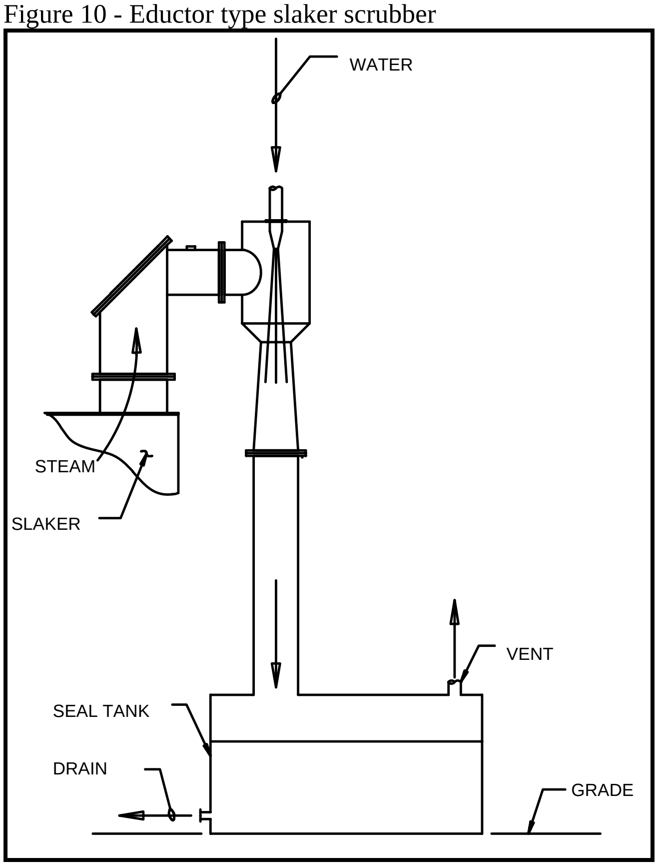



Figure courtesy of Dorr-Oliver Eimco

The retention time in a lime slaker is calculated on the total green liquor flow entering the mixing compartment and using the full volume of the mixing compartment. Typically the residence time in a lime slaker is between 15 and 25 minutes.

In a typical mill operating with a causticizing efficiency of 80 to 82 percent at the outlet of the last causticizer, the slurry leaving the mixing compartment of a lime slaker will have achieved a causticizing efficiency of approximately 75 percent. This means that most of the lime has been converted to calcium carbonate and the majority of sodium carbonate has been converted to sodium hydroxide.

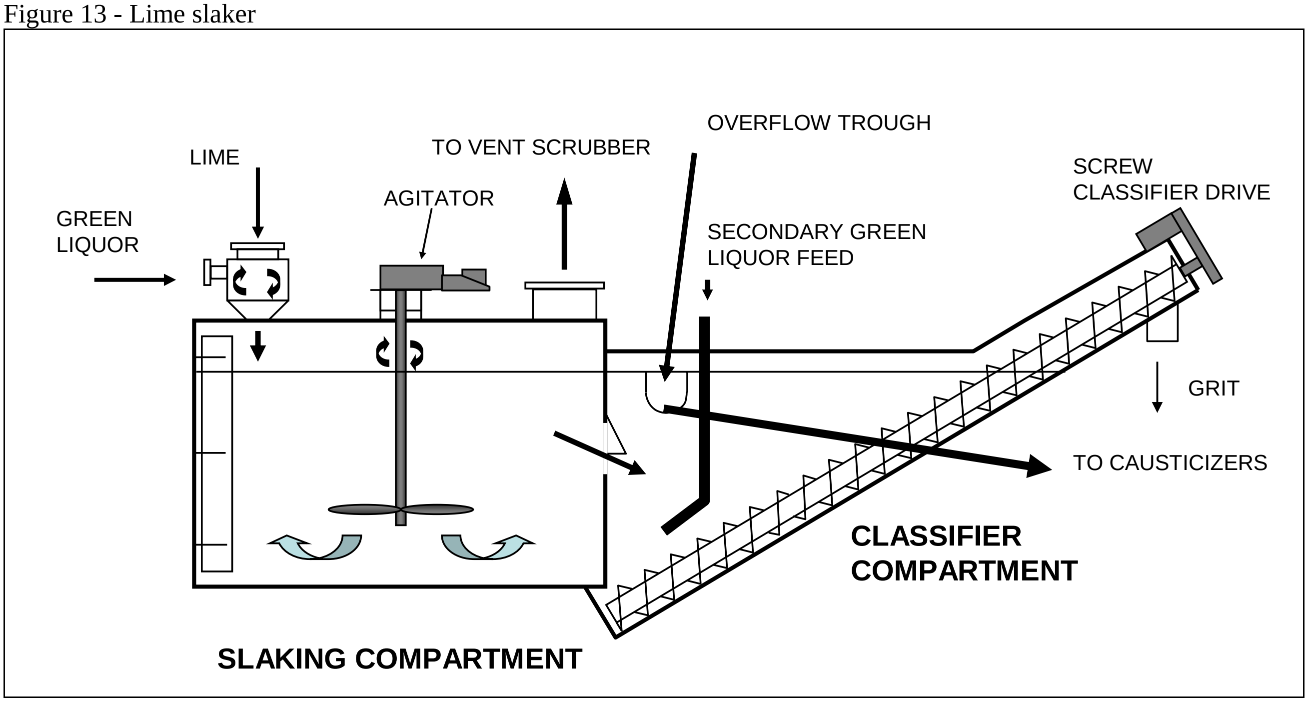
Inside the slaker, the slurry flows from the mixing compartment into the classifier compartment where approximately 65 mesh or larger solids separate out from the causticized slurry. The oversized material settles to the bottom of the classifier section and is removed using either a screw conveyor or rake type mechanism. See Figures 12 and 13 for details of a typical lime slaker.

The material that settles to the bottom of the classifier section is called grit. This material emanates from unslaked lime and reject material that comes in purchased lime as well as pieces of refractory, chain and any other small non-slakable lime components entering the lime slaker.

Figure12 - View of a lime slaker installation

Photo: courtesy of Kadant Black Clawson Inc. – Goslin™ Products Group

Figure 13 - Lime slaker



Most Kraft mills use fresh lime as make up lime for the recausticizing system, however there are a number of mills that burn limestone in the lime kiln and for various reasons, there can be partially calcined rocks coming through into the lime slaker which will find their way into the classifier section.

The green liquor feed to the lime slaker is usually equipped with a control valve and density gauge to enable proper control of the green liquor. A small proportion of the green liquor flow taken after the flow meter is diverted to the classifier section to a point near the bottom of the classifier where heavy solids can accumulate. This bypass stream serves as an agitation device in the lower portion of the classifier and can prevent bridging of slaker grits across the grit removal device.

The lime slaker is usually located under a large reburned lime silo that is equipped with a screw feeder that discharges into the lime slaker. The screw feeder is equipped with a variable speed drive to maintain the lime to green liquor ratio.

Make-up lime to the system is added in the form of purchased fresh lime. If the fresh lime is added to the reburned lime silo, there can be a layering of the materials inside the silo that can cause problems with slaker control because of the different rates of reaction of fresh lime to reburned lime. The best way to add purchased lime is to use a fresh lime silo and meter the make-up lime on a continuous basis either directly into the lime slaker or into the hot lime silo via the bucket elevator used to load the reburned lime from the lime kiln.

The temperature of the lime slaker is maintained by controlling the green liquor feed temperature. When the green liquor to lime ratio is set to produce the correct strength white liquor, the only changes required are monitoring the green liquor density and adjusting lime feed rate accordingly and also adjusting the green liquor temperature to maintain the correct slaker operating temperature.

Lime slakers are always equipped with a gas scrubbing device since a lot of steam is generated inside the slaker which can carry with it lime dust particles from the lime feed. There are a number of different types of gas scrubbers some of these are shown in Figures 10 and 11. The Dynamic or Venturi scrubber that is equipped with a fan operated gas recirculation system, generally uses green liquor as the scrubbing medium, and this is allowed to fall into the slaker. This type of scrubber generates a slight negative pressure on the slaker and is quite efficient in removing particulate from the slaker exhaust gases. Build up of scale on the fan blades can cause vibration problems and bearing failure if not cleaned regularly. This scrubber is equipped with an exhaust stack that vents to atmosphere.

The static or condensing scrubber relies on fresh cold water showers to condense the steam and thereby create a negative pressure on the slaker. This type of scrubber also performs quite well in removing particulate, however the cold fresh water scrubbing medium cannot be added to the slaker and must be dealt with separately in the recausticizing plant. This scrubber vents to atmosphere through an exhaust stack.

The eductor or ejector type scrubber again uses cold water or weak wash for scrubbing the exhaust gases, and this flow also must be returned in the recausticizing plant to maintain a reasonable water balance in the pulp mill. The eductor discharges to a sump tank so that the scrubbing liquid can be reclaimed. The sump tank is generally equipped with an exhaust stack for venting to atmosphere.

The use of hard water should be avoided in the above scrubbers because of the softening effect on the water by the lime dust in the slaker exhaust gases. De-scaling and cleaning will be more of a problem because of the carbonate build up.

