Cationic polyacrylamide as a drainage aid in mechanical pulp

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ABSTRACT: Cationic polyacrylamide as a drainage aid in mechanical pulp shows characteristics not seen in chemical pulp and not experienced with polyethylenimine. These characteristics related to problems experienced during board production in a mill.

KEYWORDS: Acrylamide, cationic compounds, drainage aids, mechanical pulps, polyacrylics, synthetic polymers.

Cationic polyacrylamide (CPAM) has wide use as a drainage aid in the paper industry. As a single polymer system, its traditional role is to improve drainage using a bridging mechanism. Addition is at levels of 0.01–0.05% on fiber after any shear-induced equipment to avoid floc destruction.

A recent modification employs CPAM with modified bentonite. The technique applies the microparticle principle to increase drainage without any negative effects on formation. Addition levels are considerably higher at 0.05–0.2% on fiber. The addition occurs before shear-induced equipment to compact loose flocs.

Although the historical application for CPAM has been in furnishes of chemical pulps, there has been some recent involvement with mechanical pulps. This may seem surprising, since mechanical pulps contain a large amount of dispersed and dissolved anionic materials that can interact with CPAM. Such interaction would seemingly reduce its effectiveness as a drainage aid.

There is presently no information available on combining these two developments. CPAM use does not often entail any control of process variables. Therefore, the aim of this paper is to examine the performance of CPAM in mechanical pulp. It will not try to present a general description. Instead it will focus on three aspects by comparing CPAM with polyethylenimine (PEI). PEI is another widely used drainage aid for both chemical and mechanical pulps.

Experimental

Materials

The samples of both the chemical and the mechanical pulps came from a particular mill's No. 1 board machine at the stuff box. The chemical pulp was a blend of purchased bleached softwood and hardwood pulps. Repulping and refining of the pulp gave it a CSF value of 380 mL. The mill made refiner mechanical pulp from spruce chips. Refining this gave a CSF value of 200 mL. **Table I** presents the characteristics of both pulps.

The pulps underwent dilution with tap water to a consistency of 1.2%. Unless otherwise stated, the pH was constant at 6.0 throughout the experimentation.

The CPAM, modified PEI, and cationic starch (CS) were all commercially available grades. **Table II** gives the cationic charge density of the polymers at pH 5.5. The addition level is the percentage of chemical solids on the total stock solids using the value for the active material from the manufacturer.

Procedures

Drainage. Drainage testing used a modified vacuum unit. During the test, a fiber mat gradually formed on the screen as drainage proceeded under the vacuum. The test stopped before drainage of all water. This minimized the adverse effect of flocculation on vacuum drainage due to formation of large pore structures in the mat. Polymer addition was into the pulp under stirring for 60 s.

Starch adsorption. Adsorption measurement used the iodine method at 580 nm on the spectrophotometer. Polymer addition was again into the pulp under stirring for 60 s.

Water retention value. Water retention value (WRV) involved filtra-

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tion with commercial filter paper, centrifugation at 2500 rpm for 10 min, drying, and measurement for weight loss.

Machine description

The No. 1 board machine produces folding boxboard at approximately 9 tons/h. The machine has five wire stations combining fourdrinier and Inverform wires at its wet end. These form five plies of board on top of one other. The plies consist of a liner, three middle plies, and a back ply. The liner and back ply use purchased chemical pulps. The middle plies use refiner mechanical pulp made on site. The machine broke goes to the middle plies during normal production.

PEI was the original drainage aid for the middle plies. Our experimental work used CPAM and modified bentonite. The addition of CPAM was at the fan pump suction at a level of 0.16% on fiber. Bentonite addition was at the Centriscreen outlet.

