

New Brownstock Wash Aids for Improved Washing and Foam Control

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Abstract

Brown stock washing is a critical step in processing fibrous material for making paper and related products. Traditional defoamers are the main class of wash aids used in these operations. With increased capacity requirements in growing markets and the development of new washing technologies, the functional requirements of wash aids have evolved. The three main requirements we have identified are drainage through the mat, foam knockdown and foam prevention. The present paper discusses new wash aids that can address all of these needs through careful selection of chemistries that are incorporated into the defoamer formulation.

Keywords: eucalyptus; kraft; pulp; defoaming; drainage; persistence; knockdown; washing; efficiency

Introduction

Increased capacity requirements in growing markets, such as South America and Asia Pacific, have made it more important to maintain adequate washing efficiencies while optimizing capital investment in equipment. These objectives can be met through the better design of washing equipment and the use of chemical facilitators such as wash aids.

The objective of brown stock washing is to separate the product (cellulose fibers) from the process chemicals (black liquor) while using a minimal amount of wash water. The washing process itself may be complicated by the variety of equipment, wood chip sources, liquor concentrations, and cooking parameters used (1). Reduced wash water results in higher black liquor solids, which in turn reduces steam demand in the evaporation process of the recovery cycle and increases energy recovery in the co-generation plant. Another advantage of improved washing efficiency is reduced soda and organic carry over with the fiber to the bleach plant, which results in a significant savings of bleaching chemicals. An added benefit is the reduction of white liquor make-up chemicals.

Defoamers were originally developed for the vacuum drum washer, which was the main technology in use several decades ago. The main requirement with open vats and vacuum systems was to control foam forming in the vats, which caused overflow and plugged washers. As new washer hardware has been developed the technology shift has changed the requirements of a defoamer. Steady state defoamer feed systems obviate the need to intermittently feed defoamer on top of the foam in the vat. Instead, the ability of a defoamer to prevent a foam head from forming translates to a good persistence performance vs 'knockdown' of the foam. Secondly, with closed chambers such as those that exist in vacuum baffle and drum displacement washers, there is no mechanism for surface foam to form. Instead air that is entrained in the system before the washer (pumps, screens) needs to be managed. In these systems drainage of the black liquor and the wash water through the mat becomes the bottleneck, and chemistries (products) designed to increase mat permeability are desired for increasing washer efficiency.

There are numerous theories and proposed mechanisms related to the formation, suppression, and prevention of foam in wood pulp cooking liquors (2). In this paper, we attempt to show the different mechanisms that are operating in foaming systems, air entrainment and mat displacement washing. Our research has suggested that two types of defoaming, knockdown and persistence (often referred to as defoaming and antifoam) are not only important but antagonistic to each other. Developing the right product for the right application involves balancing these two characteristics. We also discuss how we can use different chemistries in isolation or in combination to control each of these issues. By designing the proper laboratory measurement methods we are able to separate the different phenomena that occur in a majority of the washing operations and develop solutions to address them.

Experimental

Materials. Pulp and black liquor were obtained from North American hardwood and Brazilian eucalyptus fiber-lines. These materials were taken from the feed to the first stage washer head box, and the slurry was separated into pulp and black liquor fractions. The drainage aid DA-1 is a typical proprietary product used by Solenis LLC. Silicone resins used in defoamer formulation were either made in our laboratory or purchased from vendors. Standard surfactants and stabilizers were used to make the defoamer formulations.

Drainage Test. Black liquor and pulp were mixed to obtain a pulp consistency of 2 to 3% (based on dry pulp). The pulp slurry was then mixed under high shear which causes air entrainment, and run in the drainage apparatus at 85 °C. The amount of shear was varied by controlling the power input to the mixing device using a rheostat. When desired, additional air entrainment was obtained by sparging air at a controlled rate during the shearing step (which also aided in dispersing the air bubbles). After mixing, the slurry was filtered with a screen, under moderate vacuum in the drainage apparatus, simulating mat formation on a washer. The flow rate of filtrate was measured. The filtering was stopped in such a manner that the fiber mat had the same amount of black liquor content every time.

Displacement washing. After the drainage test was completed, deionized (DI) water at 85 °C was carefully added on top of the mat. The flow rate of the filtrate was measured under a pressure drop while collecting samples for conductivity (metal salts) and color measurement (organics).

