

Retention strategies for alkaline fine papermaking with secondary fiber: a case history

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With an advanced retention system, filler loadings could be increased as high as possible while balancing runnability, furnish costs, retention, and optical properties.

The West Carrollton mill of Appleton Papers, Inc. produces over 375 tons/day of lightweight paper for business forms (40–56 g/m²). The mill's three paper machines use a blend of purchased bleached kraft pulp and secondary fiber from an on-site deinking and bleaching facility. The mill was converted from acid to alkaline papermaking in late 1986. The reasons justifying this conversion along with a brief history are documented elsewhere.*

During the first three years after the conversion, there was a marketing demand for incremental increases in sheet brightness and opacity. At the same time, a high priority was put on improving the sheet formation on all of the grades to take a leadership position in the market. Continuous improvements were made in the wet-end chemistry optimization strategy to attain the best balance between retention, formation, and optical properties.

Here, we focus on various retention strategies adopted by the mill to improve and optimize wet-end performance. In this effort, we conducted trials on a microparticle retention system based on modified bentonite. A cationic polyamine was also tested in conjunction with an advanced retention system on certain grades. Wet-end chemistry was monitored and comprehensively analyzed in terms of retention, zeta potential, and cationic demand. In addition, we will also look at filler chronology and its relationship to optical properties.

Wet-end chemistry and additives

In the early stages of the alkaline conversion, trials were conducted using the same medium-molecular-weight polyacrylamide that the mill used on the acid side as a matter of convenience. Both first-pass retention and first-pass ash retention were unacceptable with this system, as shown in Table I. Table I summarizes various retention strategies adopted by the mill to optimize the wet-end performance.

Laboratory drainage jar studies were performed with several other anionic polyacrylamides. At the time, an anionic retention aid and a quaternary-charged cationic potato starch were the products preferred for alkaline sizing. Our in-house laboratory studies indicated that a product of higher molecular weight would improve retention. Machine trials were run, and the subsequent conversion to the high-molecular-weight anionic system improved the first-pass retention by over 10%. Although 10% was a considerable improvement, the basestock suffered from poor formation as a result of overflocculation. Furthermore, sheet sealing and high vacuum loadings caused pinholes in abundance.

The wet-end chemistry needed to be optimized further because of the poor performance of the basestock in terms of coating holdout. Limited trial work using alum at a low dosage rate (5 lb/ton) was encouraging, because it indicated that first-pass retention could be improved by 9 percentage points. However, the paper machine suffered from wet line swings and considerable variation in retention as a result of problems the mill encountered in maintaining uniform dilute alum solids and flow control. We were also concerned about the possibility of creating severe calcium carbonate scaling problems in the deinking and bleaching process through using too much alum. (In acid sizing, papermakers often use excessive amounts of alum.)

The alum trials showed that there is a high cationic demand from both the secondary fiber and the fine ground carbonate. This result led to further laboratory drainage jar studies using both anionic and cationic polyacrylamides. Out of 36 polymer products screened, the top three performers were cationic. Trial work using a high-molecular-weight cationic polyacrylamide in conjunction with the existing quaternary-charged cationic potato starch resulted in further improvements in first-pass retention. The cationic polymer also improved drainage and sheet formation, and it caused a dramatic reduction in sheet pinholes. Basestock performance was greatly enhanced.

The marketing demand for improvements in basestock

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*Ferguson, M. C., Jackowski, C. W., and Moran, W. C., 1989 Retention and Drainage Short Course, TAPPI PRESS, Atlanta, p. 99.