<u>Causticizers</u>

The causticizing efficiency is typically raised from 75% to 80-82% efficiency by passing the causticized slurry from the lime slaker through a series of mix tanks. Generally three or four single compartment-type tanks are installed for clarifier systems with a residence time of approximately 90 minutes. With a clarifier system, if the reaction isn't fully complete by the time it leaves the causticizers, there is some time for completion of reaction in the clarifier although this is not ideal. For pressure filter systems, the design retention time should be between 150 to 180 minutes, because there is no additional time for completion of the reaction in the filter vessel and any free lime will adversely affect filter performance.

The more mixing compartments installed the better the mixing and retention efficiency in the causticizers. There is very little improvement in going over six compartments or tanks, as long as the design retention time requirements are satisfied.

Causticizers are available in single or multiple compartment type units. As shown in Figures 14 and 15. The multiple compartment type causticizers allow a large volume to be installed in a relatively small footprint. Causticizers in old mills are typically 4.5m diameter x 4.5m deep; however, there are multiple compartment type or stacked causticizers, as they are sometimes called, in the order of 6m diameter x 10m high.

These large tanks are typically divided into two or more compartments by horizontal divider plates or floors mounted inside the tank. The flow enters the top compartment and flows through an annular space between the shaft and the compartment floor, right down to the bottom compartment and then up the riser pipe out into the next tank. Riser pipes can also be used on single compartment tanks to improve the retention efficiency and also reduce the build-up of coarse fraction material near the bottom of the tank.

The causticizer tanks are connected together with large diameter pipes with ample provision for clean-out or U-shaped troughs (launders) that have removable covers to aid in cleaning these troughs. The tanks are generally insulated, however the launders or pipes are not and are more subject to scale build-up as the causticized slurry flows from tank to tank. A system of reinforced rubber piping has been tried with some success. This allows the operator or maintenance

Figure 15 - Multi-compartment causticizer

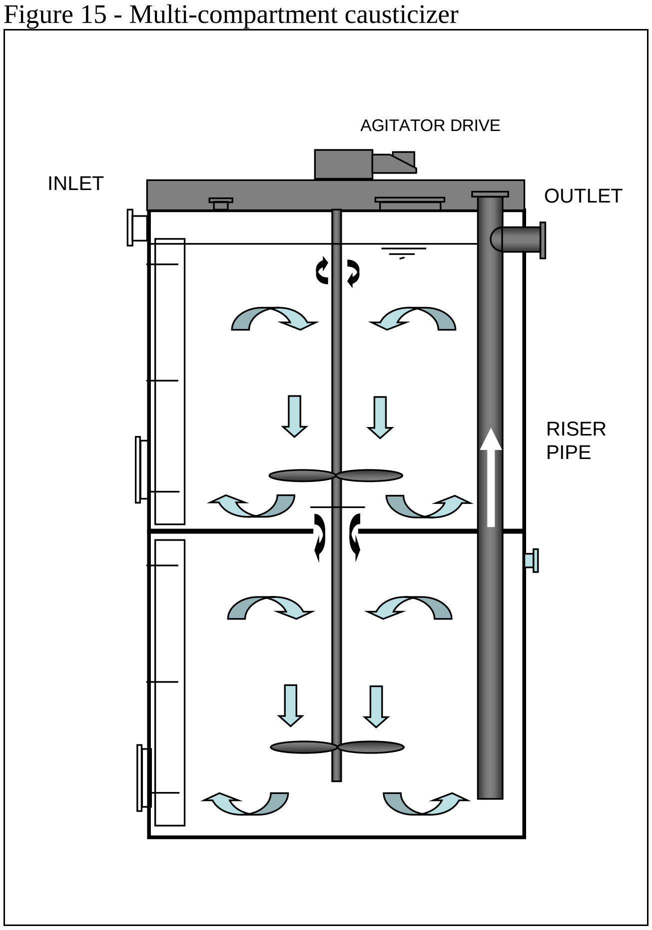
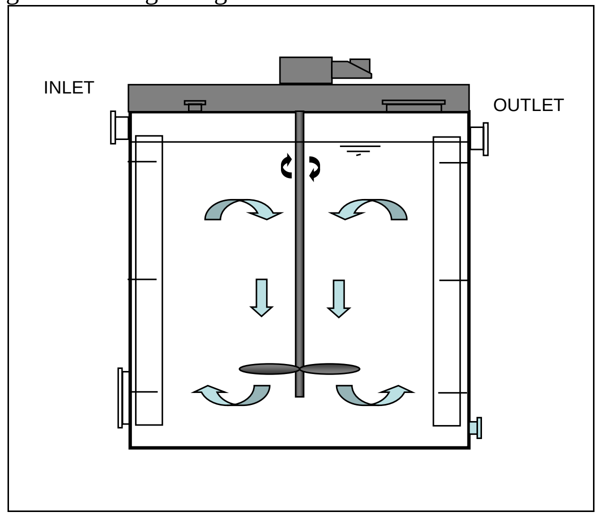



Figure 14 - Single stage causticizer




personnel to dislodge scale inside the pipe simply by banging the side of the rubber pipe with a large hammer.

It is good practice to keep the pipes or launders as short as possible between the tanks to reduce the amount of cleaning required on the main flow line. Each tank is generally equipped with a bypass so that the tank can be taken out of service for cleaning or maintenance while the other tanks are in operation. The bypass lines obviously will take a longer path than the main process lines; however, bypass lines are generally only used for shorter periods of time so that scaling is not much of a problem.

Liquor from the last tank either overflows into a standpipe from where it is pumped to clarifiers or, in the case of pressure filters, the last causticizer can be used as a pump sump with the pump suctions connected directly to the tank.

<u>White Liquor Clarification - General</u>

After the causticized slurry has been retained in the causticizers for 90 to 180 minutes, the lime mud is separated from the white liquor. The clarity of the white liquor depends on the type of device used for separating lime mud from white liquor. Lime mud is separated from white liquor in either a sedimentation-type clarifier similar to the green liquor clarifier or a pressure filter. See figures 5 and 22 for typical flowsheets. There are two types of pressure filter used today in recausticizing plants. The first is the vertical tube type pressure filter introduced in the early 80's, which has become quite popular in recausticizing plants. Vertical pressure filters have the advantage of less real estate usage, and they will consistently produce white liquor clarities in the order of 10 to 20 mg/L.

The other type of pressure filter is a disc filter, which has been introduced into the recausticizing circuit over the last five to ten years. There are quite a number of these filters operating in Europe and North America. The pressure disc

Figure 16 - View of vertical tube type pressure filter installation

Photo: Courtesy of Kadant Black Clawson Inc. – Goslin™ Products Group

Figure 17 - Vertical tube type pressure filter

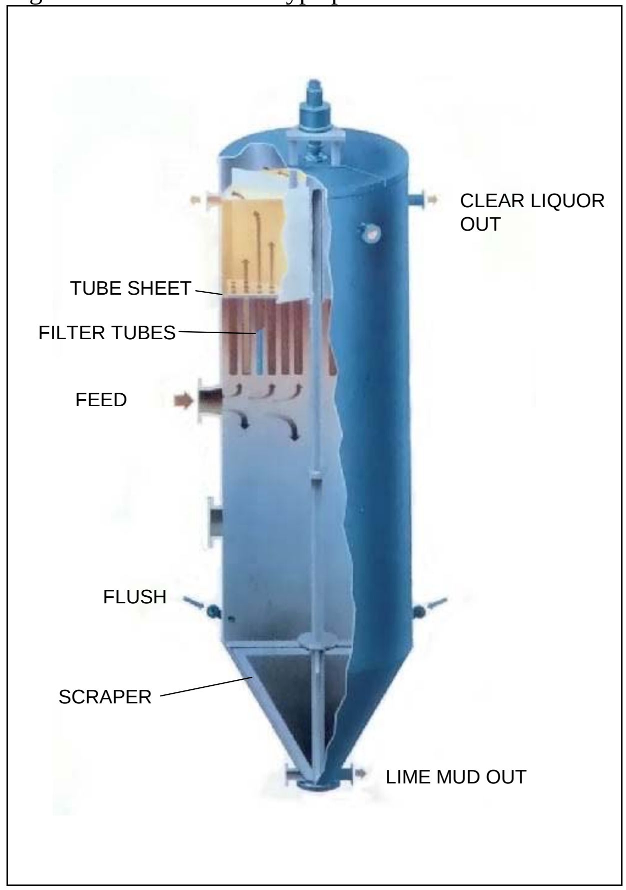



Figure courtesy of Kadant Black Clawson – Goslin™ Products Group

filter also produces good white liquor clarity, but a single pressure disc filter can replace the white liquor clarification and lime mud washing stages in a recausticizing plant. We will discuss the application of pressure disc filters a little later in this chapter.

White Liquor Clarification - Sedimentation Clarifiers

Sedimentation clarifiers have been the mainstay of recausticizing circuits for many years and are now typically of the unit storage type clarifiers as discussed in green liquor clarification.

The major difference between clarifiers used for green liquor and for white liquor is the torque rating on the rake drive. The clarifier is equipped with an automatic lifting device that allows the rakes to lift should the torque level on the drive become too high, causing the rake to stop on high load.

The tanks are provided with submerged bustle pipes and submerged feedwells just as the green liquor clarifier. The feedwell size on a white liquor clarifier is generally smaller than on a green liquor clarifier because of the better settling qualities of lime mud compared to green liquor dregs.

Older mills may also have sedimentation clarifiers of the tray type as discussed in the section on green liquor clarification.