Air Entrainment. The pulp slurry was mixed under the same conditions as described in the drainage test (with and without sparged air). At the end of the mixing, the slurry was transferred to a graduated cylinder where apparent density was measured. The difference between this density and the density of a zero-entrained air case was used to calculate the percentage of air entrainment.

Foam Cell Measurements. In order to differentiate defoamer formulations, a temperature controlled recirculating foam cell apparatus with sparging was developed and used in this research. The recirculation loop was employed to promote agitation and to provide mixing. The foam was generated in a very controlled fashion using a gas dispersion tube and a precisely regulated air source. The tests were run in two modes – i) foam persistence, measured by mixing the defoamer into a black liquor sample and measuring the rate of foam rise and ii) knockdown, measured by creating a foam with a black liquor up to a point and then introducing the defoamer on top of an existing foam column and measuring the rate of decrease, depth of fall, and persistence of foam suppression. The first method measures the ability of a defoamer in preventing foam formation and the second in destroying a foam.

Results and Discussion

Drainage Studies

The experimental method relied on the blending of wood pulp with black liquor under controlled shear, both with and without additional air sparged into the slurry. We found that entrained air increases as shear to the slurry increases (3). This is synonymous to operations in a mill, where the pulp slurry

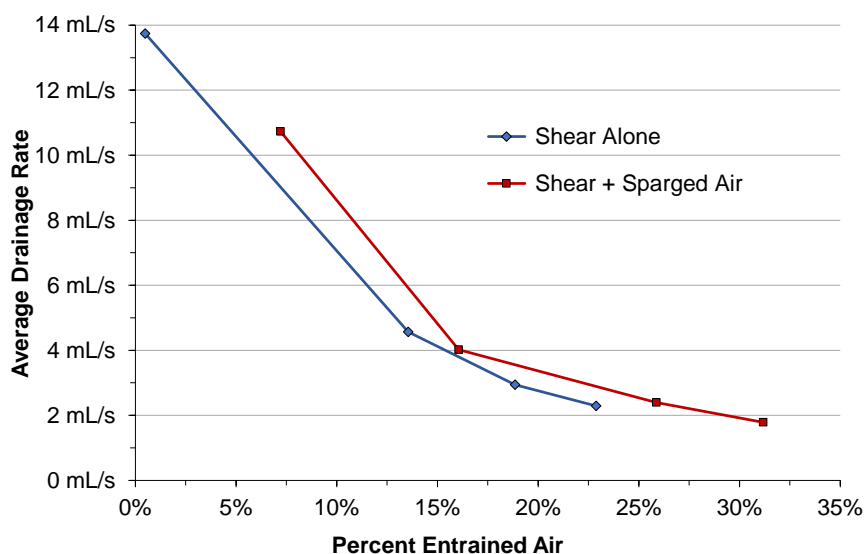


Figure 1. Entrained air compared to average drainage rate.

experiences different levels of shear in the pumps, pipes, vats and screens within the processes. We have observed a correlation between an increase in the amount of entrained air and a decrease in the rate (increase in time) of drainage (Figure 1). A high drainage rate corresponds to a pulp mat which is easily drained of black liquor. The drainage aid products were added to the slurry to test their efficacy at increasing this drainage rate.

Figure 2 demonstrates a substantial improvement in drainage rates with relatively low levels of DA-1 addition, 0.11 kg/oven dry ton pulp (right hand graph). The most significant differences in drainage rates occurred for slurries that were prepared with the highest levels of shear and with the addition of sparged air. That is, slurries under conditions that entrain the most air were the ones that benefited the most from the

