Commissioning brownstock washing controls for an evaporator limited mill

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ABSTRACT: An automated shower water control system has been implemented to reduce the volume and variability of weak black liquor being sent from the pulp mill to the evaporators. The washing controls attempt to balance the need for consistent and low soda carryover to the bleach plant with consistently high weak black liquor solids being sent to the evaporators. The washer controls were implemented on two bleachable grade hardwood lines (one with oxygen delignification, one without oxygen delignification) and one pine line. Implementation of the control program resulted in an increase in black liquor solids of 0.6 percentage points for the hardwood lines. Significant foam reduction was realized on the pine line since the pine black liquor solids were able to be consistently maintained just below the soap separation point. Low black liquor solids excursions to the evaporators were eliminated. Bleach plant carryover was stabilized and no negative impact on chemical consumption was noticed when controlling weak black liquor solids to recovery.

Application: This information can be used by kraft mills around the world. The authors have provided an easy approach to control brownstock washing and maximize pulp production by avoiding evaporator capacity reduction.

The kraft pulping industry is the first known to combine pulp washing with the recovery of materials used and produced in the wood cooking process [1, 2]. The initial motivation behind materials recovery is the fact that the chemicals used in the kraft process are expensive as compared to those employed in the sulfite process [2]. In order for the kraft process to be economically viable, it is imperative that a very high percentage of the cooking chemicals be recovered and reused [2]. An additional benefit of the recovery of the pulping chemicals and dissolved organics resulting from the pulping process is that recovery significantly reduces the amount of water pollution associated with the kraft cooking process [1,3-6]. Control of brownstock washing and the additives employed in brownstock washing are also instrumental in reducing the concentration of dioxin precursors going forward to pulp bleaching [7]. Inefficient washing results in higher effluent color, COD, and BOD in the receiving waters associated with kraft pulp mills [8, 9]. Pulp washing provides desirable benefits associated with increased efficiency in both screening and bleaching of the pulp [3,7]. Additionally, pulp quality is also improved by good washing [1,3-6]. In short, when brownstock washing is performed poorly, all areas of the mill are impacted negatively. When it is done well, increased black liquor solids, decreased carryover to the bleach plant and/or paper machine, and decreased environmental impacts result.

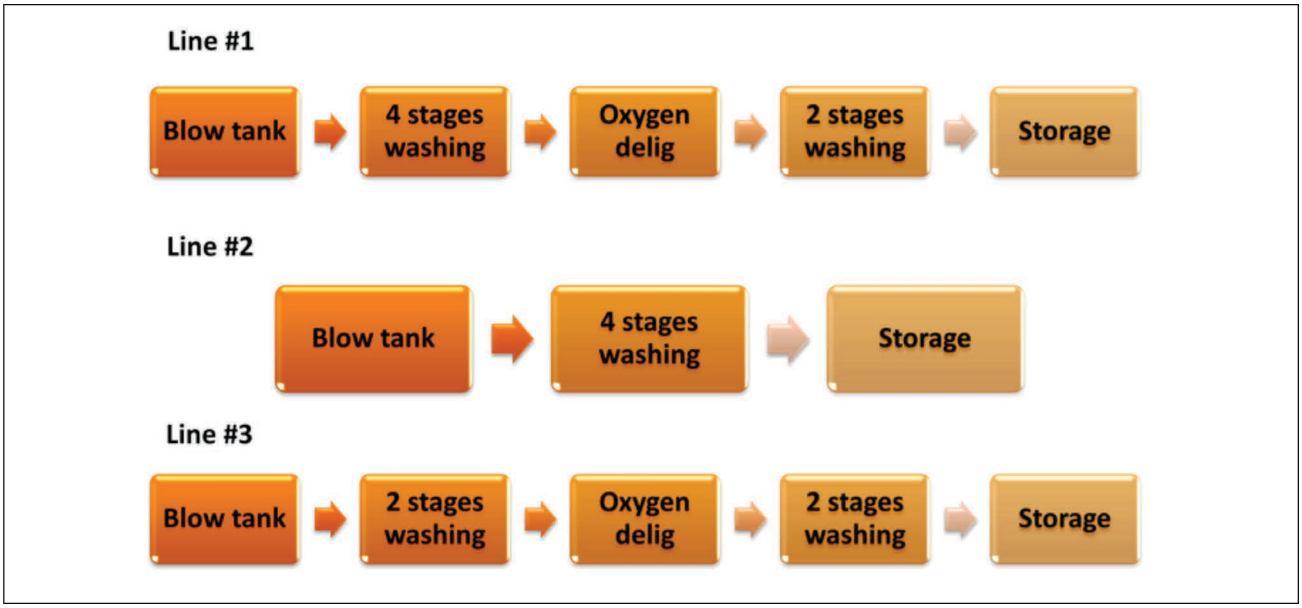
Modern washing systems have been integrated into the heart of the kraft recovery cycle [10, 11]. Satisfactory pulp washing is achieved with a multi-stage counter-current sequence [5, 12] where the cleanest water is added in the last stage and the resulting filtrate is used in the preceding stage until it reaches the blow tank or wash zone in a continuous digester [13]. It is important that the amount of "clean water" added to the last washing stage be minimized to guarantee efficient solids removal because excessive "clean water" addition effectively results in decreased concentration of black liquor solids being sent to the evaporators [14]. Minimization of "clean water" is extremely important for mills with evaporator limitations. When a mill is evaporator limited, a reduction in "clean water" to brownstock washing can result in increased pulp production.