I. Pulp characteristics

	Chemical pulp	*Mechanical pulp*
Composition	25% pine 25% birch 50% eucalypt	100% spruce some broke
Rosin size	0.8%	1.0%
Alum	1.4%	1.5%
Clay	8.0%	-

II. Characteristics of cationic polymers

Polymer	*Degree of substitution, %*	*Charge density, meq/g*
CPAM 1	24	0.5
CPAM 2	50	3.4
PEI	-	6.2
CS	-	0.1

Results and discussion

Optimum dosage

There is an optimum dosage for a cationic polymer to improve drainage. Levels outside this dosage give poor performance. A practical method to determine optimum dosage involves laboratory evaluation with a Schopper-Riegler tester, dynamic drainage jar, or vacuum drainage tester followed by machine trial confirmation.

In this work, vacuum drainage tests determined the optimum dosage of CPAM in the chemical and mechanical pulps. There were two sets of conditions that differed in charge density and pH.

Figure 1 shows the variation in drainage with CPAM addition with two different degrees of substitution (DS). **Figure 2** shows the same variation with two different values of pH. The figures indicate that the optimum dosage of CPAM varies with charge density of the polymer and with pH in the mechanical pulp. **Figures 3 and 4** indicate that this is not true for the bleached chemical pulp, however. In the mechanical pulp, the optimum dosage of CPAM is higher for highly charged CPAM and at high pH. Achieving maximum performance in mechanical pulp therefore requires more CPAM, if it has high cationic charge or the application is at high pH.

A typical scenario would involve setting an addition level of CPAM and incorporating it into the mill specifications. There would rarely be any changes. The fact that the optimum dosage varies for mechanical pulp suggests, however, that a specified addition level of CPAM may shift from the optimum range as wet-end conditions change.

Another investigation observed variation of optimum dosage in a study of reed pulp using a Schopper-Riegler tester[1]. Reed is a major raw material used for papermaking in some developing countries such as China. The optimum dosage of CPAM depended strongly on the charge density of the polymer in bleached chemical reed pulp. The optimum dosage was independent of charge density of the polymer in bleached chemical softwood pulp.

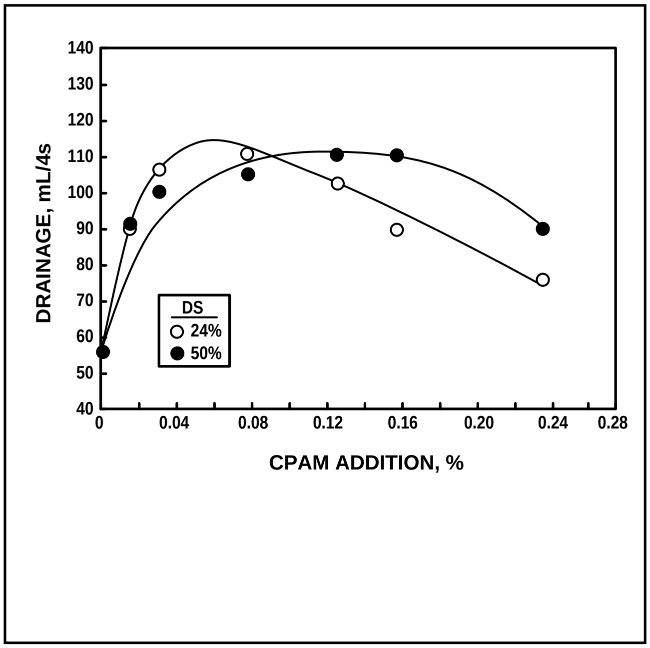
The variation in optimum dosage with charge density in the mechanical pulp and reed pulp relates to the different response of the pulp to the polymer adsorption. The adsorption of the polymer directly affects the optimum dosage of CPAM. When adsorption is low, the polymer cannot produce enough flocculation. When the adsorption is high, the particles in the paper stock repel each other due to high surface coverage by the polymer. Earlier work showed that charge density greatly influences the adsorption of CPAM[2]. Highly charged CPAM adsorbs in a flat configuration on the particle surface and occupies a greater area. Less charged CPAM adsorbs with loops and tails extending into the solution allowing more adsorption to occur.