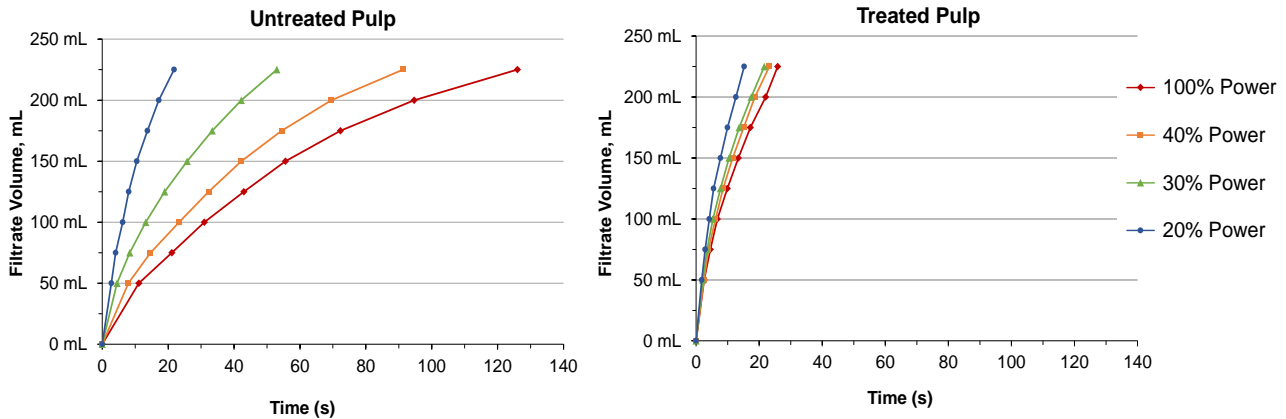


Figure 2. Filtrate drainage profiles for slurries prepared with both shear and the addition of sparged air.

treatment. When drainage aid treatment was added to the slurry, the amount of entrained air remained approximately unchanged regardless of the amount of shear applied (Figure 3).

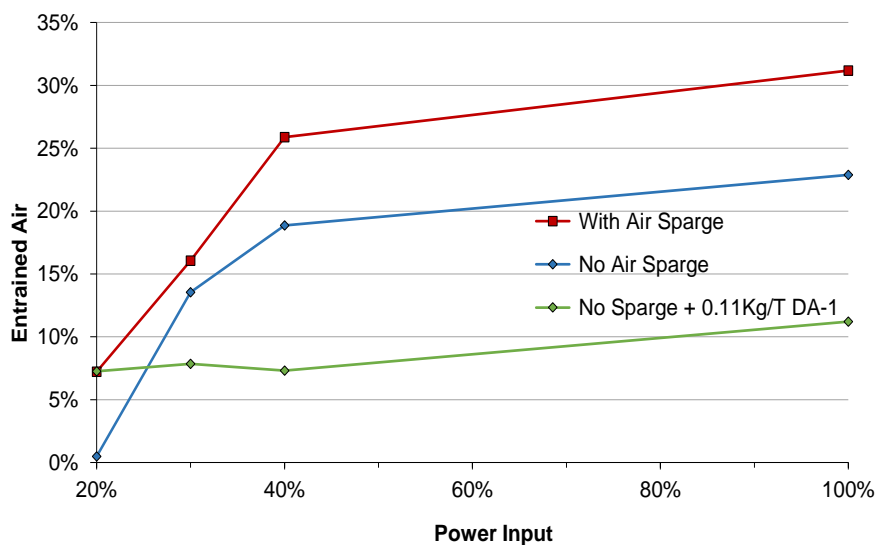


Figure 3. Comparison of entrained air as a function of power input during shear mixing, for slurries that were treated with DA-1 compared to those that were untreated.

Displacement washing was carried out with the resulting mat formed at the completion of a drainage test. This was simulated with mats formed from slurries mixed at 100% power for maximum shear. In general practice, displacement of the pulping liquor within the mat by clean wash water must be accomplished quickly, and with the lowest amount of clean water possible. This process can be enhanced by the addition of drainage aids, which increase the permeability of the mat. Figure 4 shows the rate of wash water flowing through the mat under a set pressure. The curves are more linear, since the flow for this set of tests was measured through a preformed mat as opposed to Figure 2, which was measured with dynamic mat formation. This data, in conjunction with Darcy's equation, was used to calculate mat permeability as shown in Table 1. The pulp slurries to which the drainage aid was added directly had the fastest drainage rates and

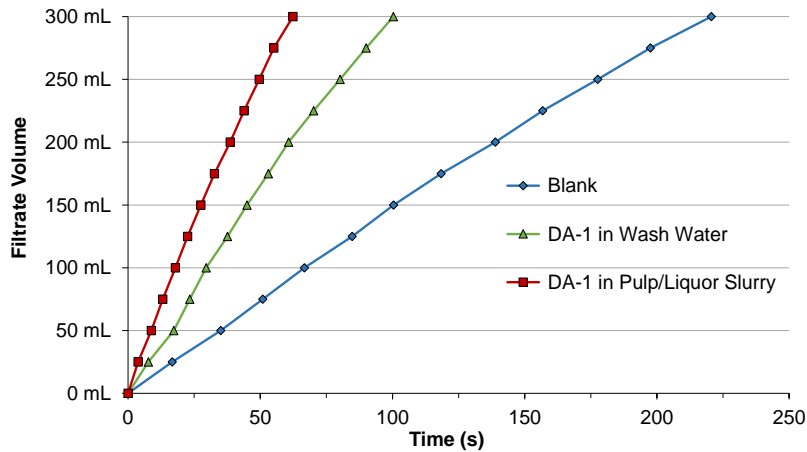


Figure 4. Displacement filtrate flow profiles for DI water through formed mats. Note: Blue line – no DA-1 added, red line – DA1 added to pulp/black liquor slurry, green line – DA-1 added to the DI wash water.