This paper explored a simple and reliable way to control the amount of "clean water" added to washing line in order to stabilize and increase the amount of black liquor solids sent to an evaporator limited plant.

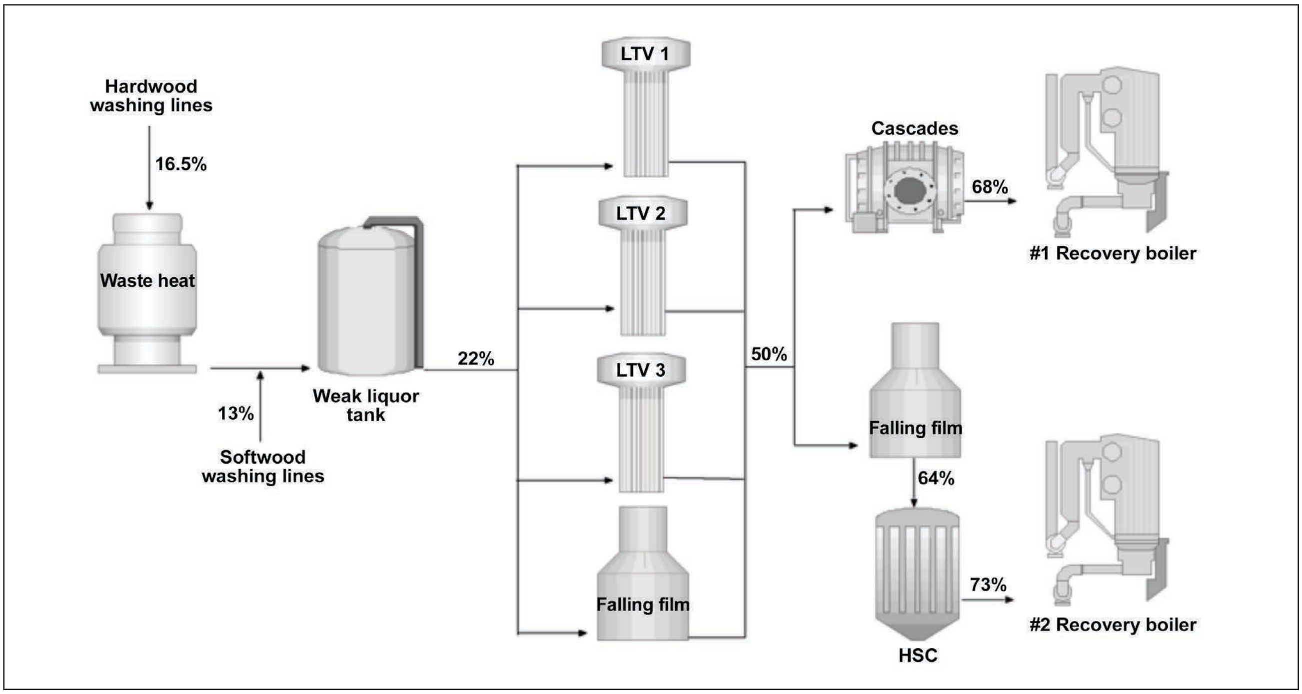
MILL OPERATIONS

The studied site was an integrated bleached softwood and hardwood mill located in the Eastern United States. The mill employs batch digesters with target kappa numbers of 31 for softwood (Line #1) and 17 for hardwood (Lines #2 and #3). Softwood production comprised 20% and hardwood production (Lines #2 and #3) comprised 30% and 50%, respectively, of the mill's pulp furnish.