To summarize, the adsorption and charge density of the polymer jointly govern the optimum dosage of

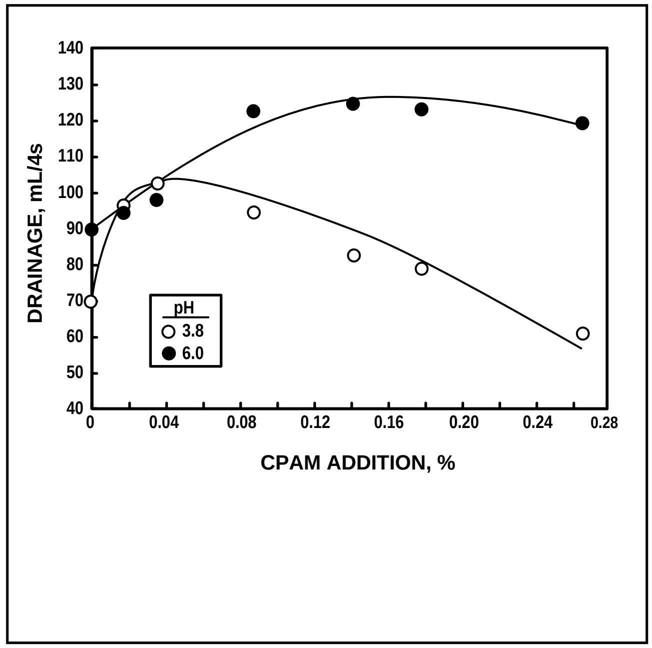
[1]Liu, J., *Tappi J.* 69(2):86(1986).

[2]Lindstrom, T. and Wagberg, L., *Tappi J.* 66(6):83(1983).

1. Drainage of refiner mechanical pulp as a function of CPAM addition for two degrees of substitution



2. Drainage of refiner mechanical pulp as a function of CPAM addition for two values of pH



CPAM. For chemical wood pulp, the increase of charge density will cause a proportional decrease in adsorption with no change in optimum dosage. Any reduction of adsorption is probably not proportional to the change of charge density in mechanical pulp and reed pulp.

Water retention value

The major advantage of CPAM as a drainage aid is its effect on free drainage. Negative particles in the paper stock can readily adsorb CPAM. The high molecular weight of CPAM allows the formation of strong bridging between particles. This bridging results in flocculation of fines that increases the web permeability by reducing the plugging of the web pore structure.

The effect on free drainage is not the only factor that determines the total efficiency of CPAM on the paper machine, however. Web behavior during wet pressing and web drying rate are also important considerations. The amount of water bound in the web affects both.

WRV is the water retained by the wet pulp after undergoing centrifugation. It is a good indication of the content of bound water. Measurement of WRV may bear little correlation to the wet press moisture, however. It will nevertheless provide very useful information on the efficiency of water removal at the dry end. The effect on WRV is also an aspect that one should investigate in the evaluation of a drainage aid.

The WRV of the mechanical pulp varies with CPAM addition. The WRV decreases on the initial addition of CPAM. Further addition causes the WRV to increase to a point that is greater than that of the pulp with no CPAM. **Figures 5 and 6** show that the extent of the WRV reduction at low addition levels, the increase at high addition levels, and the inflection point, depend on charge density and pH.

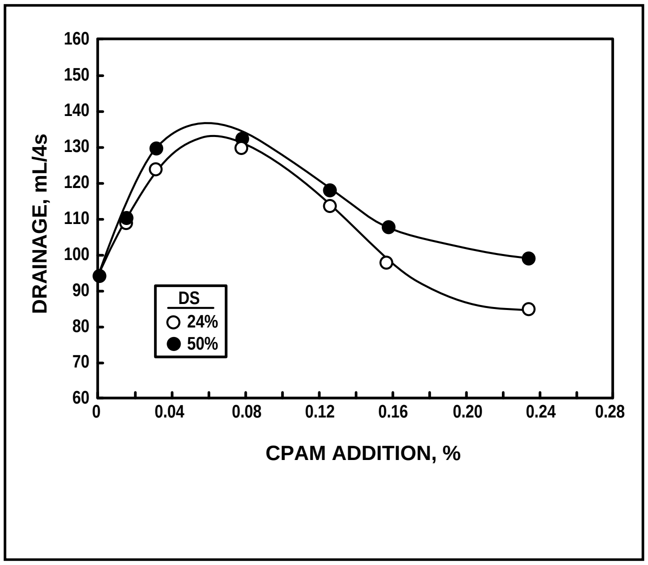
Highly charged CPAM is more effective in reducing WRV. Another investigation[3] suggested that the release of water at low dosage of cationic polymer was due to charge neutralization of the fiber surface region. This causes an aggregation of the fibrils of the internal surface. The result is a deswelling of the fiber. According to this mechanism, high charge density is obviously beneficial.