Clarifiers are a little more forgiving and easier to control than pressure filters, however over-liming of the lime slaker will produce a clarifier upset resulting in a cloudy overflow. The cloudy white liquor can cause scaling problems at the digester.

White Liquor Clarification - Vertical Pressure Filters

The vertical tube type pressure filter requires good process control at all times to avoid operating problems. Overliming in the lime slaker in a plant with a vertical tube type pressure filter will result in blinding of the filter media and cause a forced shutdown for acid cleaning.

The vertical tube type pressure filter (Figures 16 and 17) is a tall, cylindrical vessel with a filtrate compartment at the top, separated from the main body of the vessel by a tube sheet from which are suspended perforated stainless steel tubes covered with a needled polypropylene felt sock type filter cloth. The filters are available in various sizes with the largest being approximately 13 feet in diameter and having approximately 850 filter tubes and socks. The top filtrate compartment is typically divided into six sections, each with its own filtrate outlet. This feature allows for isolation of a section should the filter media in that section be damaged, resulting in dirty filtrate.

The vertical tube type pressure filter operates in a semi-batch mode. The operating sequence incorporates a filtration period of approximately 5 minutes and a short backwash of 3 to 5 seconds, followed by a resting period of approximately 30 seconds before the filter is put back on line. The head of liquor in the clear filtrate compartment provides the backwash driving force.

The solids discharged from the filter socks drop to the bottom of the vessel and are stirred by a mechanical agitator. Discharge solids from the bottom of the filter are typically in the 40 wt % solids range; however, this can vary between 35 wt % and 45 wt %, depending on the operation of the filter. During the backwash cycle of the filter, the feed flow and backwash are diverted back to the last causticizer, which serves as a pump tank for the pressure filter. The level is allowed to fluctuate to accommodate flow changes and operation of the pressure filter.

The lime mud discharging from the vertical pressure filter is controlled either by density, flow and/or level of the slurry inside the pressure filter. The only moving parts on the vertical tube type pressure filter are the scraper or agitator, and the two large butterfly valves that are commonly used for controlling the feed and backwash cycles. Vertical pressure filters are quite reliable and generally only require an annual filter media change-out. The major operating problems are associated with dirty green liquor and over-liming from the operation of the lime slaker. Both of these conditions will cause premature pressure filter shutdown for acid cleaning and/or filter media replacement.

A similar type of pressure filter has been used with some success for polishing white liquor following sedimentation clarifiers. Because the solids in the overflow of a clarifier are of a very fine particle size the filters are very prone to blinding. It is recommended that pilot work be done before installing polishing filters to avoid disappointment later.

White Liquor Clarification - Pressure Disc

The pressure disc filter comprises a center shaft with a series of discs that are submerged to approximately 50% of the disc diameter. The discs are precoated with the feed slurry. As the discs rotate in the pressurized vessel liquor is forced through the submerged portion of each disc. As each disc comes out of the slurry, the gases that are recycled in the filter displace the liquid in the cake, resulting in a dry cake discharge of approximately 70 wt % to 75 wt % solids. A small amount of wash water can be applied to the cake just as it emerges from being submerged in the filter tank, resulting in a displacement wash with very little dilution of the white liquor. The combination of discharging at 75 wt % solids and having the provision for washing the filter cake eliminates the need for a lime mud washing step in the process flowsheet. The discharge slurry from the pressure disc filter can be pumped directly to the lime mud storage tank.

Figure 19 illustrates the typical flowsheet around a pressure disc filter showing the feed tank, filter, discharge tank, filtrate receiver and compressor station, required to operate the filter. The filter operates in a close cycle loop resulting in virtually no oxidation of the white liquor.

## LIME MUD WASHING

The lime mud slurry discharge from sedimentation clarifiers or vertical tube type pressure filters contains white liquor at the same concentration as the feed to those devices. Before this slurry is dewatered for feeding to the lime kiln, the white liquor is washed out of the mud as much as possible. This requires dilution with water followed by second stage sedimentation/filtration. Earlier in the chapter we discussed how much water would be required and we determined that this dilution water is approximately the same volume of water required to make green liquor. The dilution water used is not all fresh water. Most of the water comes from mill hot water systems, recycled filtrate from the lime mud precoat filter at the lime kiln, and scrubber water from a wet-type scrubber used on the lime kilns. These flows are thoroughly mixed with the underflow or lime mud slurry from the white liquor clarifier or white liquor pressure filter.

Since the lime mud washing process is by dilution, it is important to have the correct amount of water entering the lime mud washer, so that the weak wash generated has the lowest TTA possible prior to being used for dissolving smelt at the recovery boiler.

The lime mud washer clarifier or lime mud washer vertical tube type pressure filter is exactly the same as those used for white liquor clarification. In the case of the vertical tube type pressure filter, a large lime mud mix tank is installed between the white liquor pressure filter and the lime mud washing pressure filter to act as a feed, backwash and dilution tank.