I. Wet-end chemistry and additives (50-g/m² basestock production at 610 m/min)

System chemistry		Polymer, lb/ton	Cationic starch, lb/ton	Benton- ite, lb/ton	Filler, lb/ton	Retention, %	
pH	Additive					First pass	First- pass ash
Acid	MMW anionic	0.8	15 (3° corn)	...	100 (clay)	51	15
Alkaline	MMW anionic	0.8	15 (4° potato)	...	100 (FGC)	53	15
Alkaline	HMW anionic	0.8	15 (4° potato)	...	100 (FGC)	64	21
Alkaline	HMW cationic	0.6	15 (4° potato)	...	100 (FGC)	69	22
Alkaline	HMW cationic	0.9	15 (3° corn)	...	100 (UFGC)	68	23
Alkaline	HMW cationic	0.6	15 (3° corn)	...	150 (UFGC)	68	21
Alkaline	HMW cationic	1.5 ^a	15 (3° corn)	5	275 (UFGC)	74	42
Alkaline	HMW cationic	1.8 ^b	15 (3° corn)	5	150 (UFGC) 100 (PCC)	74	40

^aInjected in the suction side of the secondary fan pump.
^bInjected in the suction side of the primary fan pump.
MMW = medium molecular weight. HMW = high molecular weight.
FGC = fine ground carbonate (1.8 μm).
UFGC = ultra-fine ground carbonate (1.0 μm).
PCC = precipitated calcium carbonate.

II. Wet-end optimization with advanced retention system

Starch	Cationic polymer, lb/ton	Modi- fied benton- ite, lb/ton	Cationic starch, lb/ton	Filler loading, lb/ton		Headbox cons., %	Retention, %		M/K form- ation index
				UFGC	PCC		First- pass	First- pass ash	
Control	0.5	0	20	275	...	0.46	64	28	26
4° potato ^a	1.5	5	15	300	...	0.34	78	44	25
3° corn ^a	1.5	5	20	250	25	0.39	74	41	27
3° corn ^b	2.2	5	20	225	50	0.40	71	37	26
4° potato ^b	2.2	5	10	225	50	0.39	67	32	28
3° corn ^b	2.1	5	15	225	50	0.44	66	29	24
3° corn ^b	2.1	5	18	225	50	0.42	71	35	25

^aPolymer to secondary fan pump.
^bPolymer to primary fan pump.
UFGC = ultra-fine ground carbonate (1.0 μm).
PCC = precipitated calcium carbonate.

brightness and opacity led to a series of trials with fine ground carbonate, ultra-fine ground carbonate, and precipitated calcium carbonate. Costs prohibited an increase in the percentage of virgin kraft in the furnish in place of secondary fiber. The substitution of ultra-fine-ground carbonate for fine-ground carbonate resulted in improved optical properties, but more of the cationic polymer was needed to maintain the same first-pass ash retention as a result of the reduction in particle size and an increase in the anionic charge of the carbonate slurry. Concurrently, laboratory studies were conducted with various cationic starches to study improvements in cost performance.

Handsheet evaluations were completed using three cationic corn and three cationic potato starches. Results of the study showed that tertiary cationic corn starches did not adversely affect alkylketene dimer size retention

and were comparable to quaternary potato starches in overall performance. Without any loss in retention, the mill accrued substantial savings in chemical costs by converting to tertiary cationic corn starch.

Optimization strategies with an advanced retention system

With the emphasis on improving the optical properties, the single-component conventional retention system offered little or no flexibility in maintaining adequate retention at higher filler loadings without adversely affecting sheet formation. At this time, laboratory studies were conducted to explore the newly developed advanced microparticle retention systems.

The advanced retention systems are based on adding a cationic polyelectrolyte of medium to high molecular

weight (starch or polyacrylamide) early in the thin stock system to develop large flocs. The shear developed in the approach flow system breaks down the large flocs, and the result is a highly dispersed, cationically charged thin stock. A second component consisting of anionically charged microparticles of high surface area is then injected near the headbox, allowing the development of microflocs. The uniform suspension of microflocs can result in improved drainage, increased fines, and filler retention, and it allows the papermaker to enhance sheet formation by virtue of reduced headbox consistency.