Figure 1 illustrates the process flow for Lines #1, #2, and #3. As can be noted, Lines #1 and #3 have an oxygen delignification stage while Line #2 does not. "Clean water" composed



1. Brownstock washing schematics for Lines #1, #2 and #3.



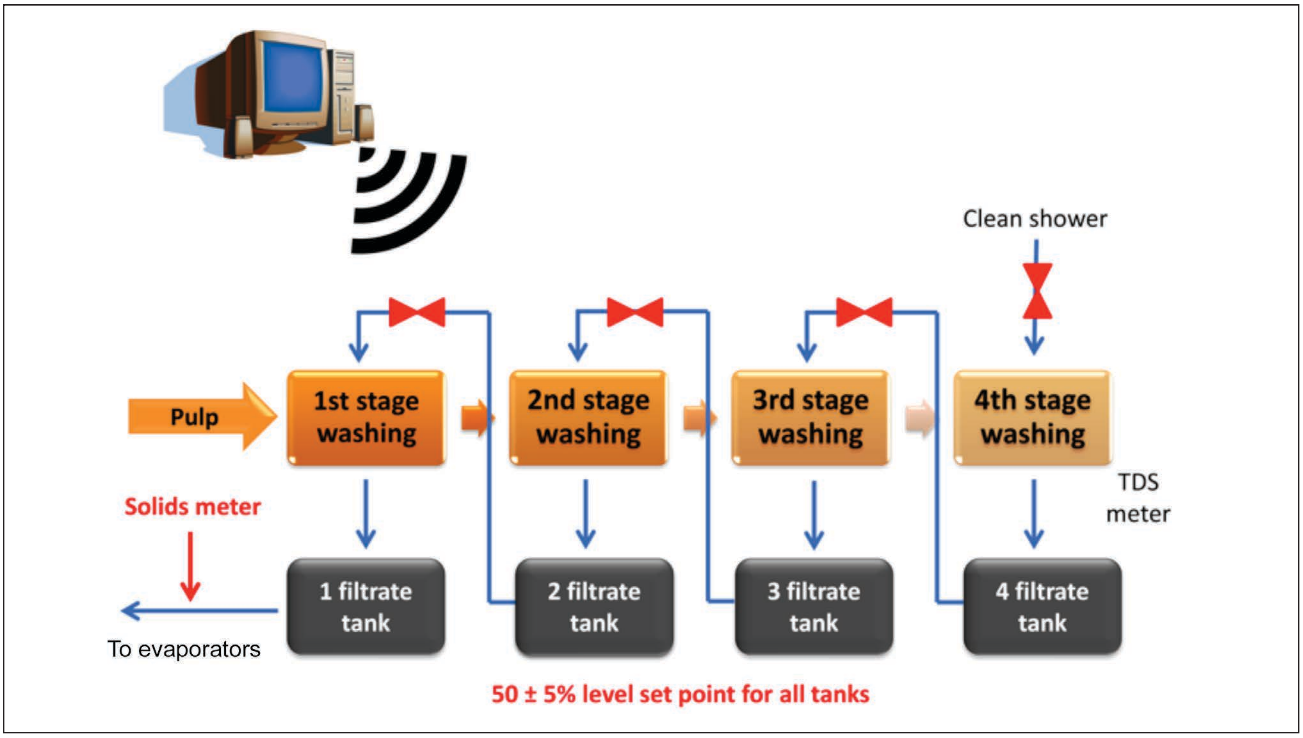
2. Evaporation plant schematic.

of clean evaporator condensate is fed into the last stage of each line and is carried counter currently throughout each of the washing stages.