Figure 18 - Typical flowsheet with vertical tube type pressure filters

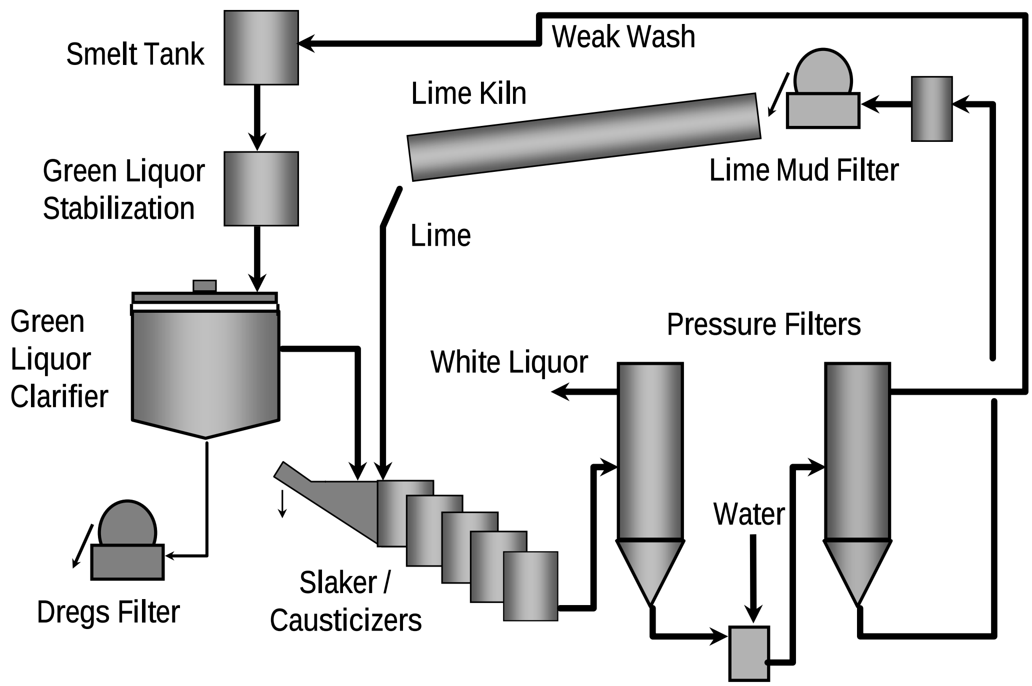



Figure 19 - Typical flowsheet around a pressure disc filter

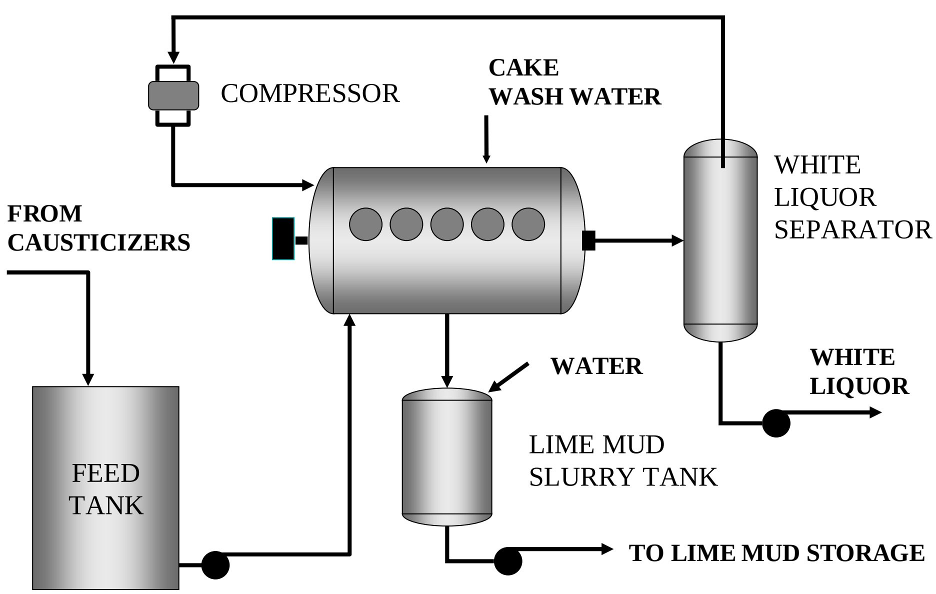


Figure 20 - Pressure Disc Filter Installation

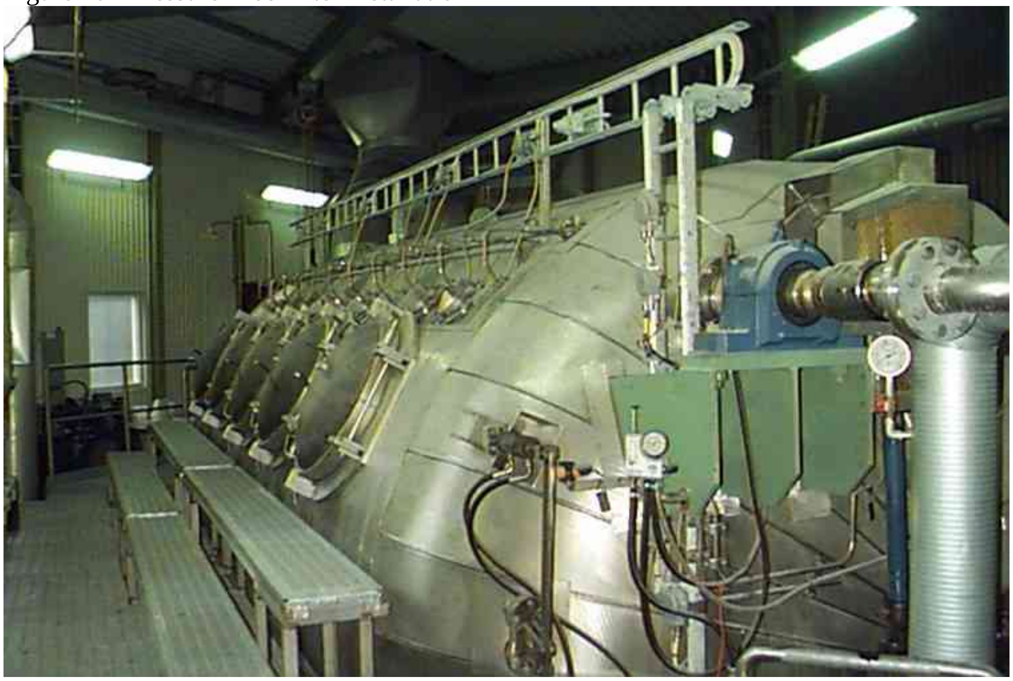


Photo: courtesy of Dorr-Oliver Eimco

With the lime mud washer clarifier, a lime mud mix tank is installed generally level with the top of the tank, and the lime mud mix tank overflows to the lime mud washer tank feedwell.

Lime mud washing is not required when a white liquor pressure disc filter is used in a recausticizing circuit. The weak wash generated in this flowsheet would come from the lime mud precoat filter and any additional water needed at the smelt dissolving tank would have to be provided from other sources within the mill. Since it is important not tolose the chemical in the weak wash, storage tanks are provided for the weak wash. In the case of the pressure disc filter installation, the amount of weak wash storage required is greatly reduced since only the filtrate from the lime mud precoat filter has to be stored.

Lime Mud Storage Tank

The lime mud storage tank serves as a buffer between the lime kiln and the recausticizing plant. It allows continued operation of the recausticizing plant when the lime kiln or lime mud filter is not operating. It also allows operation of the lime kiln when the recausticizing plant is not operating, such as during an acid wash of a pressure filter.

The washed, thickened lime mud is stored in a large tank with a slow speed stirrer or agitator (see Figure 26). It is normally stored at 40 to 45 wt % solids and, at this consistency, is fairly homogeneous and very slow to separate. If the consistency is allowed to drop as low as 25 wt %, settling will occur in this tank resulting in stalling of the agitator mechanism. It is therefore important to make sure that the controls on the slurry from the lime mud washing device are operating properly to avoid having to shut down and dig out the lime mud storage agitator tank.

To alleviate problems with power outages the agitator drive is usually equipped with a standby engine (diesel, propane or natural gas) or an auxiliary electric motor powered by an emergency power generator.

Lime Mud Precoat Filter

The 40 wt % to 45 wt % slurry from the lime mud storage tank is further diluted to approximately 25 wt % solids and filtered on a vacuum precoat filter drum. This filter is also equipped with cake wash pipes, allowing for washing of the filtered solids prior to discharge to the lime kiln.

Lime mud precoat filters vary greatly in size depending on the size of the pulp mill. One might see a filter 1.8 meter diameter by 3 meters long, or 4.5 meter diameter by 11 meters long. See Figure 27 for a typical end-view of a lime mud precoat filter.

The lime mud precoat filter operates at quite low submergence and is equipped with a scraper blade set approximately 12 mm to 17 mm from the face of the drum. When the vacuum pump is started, the filter forms a cake until it reaches the scraper blade. At this point, the top layer of filter cake is scraped off and discharged into the lime kiln.

It is customary to run lime mud precoat filters at quite high speeds compared to a number of years ago. Today the operating speeds are in the 3 to 6 RPM range, whereas a number of years ago, the speed was in the order of 2 to 3 RPM. By operating the filter at higher speeds, a thinner cake is formed on top of the precoat, which is easier to wash and also easier to dry.

The filter cake is formed at quite low submergence and is immediately washed by a series of wash pipes applying hot water to the cake. Wash water temperature should be 70°C to 73°C.

After washing, the cycle of the filter allows drying before discharge into the lime kiln. Some time after the precoat has been formed, the lime mud precoat filter will start to blind with fines, resulting in a decrease in the percent solids discharged to the kiln and poorer washing of the solids. Some filters are equipped with an advancing or adjustable scraper blade, which allows removal of the blinded layer of lime mud at periodic intervals during the life of the precoat. Use of this type of scraper blade reduces the number of times that the whole precoat has to be changed, however the arrangement of the scraper blade should be looked at carefully to avoid problems with lime kiln operation associated with discharging a large quantity of fairly wet cake into the kiln. If the scraper blade advance system is not set correctly the wet cake discharged to the kiln can cause high levels of total reduced sulfur (TRS) emissions from the kiln exhaust stack. The high TRS emission is caused by the sulfur bearing liquor in the wet cake.

A recent innovation that is being used in the industry today is a system for removing the precoat on the filter while it is actually operating, and at the same time washing the filter media. This system incorporates a high pressure water pump and a series of spray nozzles that are directed at the filter drum while it is operating. This system can virtually eliminate the need to change the precoat on the filter and helps provide a fairly consistent feed to the lime kiln. A caution should be given to operators that prolonged intervals without flushing the filter vat can result in damage to agitators due to the accumulation of grit and hard mud build-up.

Figure 21 - View of lime mud discharging from lime mud precoat filters

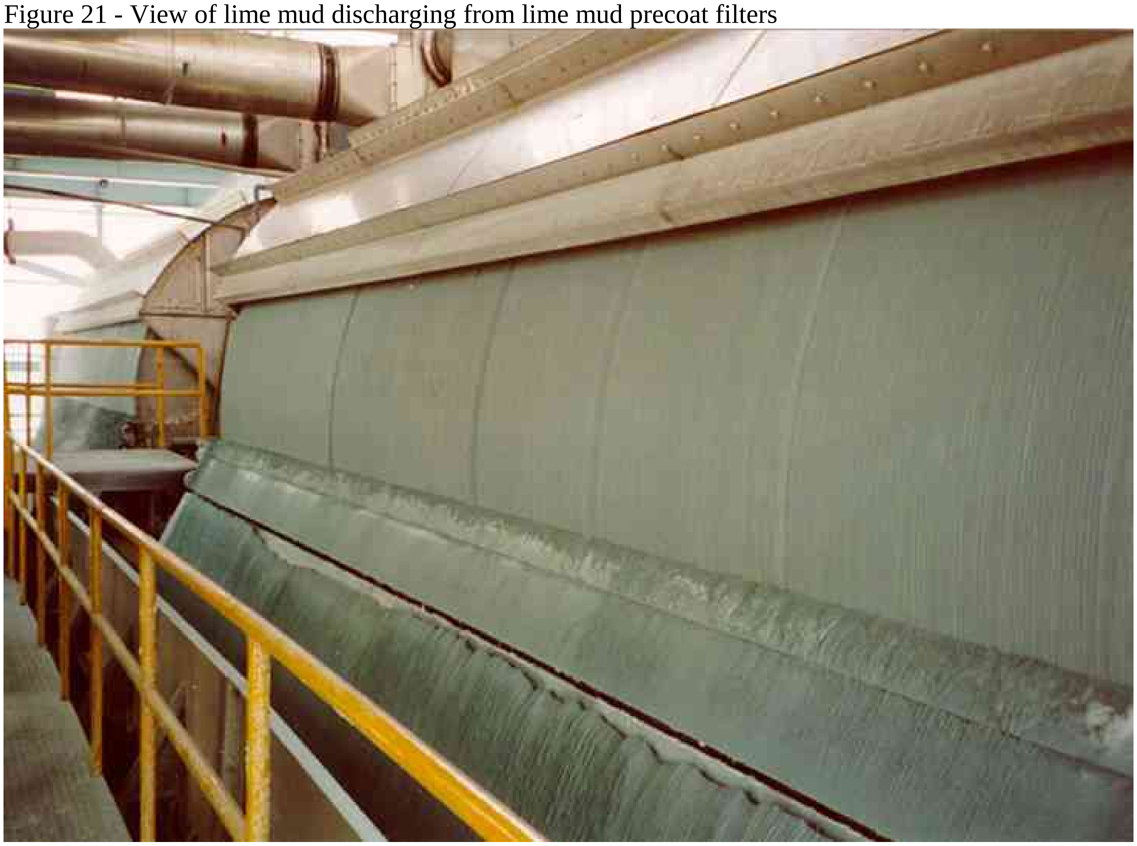


Photo courtesy of Dorr-Oliver Eimco

Figure 22 - Lime mud storage agitator and tank.