The initial trial with one of the advanced retention systems was conducted on one paper machine producing various basestock weights. High-molecular-weight cationic polyacrylamide was added to the secondary fan pump suction in the amount of 1.5 lb/ton, and modified bentonite was added to the centriscreen outlet at 5.0 lb/ton. Both first-pass retention and first-pass ash retention were improved, particularly on the higher filled grades (12% sheet ash). Sheet formation was not adversely affected by the improvements in first-pass retention and first-pass ash retention.

These encouraging results led to an extended trial on all three paper machines. The new two-component retention system was successfully substituted for the single-component system. Polymer was added to the secondary fan pump suction on two machines and to the centriscreen inlet on one machine. The microparticle component was added to the centriscreen outlet on all three machines. Immediate improvements were observed in drainage and retention. With higher and more stable retention, sheet formation was not adversely affected. In addition, moderate improvements in opacity were observed on certain grades.

Based on these encouraging results, we decided to further evaluate and optimize the advanced system. **Table II** summarizes the results of wet-end optimization with the advanced retention system on 30-lb (44-g/m²) raw stock production at a speed of 1950 ft/min (595 m/min). An improvement in both first-pass retention and first-pass ash retention was evident when the two-component advanced system was substituted for the single-component polymer system. With no adverse effects on sheet formation, first-pass retention increased from 68% to 78%, and first-pass ash retention increased from 28% to 44%. Part of the improvement was due to substitution of imported quaternary cationic potato starch for tertiary cationic corn starch. (Imported quaternary potato starch was found to yield better first-pass retention and first-pass ash retention in conjunction with the microparticle system, unlike that experienced with the single-component system.) In addition, we gained better drainage and less dye usage. However, due to several runnability problems, we pulled the potato starch out of the system.

The continued use of tertiary cationic corn starch did not cause a substantial loss in retention. First-pass retention and first-pass ash retention averaged around 74% and 41%, respectively. Sheet formation was not adversely affected. The headbox consistency was fairly low at 0.39%. Due to an increasing demand for higher opacity, we decided to substitute 25 lb/ton of precipitated calcium carbonate for ultra-fine ground carbonate. At the same time, a decision was made to change the polymer addition

point back to the primary fan pump suction to have more flexibility in polymer dosage in order to maintain the desired first-pass retention and first-pass ash retention without affecting sheet formation. First-pass retention and first-pass ash retention averaged 71% and 37%, respectively (**Table II**).

Although the system was considered to be running at desired conditions, the effort to continuously improve led us to re-evaluate the imported quaternary potato starch. A trial was designed based on the recommendations made in the previous potato starch trial. The objective was to achieve further improvement in first-pass retention, first-pass ash retention, and internal sizing at an equivalent overall cost or more economically than the program with corn starch. Results were not encouraging during this evaluation. Overall, machine runnability was good with the exception of press picking on one machine. No improvement in retention was observed. In fact, first-pass retention and first-pass ash retention dropped four percentage points (**Table II**). Certainly, the process chemistry was different at this time. We thought that the potato starch might have worked effectively when the polymer was being added to the secondary fan pump suction. Laboratory work was then undertaken to evaluate several existing process conditions. No improvements were demonstrated relative to the control corn starch.

After the potato starch trial, the system was switched back to tertiary corn starch. However, cationic starch addition was reduced from 20 lb/ton to 15 lb/ton due to poor sheet formation and a runnability problem thought to be related to wet-end chemistry. The high cationic demand of the furnish confirmed the poor wet-end performance in terms of relatively low first-pass retention, first-pass ash retention, and high headbox consistency. The cationic demand of the secondary fiber was found to be abnormally high as a result of an imbalance in deinking chemistry. Once normal conditions were restored, the cationic starch dosage was increased to 18 lb/ton. As a result, retention improved to normal levels.