Table 1. Calculated Mean Permeability of Fiber Mats Formed with Drainage.

Experimental condition	Mean, $k \cdot 10^8$ cm
No Treatment	7.9
Treatment Added to Wash	13.5
Treatment Added to Pulp	16.8

highest mat permeability values. Adding the drainage aid to the displacement (shower) water gave rates and permeabilities intermediate to direct slurry treatment and no treatment at all. We found that the wash rates during mat formation and displacement can both be doubled by using a drainage aid.

The primary goal of the washing process is to efficiently remove the dissolved inorganic salt (predominantly Na^+) and organics from the fibers and convey them into the filtrates for recovery. Less carryover of alkali and organics with the pulp into the bleach plant saves bleaching chemical costs and soda

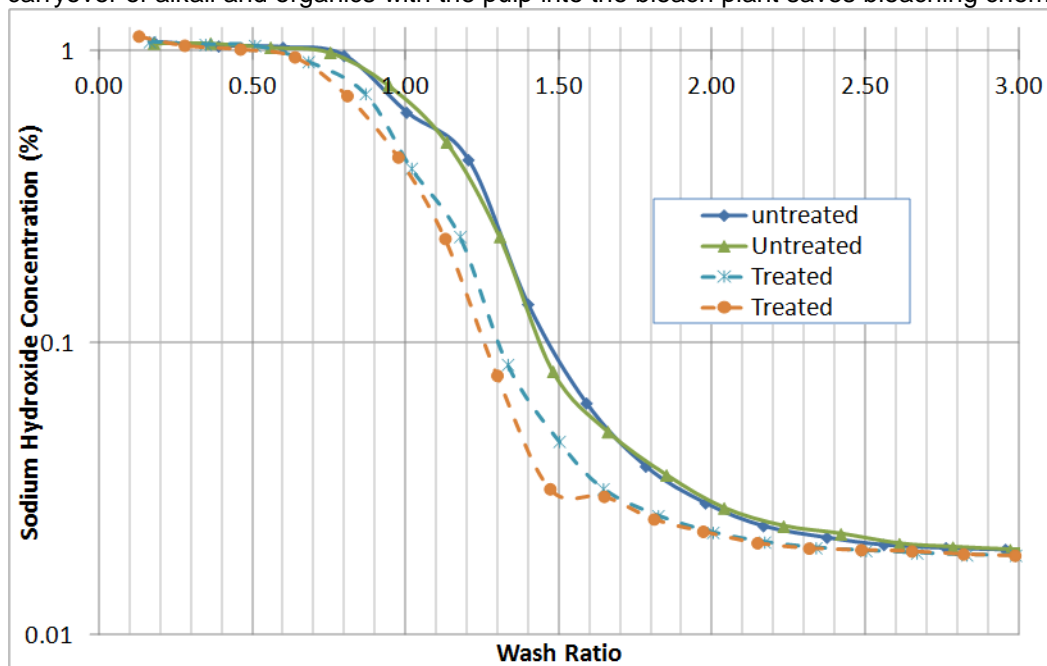


Figure 5. Displacement wash ratio vs sodium hydroxide concentration (partial log plot).

losses. The level of dissolved salts in the filtrate solution may be measured as solution conductivity, and

used to determine washing efficiency (4). Drainage experiments were performed and the conductivity of the filtrate was converted to sodium hydroxide concentration using sodium as the representative conduction ion. The displacement wash ratio was calculated by dividing the cumulative mass of wash water used by the mass of the liquid in the saturated mat (i.e. number of displacement volumes). The results in Figure 5 demonstrate that treatment of the pulp slurry with DA-1 allows a lower wash ratio to attain the same NaOH residual in the mat, i.e. an improved washing efficiency. We also observed that the washing of organic compounds (measured as color) followed the same trend, and these were removed at an even greater rate and to a larger extent.