Line #1 delivers 13% total dissolved solids (TDS) to the weak black liquor tank and the other two lines deliver 16.5% TDS to the waste heat evaporator (**Fig. 2**). The low solids set point for softwood line is due to foaming issues that occur around 14.0%, which is amplified by digester padding liquor and screen room setup at the mill. There is no tall oil recovery at this facility for the three fiber lines.

EVAPORATION PLANT

The mill's evaporation plant consists of a waste heat evaporator with 3 effects producing 24% black liquor solids; three rising film evaporator (LTV) trains with 6 effects each producing 50% black liquor solids; one falling film train with three effects producing 50% black liquor solids; two falling film bodies producing 64% black liquor solids each; two cascade evaporators producing 68% black liquor solids; and two crystallizers producing 73% black liquor solids each. Figure 2 shows the overall evaporation plant arrangement.



3. Controls system. Red color indicates system points that are part of program logic.

WASHING CONTROLS

In order to address losses in evaporation capacity, a Capstone brownstock washing automation system was developed and implemented for all three brownstock lines.

The main goal of the project was to maintain controls operation as simply as possible while guaranteeing stable black liquor solids content to recovery and low black liquor carryover to the bleach plant.

In the beginning of the project, each brownstock line was equipped with mass flow meters (Micro Motion F200, Emerson Electric; St. Louis, MO, USA) for solids measurements of the black liquor being sent to evaporators and with conductivity meters at the end of each line (bleach plant side). A DCS control strategy was developed and filtrate tank levels were allowed to move from 30% up to 70% in response to black liquor solids variation. This program was set up to control water addition from the front (first washer) to the back (last washer), meaning that "clean water" is added/removed only at the end of the controls' responses to a change in black liquor solids. As an example, when the program is running at an 18% solids set point and solids drift to a higher value, the program will first attempt to adjust solids by increasing the first stage washing shower flow (closer to the mass flow meter). Once this shower flow is increased, the leading filtrate tank level starts to decrease, and it is then compensated by an increase in shower flow of the next washer. This same logic takes place until the end of the line (last washer) when "clean water" is finally added.

After initial trials, modifications were made to the program in order to improve system up time and response to solids deviation. Instead of making use of in-line conductivity meters, hourly black liquor carryover measurements were employed (meters are explored in more detail later). Conductivity meter reliability was the main issue driving this change. The conductivity meters routinely experienced excessive scaling formation. This scale formation resulted in loss of signal and poor control performance. The operators did not like the amount of variability the control program allowed within the filtrate tanks and would routinely shut off the program due to changes in filtrate tank level. Therefore, another program modification was the reduction in filtrate tank level variation allowed by the controller. Instead of allowing filtrate tank level variation to range from 30% to 70%, the program was set to control it to a much tighter range. The improved control parameters only allowed a 5% level set point deviation in each filtrate tank. These modifications improved program reliability and up time, and were essential in reducing operators' frustration during the implementation phase. **Figure 3** shows the control's response strategy.

The control was also equipped with logic to quickly adjust shower flows in response to production rate swings. This was done by base loading the dilution factor at all times. Shower flows would then increase or decrease in response to load changes, keeping the ratio of gallons of water per ton of pulp constant.

To guarantee and monitor low black liquor carryover to the bleach plant, the last washing stage of each line was equipped with handheld total dissolved solids measurement devices (TDS-Accumet AP85, Thermo Fisher Scientific; Waltham, MA, USA) for hourly tests.

RESULTS

In general, implementation of brownstock washing controls resulted in reduced evaporator curtailments occurring in the pulp mill. The gain in evaporator capacity was achieved by reducing brownstock shower water flows and also by an increase in and stabilization of the black liquor solids being sent to the evaporators.

Water reduction

Brownstock washing water reduction (gal/ton) can be achieved in two different ways when utilizing this particular control program: (1) by increasing the black liquor solids target to the evaporators; or (2) by reducing solids variation (excursions) going to the evaporators. Prior to this project, there were no specific black liquor solids targets to the evaporators. Basically the amount of water added was controlled by manual Baume testing of the last washing stage.