Currently, the advanced system is running with polymer being added to the primary fan pump suction and the microparticle component being added to the centriscreen outlet. The tertiary cationic corn starch is being added, along with alkylketene dimer size, to the secondary fan pump suction (**Fig. 1**). Based on limited experience, we believe that there is potential to further improve wet-end performance with the advanced retention system.

Filler type and loading vs. retention and optical properties

A transition from 200 lb/ton of fine-ground carbonate (1.8 μ m) to 250 lb/ton of ultra-fine-ground carbonate (1.0 μ m) wet-end filler loading had an adverse effect on first-pass retention and first-pass ash retention (**Fig. 2A**) employing a single-component, high-molecular-weight cationic polyacrylamide. At the same time, sheet formation, brightness, and opacity were all enhanced (**Fig. 2B**) by switching to ultra-fine-ground carbonate at higher filler loading levels.

With the introduction of an advanced retention system, filler loading levels could be increased as high as economically possible, balancing paper machine runnabil-

ity, furnish costs, retention, and optical properties. Results indicate that the implementation of an advanced retention system improved first-pass retention and first-pass ash retention while maintaining slightly higher sheet formation, brightness, and opacity relative to the single component retention system at equal filler loadings.

Cationic polyamine results on 39-g/m² blue basestock

Typically, the first-pass retention on blue basestock had run about 8-10 percentage points lower than other colors. We believed that the highly anionic blue dye was causing a system charge imbalance and, in turn, was adversely affecting retention. We ran a trial to evaluate the effect of cationic polyamine (low molecular weight, high charge density) on 39-g/m² blue basestock in terms of first-pass retention and first-pass ash retention.

With the addition of cationic polyamine to the machine chest, first-pass retention increased by 12-15 percentage points and first-pass ash retention increased by 18-20 percentage points (Fig. 3). In addition, the fines retention increased from less than 2% to nearly 40%. With the addition of polyamine, the zeta potential also decreased as expected (Fig. 3), and sheet ash increased from 6.8% to 8.5%. Based on the initial results, a feed rate of 1.0 lb cationic polyamine/ton of pulp appeared optimum for this blue basestock.

With an improvement in total retention and first-pass ash retention, along with a decrease in system charge, we concluded that the high anionic character of the wet-end system was the root cause of the poor performance on blue grades. An extended run of cationic polyamine has been proposed so that we may study its effect on sizing and dye usage.

Analytical techniques

Zeta potential

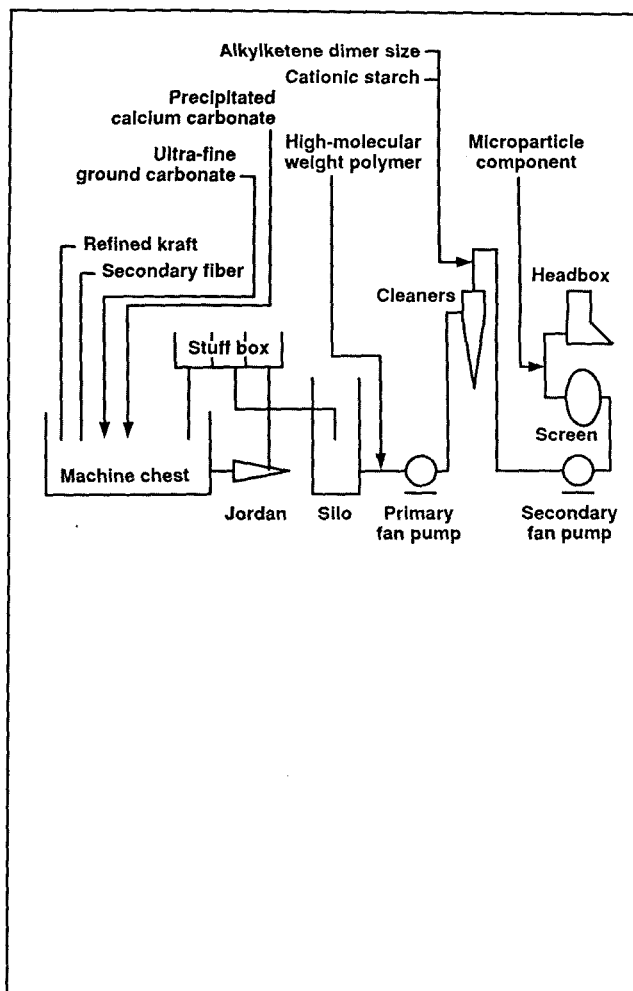
A zeta potential meter is used to measure the zeta potential by determining the rate at which the colloidal particles move in a known electric field. This measurement is done on a weekly basis and also on an as-needed basis. Although zeta potential alone does not provide enough information about the chemical balance of the system, it is helpful in troubleshooting or optimizing the wet-end chemistry when combined with cationic demand and measurements of the cationic titration ratio.