Mill Experience

The performance of the wash aid in the actual mill setting is the final determinant of success or failure for product development. A number of developmental drainage aids were tested at a large eucalyptus kraft pulp mill in Brasil. It was immediately apparent that the drainage rate for this pulp was much higher than the rate for different hardwood pulps used in previous laboratory experiments. Adjustments to the testing parameters and dosage rates allowed clear differentiation between the various products. Previous experience with performance, as it is related to the location of product application in the washing process, was re-affirmed. The drainage aid performed most effectively when added directly to the pulp slurry as shown in Figure 6.

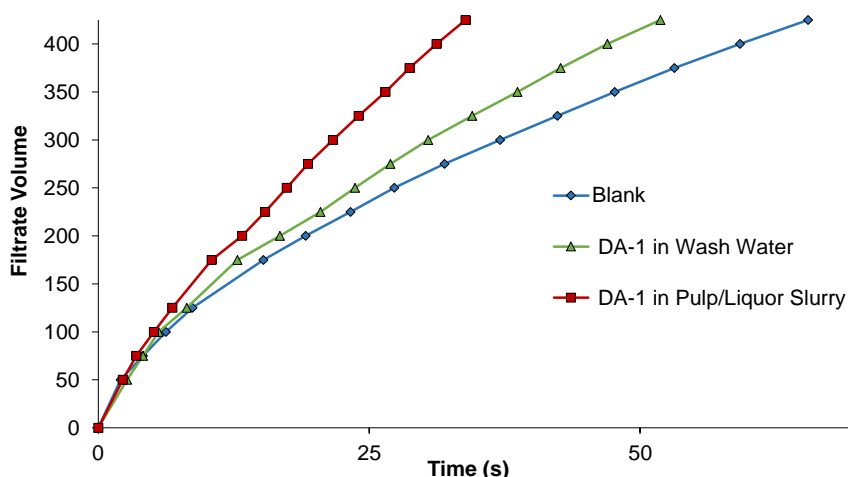


Figure 6. Displacement drainage of eucalyptus pulp with drainage aid applied at different locations.

Defoaming Studies

Silicone defoamers can be effective at preventing foam from forming (persistence) and reducing existing foam (knockdown). Furthermore, our research has suggested that both are not only important but are generally antagonistic to each other. Efforts to develop the right product for the right application often involves balancing these two characteristics. For the purpose of demonstrating this effect, two defoamer formulations were prepared and evaluated in two different types of tests. By judiciously choosing the proper organo-silicone chemistry, Formulation A was designed for foam prevention or high persistence against foam. A separate organo-silicone material was chosen for Formulation B, which was aimed at providing a rapid knockdown of an existing foam. The results of both types of foam cell tests are shown in Figure 7. Formulation A provides strong defoaming over an extended amount of time as seen in the persistence test below. On the other hand its ability to quickly knock down a foam is limited, although it does prevent foam from building further. In order to quickly destroy a standing head of foam, it is clear that Formulation B is superior. However, its effectiveness at preventing foam formation, as in the persistence test, is not very good relative to Formulation A.

Although it is generally accepted that increased persistence can dramatically reduce overall defoamer usage, there are times when a higher level of knockdown is also valuable. This is true in scenarios such as a system upset, which is often observed at hardwood/softwood swing mills. Other applications may include direct control of foam height in filtrate tanks or in low black liquor concentration zones such as in a decker. For these situations, we can formulate products that display extremely active knockdown characteristics as shown below.