When the new washer control program was installed, Baume testing was no longer being used as a control parameter for changes in shower water flows by operators. Operational control targets for the new controls program, based on bleach plant carryover (TDS measurements) and solids to recovery were developed and implemented. The Line #1 black liquor target was set at 13% solids, line #2 at 16%, and line #3 at 16.8%. With the program running at targets, water reduction for all the lines was achieved. Results are shown in **Table I**.

Line #	Clean Shower Reduction, gal/ton
1	62
2	88
3	111

I. Water reduction achieved (gal/ton) for each of the three lines.

Black liquor solids gain and stabilization

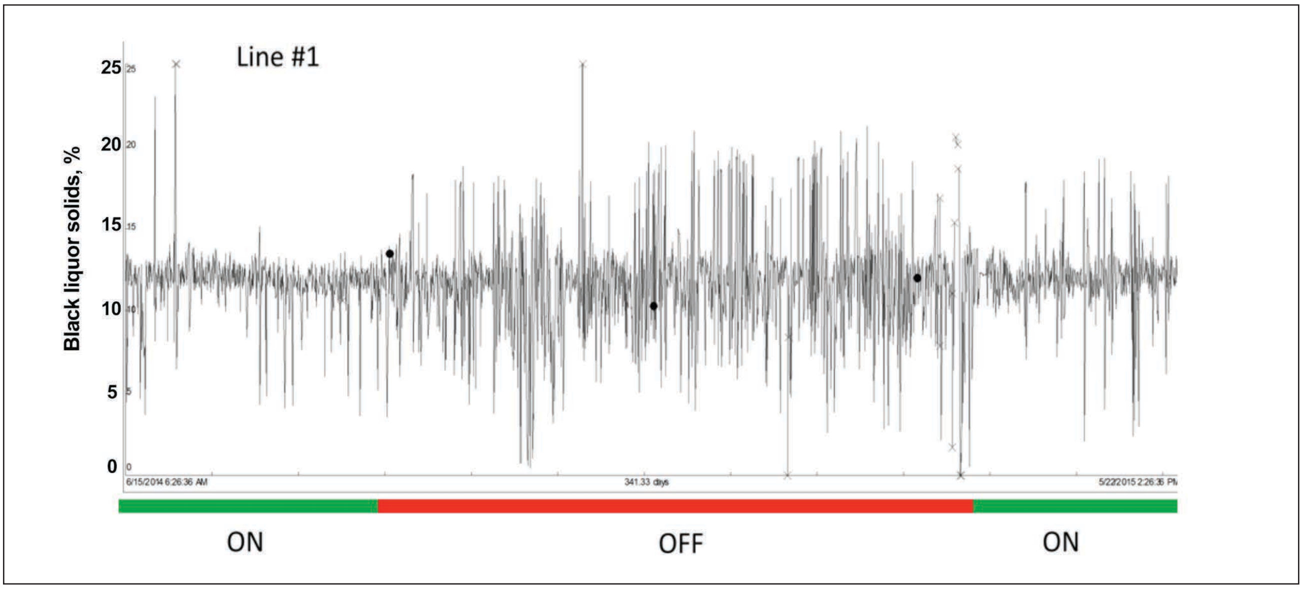
One of the basics rules to improve evaporator performance is the stabilization of black liquor solids sent to the first effect. Solids stabilization reduces the amount or frequency that soluble scale is formed on the evaporator's tubes walls [15].

As a result of solids controls implementation, black liquor solids from line #1 were stabilized at 13%, while line #2 was stabilized at around 16% and line #3 at around 16.8% (**Figs. 4–6**). Solids stabilization resulted in about a 0.6% point increase in black liquor solids content for the hardwood lines, which represented energy savings in evaporator steam usage. It also allowed for increased pulp production as the evaporators were able to process an adequate amount of black liquor and allow the pulp mill to run continuously.