Colloidal titration ratio

The colloidal titration represents an approach to measuring net surface charge that enables the entire furnish to be utilized instead of just the fines fraction. In this technique, the amount of cationic and anionic polymers adsorbed are measured. This determination is important in assessing which type of additives will give the best performance.

The cationic titration ratio, or ionic ratio, is calculated by taking a quotient of anionic demand (in mL) to cationic demand (in mL). If the ratio is above 1.0, the stock has a net cationic charge; if the ratio is below 1.0, the stock has a net anionic charge. The ionic demand per gram of

1. Points for admitting additives in the advanced retention system



fiber is determined as follows:

$$\text{Cationic demand, meq/g of fiber} = 10 \times \text{cationic demand, mL/consistency, \%}$$

$$\text{Anionic demand, meq/g of fiber} = 10 \times \text{anionic demand, mL/consistency \%}$$

Currently, cationic titration ratio is determined on an as-needed basis.

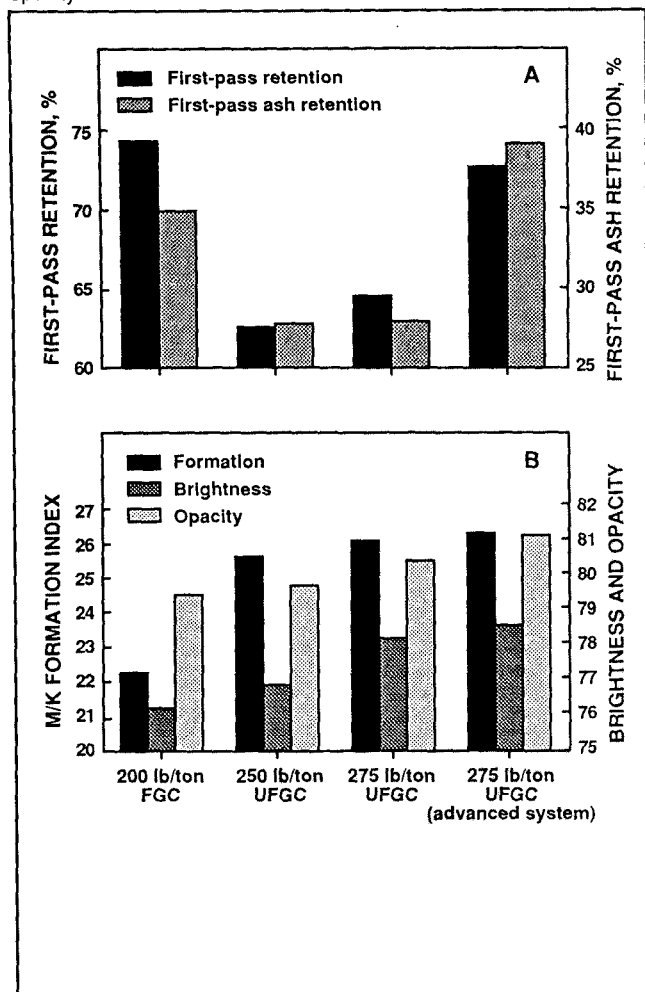
Cationic demand

Cationic demand refers to dissolved and colloidal anionic materials that interfere with the action of cationic and anionic retention aids. It is expressed as the amount (in lb/ton) of high-charge-density, low-molecular-weight cationic polymer required to titrate the system to a zero zeta potential (isoelectric point). This measurement is performed on certain chemical additives on an as-needed basis.