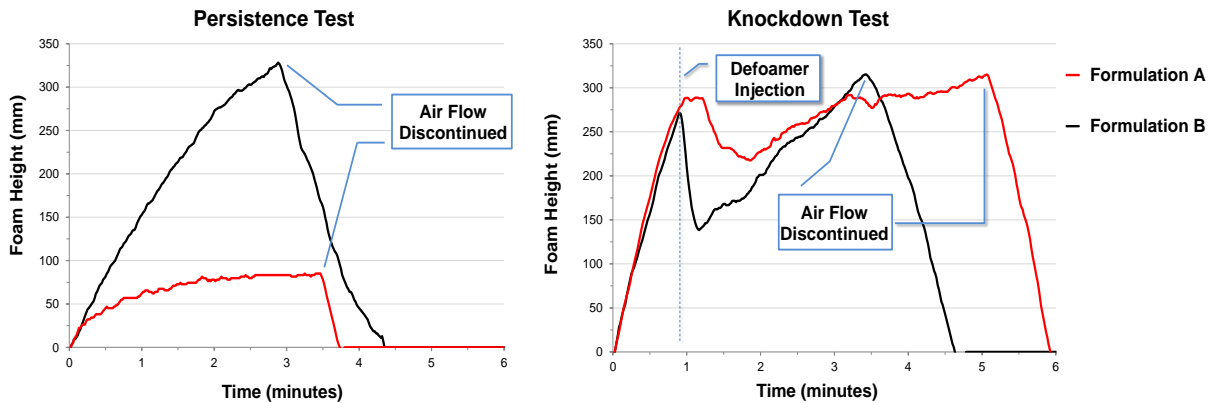


Figure 7. Knockdown and persistence testing for two different defoamer formulations on North American softwood pulp black liquor filtrate.

The pattern of defoamer performance observed for North American softwood was similar in Brazilian eucalyptus pulp. Of notable difference was the propensity of the eucalyptus black liquor to quickly form stable foam that continued to grow with the further addition of sparged air. This foam could be controlled by both the persistence and knockdown formulations as shown in Figure 8.

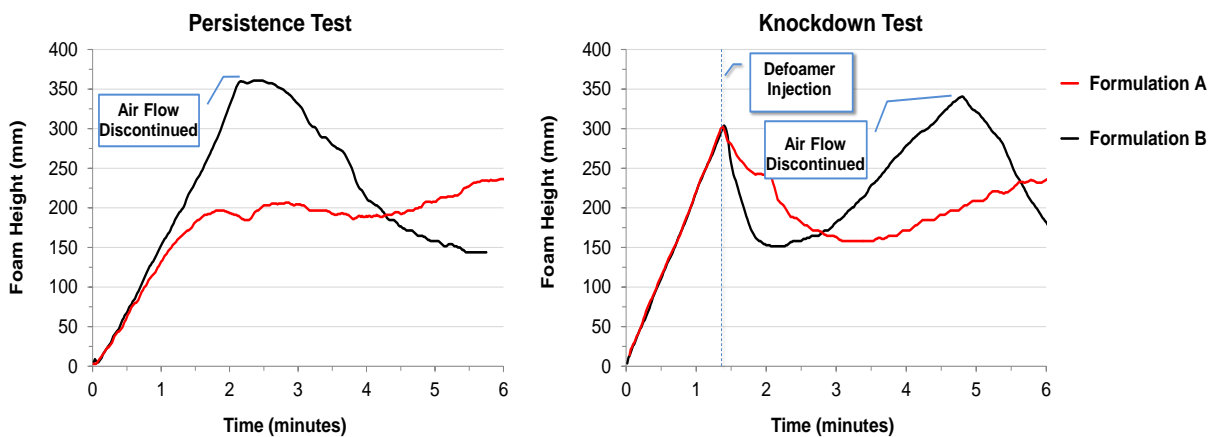


Figure 8. Knockdown and persistence testing for two different defoamer formulations on Brazilian eucalyptus pulp black liquor filtrate.

It is possible to formulate a range of products optimized for each component of the washer system. For example, if a mill needs to control foam and improve drainage in the first and second stage washers, a product can be formulated with excellent persistence and drainage. Extended persistence is one method for reducing total silicone use, by reducing defoamer usage to maintain an acceptable foam/entrained air level where the washers operate in a steady state. It can take 10 to 20 minutes for the system to equilibrate after a change in defoamer type or concentration.

The ultimate goal of a brown stock washer is to remove impurities from pulp with a minimal water usage. Toward this goal, it is possible to develop persistence formulations that are completely optimized for high temperatures, high black liquor concentrations and that offer excellent drainage.

Conclusions

The proper design of brown stock washing aids may control foam in different ways, and provide for fast efficient drainage of the pulp mat.

- Products that can address the multiple needs of a brownstock washing operation are the most beneficial for a pulp mill. This can be accomplished by balancing the product chemistries with the specific requirements of the washing system in which the product is applied.
- Operational benefits may be considered. For example, certain formulations might be selected for good performance during system upsets, minimizing losses and excess water use.
- Defoaming persistence, knockdown, and mat drainage can be quantified and formulated separately. Balancing these attributes can be a part of the mills cost consideration.

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