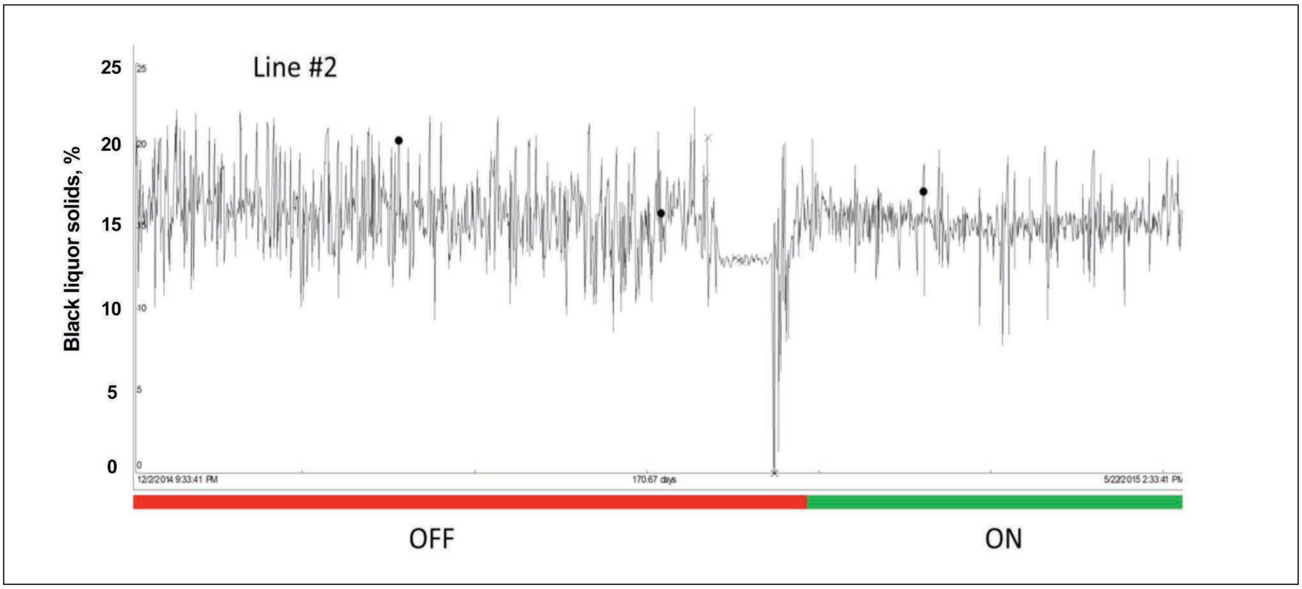
Another positive result from having shower controls implemented was the elimination of Line #1 foaming events. Prior to this project, softwood black liquor filtrate tanks (pulp mill) routinely foamed. Foaming was caused by high black liquor solids excursions (higher than 13.5%) resulting in soap separating from the liquor. Foaming events were followed by the operators increasing the shower water for long periods of time in order to eliminate foaming. This behavior added substantial amounts of water into the system, requiring extra evaporator capacity. The control program allowed for a much improved black liquor solids control, and consequently, a reduction in foaming events and in black liquor solids dilution.

Oxygen delignification stabilization and bleach plant carryover

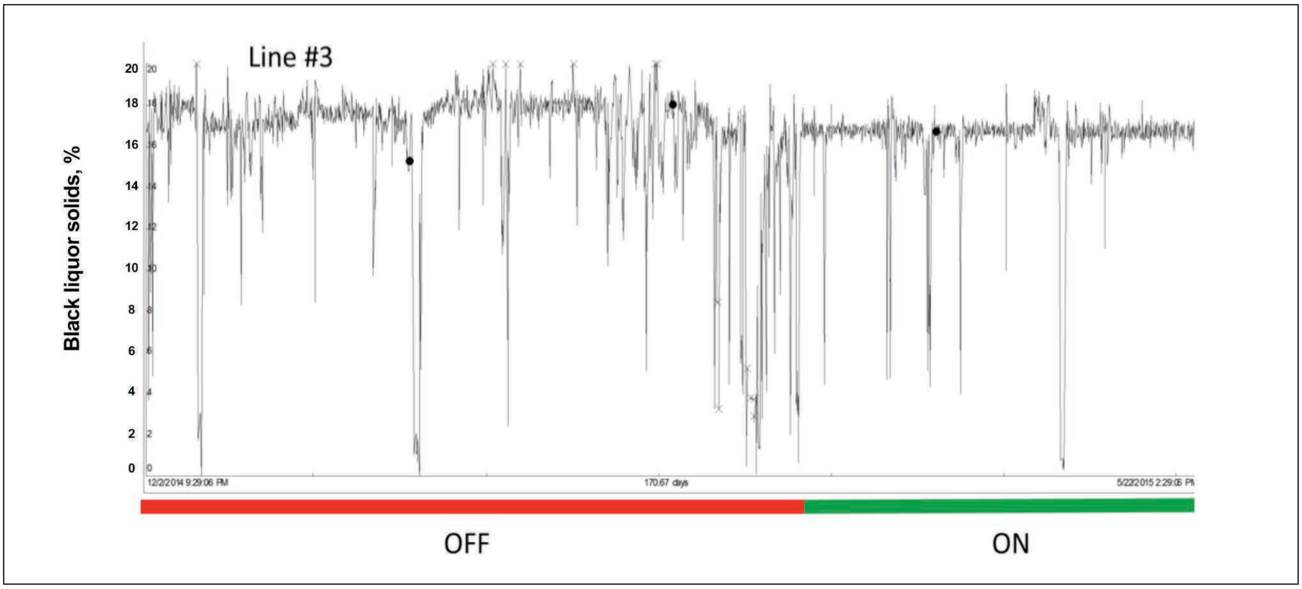
Another important aspect of brownstock washing is to minimize black liquor carryover to oxygen stages and to the bleach plant. The presence of elevated black liquor content in the