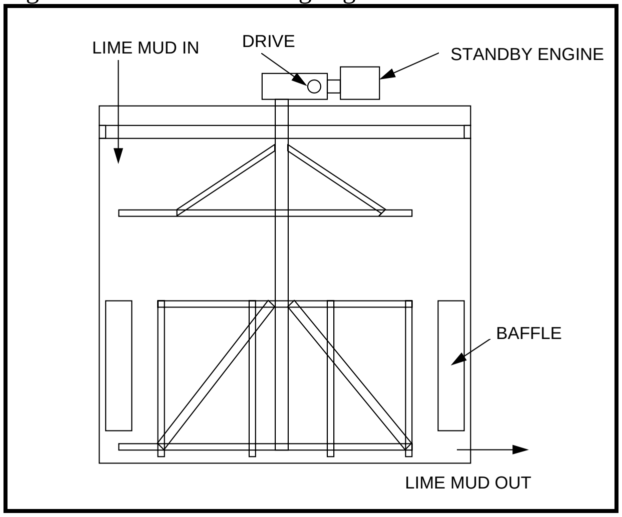



Figure 23 - Lime mud precoat filter

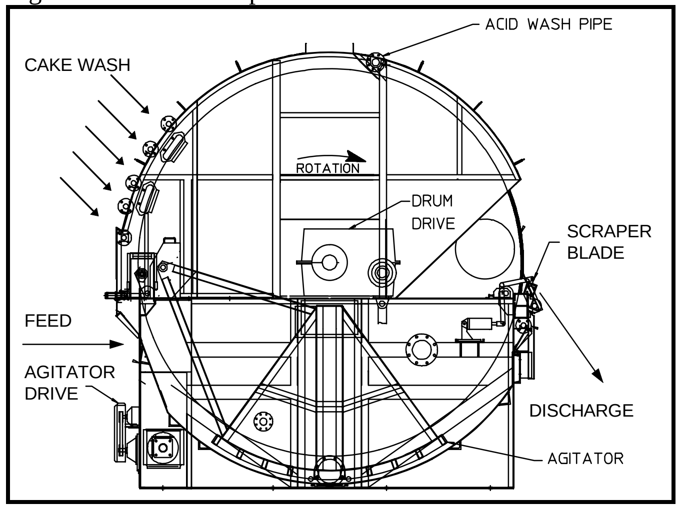



Figure courtesy of Dorr-Oliver Eimco

The lime mud precoat filters are generally equipped with a vapor hood to contain steam and vapors emanating from the filter and wash shower system. The hood is equipped with an exhaust fan for discharging outside the lime mud filter building. Even for filters that are located outside, the hood is a good idea because it keeps rain water off the lime mud filter while it is operating, and also protects the filter media from the direct rays of the sun when the filter is not operating.

Lime mud precoat filters require a large amount of air, approximately $3m^3/min/m^2$ of filter area at approximately 560 mm of Hg vacuum. This vacuum is provided by a large wet ring vacuum pump. To maximize the capacity of the vacuum pump, the condensing effect of cold water sprays in the inlet manifold should be utilized as well as the normal seal water connections on the side of the pump.

The filtrate from the lime mud precoat filter is generally pumped to the lime mud mixer, or in the case of a pressure disc filter installation, it would be directed to weak wash storage.

A recent development is the application of disc filter technology to the filtration of lime mud for the lime kiln. The same loading rates etc. are used for sizing the filter. The advantages for mills are the smaller footprint of the equipment allowing a filter with more area to be installed in the same space occupied by an existing filter or in the case of a new installation a smaller kiln feed end building.

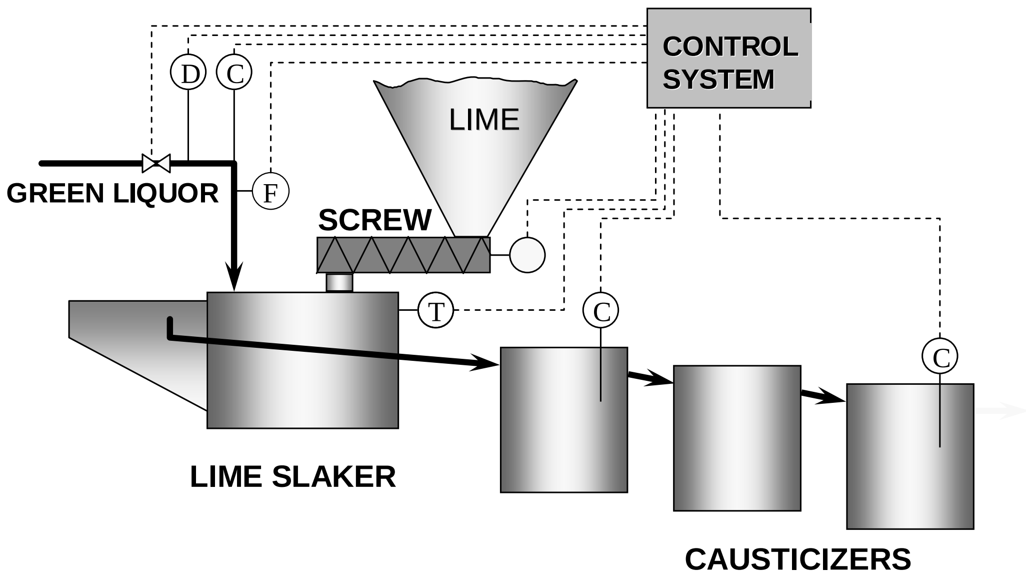
Figure 24 – Lime Mud Disc Filter


Photo Courstesy of Dorr-Oliver Eimco

Causticizing Control Systems

There are a number of causticizing control systems available on the market today and being employed quite successfully by a number of mills. The most common is an electronic conductivity system[4,5]. The simplest system employs a conductivity probe in the first causticizer, which is used to monitor the process and/or control the lime feed rate. A more complex system can comprise a number of control loops that, a) control the TTA of the green liquor by measuring the density and adding weak wash to maintain a set point, b) adjust the lime feed rate based on the green liquor flow, density and conductivity, c) adjust the lime feed rate by measuring the conductivity in the first causticizer, and d) make correctional adjustments to lime rate based on the conductivity in the last causticizer.

Figure 25 - Typical conductivity slaker control system




The conductivity system generally requires maintenance of the probe to keep the electrodes clean for best performance.

Figure 25 shows a schematic of a typical control system using conductivity probes. Instruments measure the density, conductivity and flow of the green liquor. The flow of green liquor and lime are controlled and the temperature of the slaker is monitored.

Another type of system is an on-line titration system[6] that takes samples approximately every fifteen minutes from the system, and runs a series of titration's calculates the results and provides the actual TTA's, AA's, etc., to the operator. The system can also designed to provide control signals to make adjustments to lime and green liquor flow rates.

There is also a proposed control method using near-infrared spectroscopy[7] for on-line analysis of the liquors in the recausticizing plant.

PROCESS RELATED PROBLEMS

The following problems relate to the effects of various upset conditions on the recausticizing plant operation. For remedies see the following section.

Dirty green liquor will:
- Blind filter media in pressure filters, causing frequent acid washing
- Reduce underflow mud densities from white liquor clarifiers and lime mud washers
- Reduce mud solids from lime mud precoat filters
- Reduce white liquor quality
- Reduce lime availability

Low temperature cake wash water on the dregs filter will:
- Reduce wash efficiency
- Increase soda lost to landfill

A dull scraper blade on the dregs precoat filter will:
- Reduce filter capacity
- Reduce washing efficiency
- Increase moisture in the discharged cake

Overliming will:
- Blind filter media in pressure filters
- Cause lower mud solids from pressure filters
- Cause cloudy overflow from sedimentation white liquor clarifiers
- Cause lower mud densities from sedimentation white liquor clarifiers and lime mud washers.
- cause problems on the lime mud precoat filter

Low causticizing efficiency can:
- Increase dead load of chemicals to evaporators reducing their efficiency.
- increase caustic make-up required at the digester
- increase white liquor required at digester to achieve total active alkali charge to digester

Slaker boiling will:
- Be a safety hazard
- Cause grit to be carried out of the classifier and ultimately cause problems with 'sanding-in' of the lime mud filter agitator
- Overload the slaker vent scrubber
- Cause finer mud particles to be produced reducing underflow densities and filtration rates.

Low mud solids from white liquor clarification will:
- Increase green liquor flow required at the slaker
- Cause problems with mud washing
- Unnecessarily increase theTTA of the weak wash
- Increase dead load in the liquor cycle

Dirty white liquor can:
- Cause storage tanks to fill up with fines resulting in white liquor loss when cleaning
- Result in more frequent acid cleaning of digester screens and plugging of lines to digester
- Increase chemical costs for bleaching because of calcium carried with the fiber, "blue pulp"

Dirty weak wash can:
- Plug smelt dissolving tank showers
- Cause high torque in the green liquor clarifier

Low mud solids from lime mud washer will:
- Increase soda to lime mud precoat filter
- If below 25 weight % solids will cause settling or sanding problems in the lime mud storage tank

Low discharge solids from the lime mud precoat filter can:
- Increase fuel consumption
- Increase soda carry over
- Increase TRS emissions

High soda from lime mud precoat filter to calciner can:
- Cause high TRS emissions from the lime calciner
- Cause ringing or balls in a rotary lime kiln

Low temperature cake showers on the lime mud precoat filter can:
- Cause poor cake washing
- Lower mud solids discharging from the filter

A dull scraper blade on the lime mud precoat filter will:
- Cause a drop in capacity
- Cause the precoat heel to seal over giving the effect of blinding and lowering of cake solids

Variations in the lime mud rate and percent cake solids to the calciner can:
- Increase fuel consumption of the calciner
- Increase TRS emissions from the calciner
- Cause a poor lime product from the calciner
- Affect the slaker operation and the rest of the recausticizing plant.