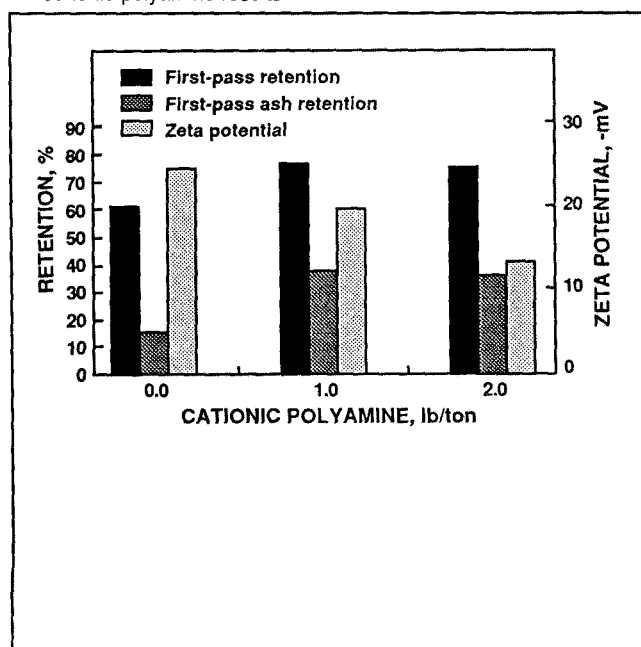
Comprehensive retention

TAPPI Test Method T 269 pm-85 is a procedure for accurately determining retention of various solid components. By using a dynamic drainage jar, first-pass fiber retention, filler, and fines retention can be determined.

2. The effects of filler type and loading level on (A) first-pass retention and first-pass ash retention and (B) sheet formation, brightness, and opacity



3. Cationic polyamine results



Ashing at 400°C for 8 h allows the separation of first-pass fines retention into first-pass pulp fines retention and first-pass filler retention.

This procedure was found to be extremely valuable in providing accurate information regarding wet-end retention. The comprehensive retention method was originally adapted in the mill as a short term test to determine the most accurate and consistent sampling point for paper machine white water on all three paper machines which, in turn, would ensure accurate retention data from the test laboratory.

The method provided data that satisfied this objective and yielded other valuable information such as first-pass and overall filler retention, filler loading throughout the system, and fiber content in the white water. As a result, comprehensive retention tests are now being performed routinely on each paper machine once per week to build a database for future trial work and subsequent optimization of wet-end chemistry.

Summary

Using an advanced microparticle retention system, continuous improvements were made in first-pass retention and first-pass ash retention, while increasing filler loadings and moving toward a filler of finer particle size. Sheet formation was not adversely affected by the retention increase.

Optimization of the wet-end chemistry to get the best balance of retention and formation is facilitated by the use of various analytical techniques including monitoring of zeta potential, colloidal titration ratio, and cationic demand. Routine comprehensive retention analysis provides a complete picture of wet-end chemistry and is an integral part of assessing new wet-end chemicals and strategies. □

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CORRECTION

MacMillan Bloedel builds plant in Minnesota

The cost of the MacMillan Bloedel lumber facility built near Brainerd, Minn., was inadvertently printed as US\$ 5-million on page 28 of the January 1991 *Tappi Journal*. It is actually a US\$75-million lumber facility. *Tappi Journal* regrets any inconvenience due to this error. □