4. Line #1 solids with shower controls ON and OFF.



5. Line #2 solids with shower controls ON and OFF.



6. Line #3 solids with shower controls ON and OFF.

oxygen delignification stage can reduce lignin removal efficiency, which can impact the bleach plant, waste treatment plant, and the energy cycle. A typical oxygen delignification stage can remove up to 45% of the lignin left in the pulp after cooking [16]. This lignin is then washed away to be sent to the evaporators for concentration and to the recovery boiler to be burned and generate steam. As the oxygen delignification stage becomes more inefficient, the amount of lignin to serve as fuel for steam production is also reduced, which can impact the overall mill energy balance. Another negative impact of black liquor carryover to the oxygen delignification stage is a loss of pulp viscosity (potentially an indication of reduced pulp strength). As overall stage efficiency goes down, there is a tendency to compensate for the lost efficiency by adding more caustic (i.e., oxidized white liquor, in general) to the system. This extra caustic addition will favor carbohydrates peeling reactions, which will reduce pulp viscosity and can affect fiber strength properties.

If black liquor carryover extends to the bleach plant, there will be an increase in bleaching chemical usage and in the amount of BOD and AOX to the waste treatment plant, in addition to increased potential for scale formation, such as barium sulfate. Barium sulfate is well known for being difficult to remove, requiring extremely high water pressure when blasting lines and equipment.

Because of the adverse impacts of black liquor carryover explained previously, this parameter was closely monitored during shower controls implementation. Handheld total dissolved solids measurement devices were utilized on an hourly basis to test and monitor carryover to the bleach plant. The tests were performed on the actual filtrate coming out of the last brownstock washing stage in each line. Normally, this testing would be performed utilizing filtrate obtained from pulp mat, but due to operators' safety concerns of collecting and squeezing hot pulp, the testing was done on the filtrate itself using an overflow pot beside the washer. In this way, operator/filtrate interaction was kept to a minimum. Even though a reduction in shower water per ton of pulp was achieved, no increase in black liquor carryover was noticed with the new program implementation.

CONCLUSIONS

Implementation of an automated Capstone brownstock washing controls program to the three brownstock washing lines proved to be effective in reducing the amount of water utilized by the pulp mill. The program successfully increased pulp production capacity through an increase in and stabilization of the weak black liquor solids being sent to the evaporators, while maintaining low carryover levels to the oxygen delignification and bleaching stages. The program implementation also resulted in a substantial reduction in the foaming tendency of the softwood washing line and significantly reduced process fluctuations in the weak black liquor flow to the evaporators. **TJ**

ABOUT THE AUTHORS

This research provides a simple approach to accomplish brownstock washing while reducing the amount of water to the evaporation plant. The most difficult aspect of this research was tuning the brownstock washing program. The most interesting discovery from this research was how a simple approach can have a major impact on pulping production.

Mills can benefit from this research by improving their brownstock washing process, which has major impact on pulping production and overall mill economics.

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