## TROUBLE SHOOTING OF COMMON RECAUSTICIZING PROCESS PROBLEMS

### Green Liquor Clarifier

**Density control**. Proper clarification is a function of the settling rate, which is closely related to the difference between the density of the green liquor dregs particle and the density of the green liquor. Density is directly related to the TTA of the green liquor. If the green liquor does not have proper density control, variations into the higher range will minimize the solids / liquid density difference and poor overflow clarity will be experienced. A good density control technique is to add a stabilization tank prior to the clarifier. A trim control that uses weak wash to control the density can be installed between the stabilization tank and the clarifier.

**Recovery boiler operation.** High dregs concentrations of 2000-3000 mg/l can indicate poor recovery boiler operation. A temporary solution until recovery operation can be corrected is to add polymers to the clarifier feed to attempt to coagulate and settle the dregs particles.

**Air in the green liquor feed**. Feed flows can contain some entrained air. This tends to show up particularly in storage type green liquor clarifiers with submerged feedwells. Air bubbles attached to dregs particles can be carried out of the feedwell if there is a poor seal between the feedwell and the rake shaft. The solution to this problem is to make modifications to the feedwell at the next mill shutdown. The equipment supplier should be able to make recommendations.

**Proper unit size**. An overloaded green liquor clarifier will have difficulty obtaining good overflow clarity. If the overflow rise rate exceeds the particle settling velocity, the smaller sized dregs particles will be carried with the upflow and the result will be a dirty overflow. Proper sizing of such a clarifier should not exceed a rise rate of 0.60 meters/hour and preferably be in the range of 0.4-0.5 meters/hour.

**Contaminated condensate usage**. Occasionally, dregs carry-over will be experienced which cannot be attributed to the above items. The source of the problem could be the use of contaminated condensate in various washing operations such as at the lime mud washer. Organics from black liquor evaporation that find their way into the condensate tend to act as a dispersant hindering the settling process. The source of poor settling of dregs in the green liquor clarifier, therefore, may be as far away as the lime mud washer where contaminated condensate has been used for dilution. The solution to this problem is to monitor condensate additions very closely and divert them when a problem has been identified. Conductivity of the condensate can be used as an indicator.

Dregs Precoat Filter

**Filtration rate**. Filtration rate problems can occur if the dregs precoat filter is undersized or if the feed to the filter is difficult to handle. The filtration rate is directly proportional to the feed solids concentration. The best way to feed the filter is from a dregs holding tank equipped with a low shear agitator. In that way, the green liquor clarifier underflow pump can be regulated with a timer mechanism so as to pump periodically to the holding tank and maximize the underflow concentration. The loading rate of 20 $kg/m^2/hr.$ should be satisfactory at a feed solids level of 5-7%, but higher feed solids levels could improve this rate slightly if the filter is being operated at an overloaded condition.

**Sudden drop in capacity**. Indications of a problem with low capacity may be indicated by a shiny black color on the dregs filter surface instead of the normal dull black color. A shiny surface may indicate that the precoat is blinding because the doctor blade is not advancing fast enough, and the dregs have either penetrated the bed and are not being removed completely, or are being pressed into the bed by a dull blade. The solution is to increase the rate of blade advance until an improvement is seen and then correct the blade advance rate to maintain a proper operation or change the dull blades.

If the vacuum level is abnormally high, filter media blinding may be the cause of a sudden loss in capacity. Usually filter media blinding causes a slower drop in capacity over a period of time, but process upsets can accelerate the blinding process. Acid cleaning should be used to remove any embedded lime mud particles or the filter media can be changed. High pressure water showers have also been used with some success.

**Precoating difficulties**. Occasionally, larger dregs precoat filters may have difficulties during application of the lime mud precoat if the vacuum pump is not performing properly or if it is undersized. The condition will be noticed if some of the precoat material falls off during the application of the precoat bed. To solve this problem the filter media should be checked for blinding and the vacuum pump should be checked for capacity. Precoating can be improved by diluting the lime mud to 25% solids and running the drum at a higher speed to build the precoat bed in thinner layers. Another problem can be sudden loss of the vacuum pump during application of the precoat. This can be attributed to a flooded vacuum receiver overflowing into the vacuum pump. A filtrate pump that is not sized for the higher flow of filtrate during application of the lime mud precoat on the filter will cause flooding of the vacuum receiver. To solve this problem, the feed rate of the lime mud slurry should be reduced until it is less than or equal to the output of the filtrate pump.

**Electrical power failure**. A power failure will cause the vacuum pump to stop. The main difficulty during any electrical outage will be a loss of vacuum that causes the precoat bed to drop off. If this is in the early stage of operation after a new precoat has been applied, the bed thickness may be up to 150 mm. The material will have to be sluiced out of the vat into an adjoining dregs holding tank prior to restarting. The material in the dregs holding tank can be mixed with fresh dregs and filtered during the next operating cycle.

Lime Slaker Classifier

**Overliming**. By far the most critical aspect in the operation of the slaker is maintaining the correct ratio of lime and green liquor so that liquor of the proper strength and good quality lime mud are produced. The green liquor density must be held at the target level, and the flow controller must be accurate. Lime must be metered at a proper ratio to the green liquor flow; however, the ratio will need to be adjusted to compensate for varying lime quality and green liquor strength. There are commercially available control systems based either on conductivity or on-line titration.

**Slaker boiling**. Steam puffing out of the slaker or frothing inside the slaker indicates boiling. Frothing may be observed through the inspection openings on the classifier. Boiling can be attributed to poor control of green liquor temperature or operating a slaker with a short residence time for the production required by the mill. Overliming is an obvious source of the boiling problem and is easy to remedy by reducing the lime feed rate. Because of the potential boiling problem, it is a good idea to keep the area underneath the lime slaker clear of pedestrian traffic. As a minimum, chains with caution labels should be included to prevent personnel from lingering underneath the lime slaker while it is operating.

**Poor settling lime mud**. This is usually the result of overliming, and it can be checked by a 5 minute settling test performed on the overflow from the slaker classifier section. The interface level after five minutes should be 40% down from the top of the liquid surface with clear liquor above this interface. If the lime mud does not settle rapidly enough and the liquor is cloudy, overliming may be the cause, and additional titration tests should be performed to determine the extent of correction required.

Another source of difficulty could be a surge of fresh lime added as makeup. Separate silos should be employed for the storage of reburned and fresh lime. If a single storage silo is used, it can be divided internally with a concentric tube. The inner tube would receive the fresh lime and the outer part of the silo would receive the reburned lime. The two products blend together at the bottom of the silo. If separate silos are utilized, a small, constant feed of the fresh lime can be used to minimize its impact on the system.

The temperature in the slaking compartment should always be monitored and maintained at approximately 102-104°C for optimum particle size formation. Also, a proper mixer design with low shear should be used so as not to degrade the lime mud particle size.

**Grit not discharging from the classifier**. A reduction in the normal amount of grit or no grit being discharged can be caused by two problems. First, the most common difficulty is carryover of unslaked lime into the classifier section resulting in lime slaking in that area and creating a “bridging over” condition that keeps the grit from settling down to the grit conveyor. Grit is then carried out with the overflow and can create problems in subsequent equipment. This condition can be corrected by adding a small stream of green liquor continuously through the secondary feed inlet in the classifier area to create sufficient turbulence to prevent a grit build up. If the problem is noticed early enough a temporary increase in the flow of the green liquor to the classifier is probably all that is required. Of course, if bridging over is severe enough, a mechanical breakup may have to be used and this could involve draining the slaker to access the problem area.

The second cause of low grit discharge is the addition of too much water to wash the grit. If the water flow to the sprays is too high, grit will be washed off the conveyor and kept from discharging. The obvious solution is to reduce the water volume and only use extremely fine sprays. For thorough washing of grit, a separate wash stage should be considered. There are grit washers available to further wash the grit to a lower pH to meet environmental regulations. Another way to process grit is to grind or pulverize it and then filter and wash it on a dregs precoat filter.

**Too much slaker grit**. Unusual amounts of grit being discharged from the classifier can be the result of a poor lime quality from the lime kiln. Another cause is that the slaker flow is much less than the design capacity of the slaker, resulting in the settling of lime mud smaller than 65 mesh in the classifier section.

**White Liquor Clarifier/Mud Washer**

**Poor white liquor clarity**. This will be dependent upon the type of clarifier employed. If it is a pressure filter, the first area to investigate is the filter media as there is probably a leak or a tear in the cloth. Most vertical tube type pressure filters have sectionalized filtrate compartments at the top of the filter that can be sampled to locate the source of the leak. Tubes with damaged filter media can be changed or plugged temporarily. In addition the tube retaining plates can work loose causing a leak at the ‘O ring’ joint between the tube and tube sheet.

Poor clarity in a sedimentation clarifier is most often attributed to operation of the slaker and the green liquor clarifier. High dregs carryover from the green liquor clarifier and/or over-liming in the slaker will produce high suspended solids in the clarified liquor. Also, if the clarification device is a storage type sedimentation clarifier, the submerged feedwell may be too small, or possibly entrained air in the feed may be leaking at the junction of the feedwell top and the shaft, carrying solids into the storage zone. Another cause may be that the clarifier is too small. In this case the loading rate should be checked against the design standards.

**Low solids concentration in the underflow**. Low lime mud percent solids in the underflow of sedimentation clarifiers and vertical pressure filters can generally be attributed to high dregs carry-over from the green liquor clarifier, overliming in the slaker, and/or poor instrumentation for controlling density and flow from the bottom of the vessel. In the case of sedimentation clarifiers underflow pumping control is important. The pumps should be set to run constantly on flow control with a density gage controlling the set point of the flow. A torque indicator on the drive can be used to override the density control should the rake operation get into difficulty. If the density is set too high the rakes will lift too frequently causing erratic operation of the plant.

**Poor lime mud washing**. Proper mixing of the lime mud from the white liquor clarification device with water and other streams is important. A lime mud mix tank having a retention time of at least 5 minutes is required. The biggest problem is not adding enough water to provide the necessary dilution. As a rough guide the total of the dilution streams entering the lime mud mix tank should approximately equal the green liquor flow required at the slaker.

**Dirty weak wash**. This can be caused by pressure filter leakage, as with white liquor pressure filters. In the case of sedimentation lime mud washing it can be caused by a number of factors such as feedwell design, loading rate, using contaminated condensate or a high loading of recycled kiln scrubber fines. The organics that can be present in contaminated condensate will act as a dispersant causing cloudy overflow in the lime mud washer and even cause dregs settling problems downstream in the green liquor clarifier.

**Power failure**. If the power has been off for longer than 30 minutes pressure filters should be drained and then restarted. This prevents any problems occurring with the scraper drive. For sedimentation clarifiers if the power has been off for longer than 15 minutes the rakes should be raised manually before the rakes are restarted. The rakes can then be lowered slowly to the normal operating position.

**Pressure Filters**

**Frequent acid washing**. A reasonable acid washing frequency for pressure filters is every 6 - 8 weeks. Some mills with conservatively sized filters and good process control have acid washed as little as twice per year. Mills with inadequate controls and poor green liquor may acid wash every week. Dirty green liquor blinds the filter media with fine carbon that can not be washed out. Each time the filter is acid washed the pressure drop across the media does not return to the clean media or base value. The base pressure drop increases until the filter media has to be changed. Typical filter media life is one year. The other major cause of acid washing is overliming. Free lime builds up in the filter media and has to be removed by acid washing. A good slaker control system will solve this problem, but be aware of the process upsets caused by sudden changes to fresh lime from reburned in a single lime silo system.

**High pressure drop**. High pressure drops other than the steady increase in base pressure as the filter media gets contaminated with acid insoluble material, can be due to a number of process problems. Overliming will cause a fairly rapid increase in pressure eventually shutting down the filter on high pressure. Using a lot of purchased fresh lime can cause high pressure drops, but the problem usually goes away when reburned lime is used. Fresh lime produces finer lime mud with poorer filtration properties. If the lime mud level is allowed to get too high inside the vessel and reaches the filter tubes it will also cause a sudden increase in pressure drop. Recalibrating the level sensors on the filter vessel controls this problem.

**Lime Mud Storage Agitator**

**High torque / Unit stalling out**. If the lime mud storage agitator stops when the tank is full of slurry, the mill has a major problem. Cleaning out the tank is a difficult task because of the amount of heavy slurry involved. The feed concentration of solids should be 40 - 45 wt % solids for optimum operation. If the slurry is allowed to fall below 25 wt % solids, the solids will start to settle and cause the agitator to load up and stop. Never try to restart an agitator that has stopped because of high torque load. The tank should be drained and the cause ascertained before restarting.

Density control of the mud slurry entering the lime mud storage tank is very important not only for preventing problems with the agitator but to also provide the best mud washing performance from the system.

**Lime Mud Precoat Filter**

**Variation in feed to the calciner**. Fluctuations in the quantity and consistency of the lime mud leaving the filter can result in calcining problems, by creating over or under-burned lime. This can cause poor slaker product when this lime is recycled which in turn can adversely affect the entire recausticizing operation.

At least 4-6 hours of lime mud should be stored in the lime mud storage agitator tank. The feed to the filter should be on flow control with the flow level being set by the calciner operator based on an equivalent of mud tonnage required by the kiln. Dilution of the feed to the filter to 20-25 wt % solids is accomplished with a density gage that controls the dilution water feeding the inlet side of the feed pump. An interlock must be used on this control to prevent dilution of the mud in the storage tank if the pump is stopped.

As the lime mud precoat filter operates, the vat level will slowly rise as fines build up in the precoat “heel”. The heel is the lime mud layer that remains on the drum after the filter cake has passed the discharge point or scraper blade. A vat level indicator is used to provide information to the calciner operator as to how fast the level in the vat is rising. When the vat level reaches a set point, the operator can momentarily suspend operation and remove the precoat layer on the drum and then immediately restart everything and resume operation. Some mills include a high pressure wash sequence in this precoat change and in fact this entire sequence can be automated such that the maximum down time is in the order of 5 to 10 minutes.

The operation of an automatic advancing scraper blade needs to be checked to make sure that an excessive amount of cake is not removed.
The installation of a high pressure shower-type precoat renewal system should be investigated as this would virtually eliminate the fluctuations in kiln feed and greatly reduce the number of times the heel is dropped.

**High lime mud moisture**. There are a number of process problems that can cause high lime mud moisture levels in the discharged cake going to the calciner. The first point to check is the color of the cake coming off the filter. If this cake has a green color, it would indicate that dregs are being carried through from the green liquor clarifier and these will blind the cake causing high moisture levels. The suspended solids in the overflow from the green liquor clarifier should be less than 100 mg/l.

Overliming in the lime slaker will also affect the performance of the lime mud precoat filter due to the presence of the fine unreacted lime blinding the lime mud filter cake. In mills that do not have separate make-up lime storage facilities, processing large quantities of make-up purchased lime can also cause problems with high moisture in the discharged cake from the lime mud precoat filter. Purchased or fresh lime does not settle or filter as well as reburned lime.

Another source of fine material in the recausticizing plant is recycled slurry from the lime kiln scrubber. If scrubber dust is recycled through the lime mud washer and lime mud precoat filter, this can affect the performance of the lime mud filter, especially if there is a large amount of very fine dust being recycled. The fine material slows the filtration rate and retains more moisture because of the higher surface area of the particles in the filter cake.

The above problems relate to process upset conditions in a well designed mill. However, it is also possible that the vacuum pump is not working to maximum efficiency or has been undersized for the current operation. The vacuum pump should be checked for proper operation and the correct application of seal water, not only for providing a seal but also for cooling the inlet gases to the pump.

Another process problem is the inefficient washing of the lime mud coming from the lime mud washer. Lime mud that has too much chemical in it will be difficult to dewater and is important that adequate shower water be provided on the lime mud precoat filter to enable the cake to be dried before discharging to the lime calciner.

**High Soda in Cake**. Most lime mud filter installations should have no problem in removing the residual soda from the feed stream. Problems occur because of poor underflow control at the white liquor clarifier and lime mud washer. High dregs carry-over from the green liquor clarifier will also affect the ability of the showers to wash the residual soda out of the cake.

It is important to use shower water of at least 70 to 73 degrees C to insure proper washing of the lime mud filter cake. Hot water has a lower viscosity and penetrates the filter cake easier than cold water resulting in better displacement of the chemical bearing liquor in the cake. Calcium becomes insoluble at elevated temperatures and can result in precipitation in the precoat and the resultant blinding that can cause problems for filter operation. In the case of a mill that has some free lime in the filter feed and want to raise the temperature of the filter, it would be better practice to heat the dilution water and make sure the shower is no hotter. This practice would encourage the calcium to come out of solution in the feed slurry rather than the precoat.

## SUMMARY

This chapter covered the basics of recausticizing chemistry and reviewed the basic flowsheet. There is sufficient information provided to perform calculations to determine the size of equipment required to meet the production needs of a mill. If further reading is desired there are numerous books and technical papers written on the subject of slaking reactions and the control of causticizing systems.

As any experienced chef will tell you, the best quality ingredients are necessary to make the recipe work. To make good white liquor and have the least problems in the recausticizing plant it is essential to have clean green liquor, high quality reburned lime and good causticizing control.

The success of a recausticizing plant operation depends on good process control as well as having properly sized equipment. The majority of new mills or major refits are utilizing pressure filters that are sensitive to green liquor dregs and free lime in the feed slurry. Mills that have installed a raw green liquor stabilization tank will attest to the benefits it has on the performance of the green liquor clarifier. Causticizing control systems can help control the lime addition rate to level that does not cause problems with the filtering or settling of the lime mud, and at the same time provide white liquor with a high causticizing efficiency.

Operator training is very important, and it is suggested that refresher courses be carried out every few years. This gives the new operators a chance to understand the process in more detail and it is an opportunity for experienced operators to review the goals of the recausticizing process.

This chapter has hopefully given the reader a better understanding of the recausticizing process and the equipment required to make the process work.

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(Kraft Recovery Short Course January 2007)

**CALCULATIONS FOR THE RECAUSTICIZING PLANT**[2]

Material balance based on 1 oven dry metric tonne of pulp

The following abbreviations are used;
AA = Active alkali
DT = Dissolving Tank
GL = Green liquor
GLC = Green liquor clarifier
LM = Lime mud
LMW = Lime mud washer
WL = White liquor
WLC = White liquor clarifier
WW = Weak wash

| Item | Unit | Amount |
|---|---|---|
| Pulp Yield | % | 48 |
| AA on OD Wood as $Na_2O$ | % | 16.5 |
| WL total alkali as $Na_2O$ | $kg/m^3$ | 120 |
| WL activity | % | 85 |
| WL sulfidity on AA | % | 25 |
| Weak wash total alkali | $kg/m^3$ | 18 |
| Lime availability | % | 85 |
| WL specific gravity | - | 1.16 |
| Weak wash specific gravity | - | 1.02 |
| GL specific gravity | - | 1.19 |
| Makeup lime | kg/OD t | 10 |
| Ratio of actual chemical to total alkali as $Na_2O$ | | |
| For White Liquor | - | 1.33 |
| For Green Liquor | - | 1.61 |

| Item | | Unit | Amount |
|---|---|---|---|
| **1.** | **Alkali to digester** | | |
| | Active alkali<br>1000 x 0.165 / 0.48 | kg | 344 |
| | Total alkali<br>344 / 0.85 | kg | 405 |
| **2.** | **White liquor to digester** | | |
| | W.L. volume<br>404 / 120 | $m^3$ | 3.38 |
| | W.L. weight<br>3.38 x 1000 x 1.16 | kg | 3921 |
| | Weight of chemicals<br>3.38 x 120 x 1.33 | kg | 539 |
| | Water in W.L<br>3921-539 | kg | 3382 |
| **3.** | **Lime calculation** | | |
| | NaOH = 344 x 0.75 as $Na_2O$ | kg | 258 |
| | CaO = 258 x 56/62 | kg | 233 |
| | Lime = 233 / 0.85 | kg | 274 |
| | ( of which makeup lime is ) | kg | 10 |
| **4.** | **Lime mud calculation** | | |
| | $CaCO_3$ = 233 x 100 / 56 | kg | 416 |
| | Inerts = 274 - 233 | kg | 41 |
| | Total lime mud solids | kg | 457 |
| **5.** | **White liquor clarifier underflow** | | |
| | Underflow solids | % | 40 |
| | Total underflow = 457 / 0.40 | kg | 1143 |
| | Liquor = 1143 - 457 | kg | 686 |
| | Sodium in underflow as $Na_2O$<br>(686 / 1000 x 1.16) x 120 | kg | 71 |
| | Weight of actual chemical in underflow<br>(686 / 1000 x 1.16) x 120 x 1.33 | kg | 94 |
| | Water in WLC underflow<br>686 - 95 | kg | 592 |
| **6.** | **Lime mud washer underflow** | | |
| | Underflow solids | % | 45 |
| | Recirculation from filter and kiln scrubber as a percentage of kiln feed | % | 10* |
| | Total solids<br>457 / (100-10/100) | kg | 508 |
| | Total underflow<br>508 / 0.45 | kg | 1129 |
| | Liquor 1129 - 508 | kg | 621 |
| | Sodium in underflow | | |

| Item | | Unit | Amount |
|---|---|---|---|
| | (621 / (1000 x 1.02)) x 18 | kg | 11 |
| | Weight of chemical in underflow (621 /(1000 x 1.02)) x 18 x 1.33 | kg | 14.6 |
| | Water in underflow 621 - 14.6 | kg | 606 |
| **7.** | **Green liquor to slaker** | | |
| | Total alkali to digester as $Na_2O$ | kg | 405 |
| | Total alkali with lime mud as $Na_2O$ | kg | 71 |
| | Alkali in slaker grits as $Na_2O$ | kg | 1* |
| | Total alkali to slaker as $Na_2O$ = 405+71+1 | kg | 477 |
| | Volume of GL to slaker 476 / 120 (Note GL TA = WL TA) | $m^3$ | 4 |
| **8.** | **Green liquor clarifier underflow** | | |
| | GL Dregs ( assumed ) | kg/Odt | 5 |
| | GLC underflow solids (assumed) | % | 6 |
| | Total underflow = 5 / 0.06 | kg | 83 |
| | Liquor = 83 - 5 | kg | 78 |
| | Sodium in underflow (78/1000 x 1.19) x 120 | kg | 7.9 |
| | Weight of chemical in the underflow (78/1000 x 1.19) x 120 x 1.61 | kg | 12.7 |
| | Water in the GLC underflow 78 - 12.7 | kg | 65 |
| **9.** | **Green liquor dregs filter (precoat)** | | |
| | Cake discharge solids | % | 50 |
| | Total cake = 5 / 0.5 (excluding precoat material) | kg | 10 |
| | Liquor with cake = 10 - 5 | kg | 5 |
| | Sodium in filtrate as $Na_2O$ | kg | 7.5 |
| | Cake wash showers on filter = 2.5 x 5 ( 2.5 displacements of liquor in the cake) | kg | 12.5 |
| | Filtrate recycled to GLC 78 + 12.5 - 5 | kg | 86 |
| | Excess water in recycle to GLC 86 - 78 | kg | 8 |
| | Water in filtrate 65 + 12.5 - 5 | kg | 73 |
| **10.** | **Green liquor from dissolving tank** | | |
| | Total alkali to slaker as $Na_2O$ | kg | 477 |
| | Total alkali in discharged dregs as $Na_2O$ | kg | 0.4 |
| | Total alkali from the dissolving tank as $Na_2O$ | kg | 477 |
| | Water in total green liquor 477 x 1000 x 1.19/120 - 477 x 120 x 1.61/120 | kg | 3962 |
| | Water in GL from smelt dissolving tank = 3962 - 7.5 | kg | 3955 |
| **11.** | **Lime mud filter** | | |
| | Lime mud solids (from lime mud washer) | kg | 508 |
| | Feed solids (assumed) | % | 25 |
| | Weight of feed = 508 / 0.25 | kg | 2032 |
| | Water in feed = 2032 - 508 | kg | 1524 |
| | Filter discharge solids | % | 75 |

| Item | Unit | Amount |
|---|---|---|
| (assumed) | | |
| Total discharge = 508 / 0.75 | kg | 677 |
| Liquor with cake = 677 - 508 | kg | 169 |
| Filter shower water 169 x 1.5 ( 1.5 displacements of liquor in the cake) | kg | 254 |
| Total filtrate 1524 - 169 + 254 | kg | 1609 |
| Sodium in the cake as $Na_2O$ (% of dry lime mud) | % | 0.1 |
| Sodium in the cake as $Na_2O$ 508 x 0.001 | kg | 0.5 |
| Sodium in the filtrate as $Na_2O$ = 11 - 0.5 | kg | 10.5 |
| Water in filtrate = 1609-10.5 | kg | 1599 |

**12. Weak wash**

Lime mud washer

| | | |
|---|---|---|
| Sodium from WLC as $Na_2O$ | kg | 71 |
| Sodium from LM Filter as $Na_2O$ | kg | 10.5 |
| Sodium in mud from LMW as $Na_2O$ | kg | 11 |
| Total sodium to weak wash as $Na_2O$ = 71 + 10.5 - 11 | kg | 71 |
| Water from WLC | kg | 592 |
| Water from LM Filter | kg | 1599 |
| Water from Kiln Scrubber | kg | 500* |
| Lime mud dilution and makeup water (calculated) | kg | 658 |
| Water in mud from LMW | kg | 606 |
| Total water to weak wash | kg | 3955 |

GL Dregs

| | | |
|---|---|---|
| Sodium in GL dregs filtrate as $Na_2O$ | kg | 7.7 |
| Water in GL dregs filtrate | kg | 73 |

**13. Water balance**

| Item | Unit | Amount |
|---|---|---|
| OUT | | |
| White liquor | kg | 3382 |
| Slaker grit | kg | 5* |
| GL Dregs | kg | 5 |
| Dissolving tank vent | kg | 50* |
| Lime mud | kg | 169 |
| Kiln scrubber evap | kg | 500* |
| Evaporation | kg | 20* |
| Total | kg | 4109 |
| IN | | |
| Lime mud dilution | kg | 1832.5 |
| Lime mud filter showers | kg | 254 |
| GL dregs filter showers | kg | 12.5 |
| Slaker classifier wash | kg | 10* |
| Lime kiln scrubber makeup | kg | 2000* |
| Total | kg | 4109 |

**14. Soda balance as $Na_2O$**

| | | |
|---|---|---|
| OUT | | |
| White liquor | kg | 405 |
| Slaker grit | kg | 0.1 |
| GL Dregs | kg | 0.4 |
| Lime kiln stack | kg | 1* |
| Total | | 407 |
| IN | | |
| Smelt without make-up | kg | 405 |

Notes

1. The above calculations have been rounded to simplify for illustration purposes.

2. The water balance is made using some assumptions for evaporation losses etc. these are shown with an asterisk (*)

3. No corrections have been taken for variation of the density of water with temperature.