Similar to its effect on drainage, CPAM exerts a different influence on the WRV for the chemical and mechanical pulps. CPAM can increase the WRV at high addition levels in the mechanical pulp. There is a more pronounced increase of the WRV at low pH. For chemical pulp, however, **Fig. 7** shows that CPAM hardly influences the WRV of the chemical pulp even at low pH.

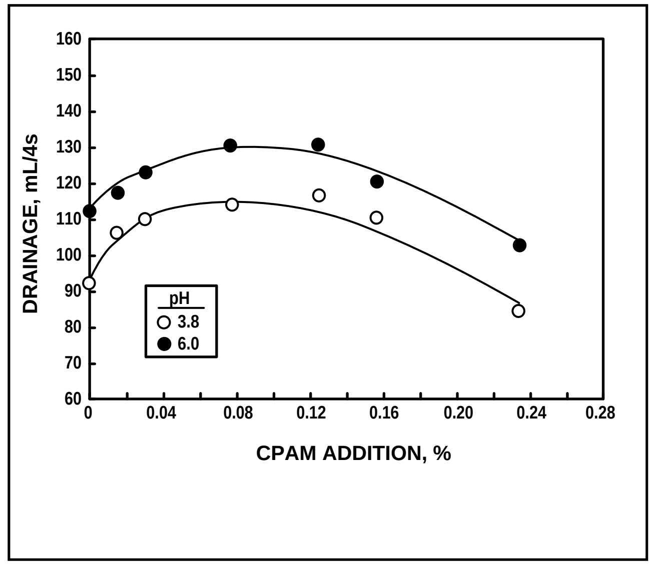
The pH can significantly affect WRV in the presence of CPAM. An accident on No. 1 machine supported this statement. A malfunction of the chalk pump led to introduction of a large amount of calcium carbonate into the stock for the middle plies. This caused the stock pH to increase considerably. With the wet press moisture remaining unchanged, the moisture at the take-up reel fell from 10% to 3.8%. The conclusion was that the board sheet dried easily due to a reduced WRV.

[3]Strom, G. and Kunnas, A., *Nordic Pulp and Paper Research Journal* 3(1):12(1991).

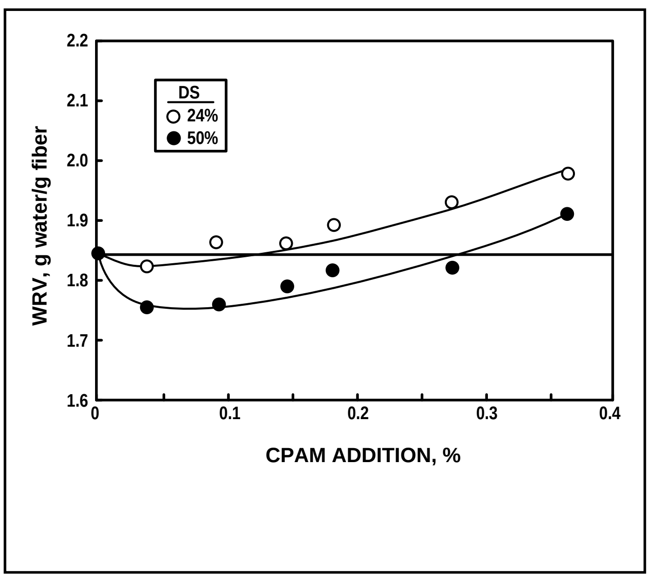
3. Drainage of bleached chemical pulp as a function of CPAM addition for two degrees of substitution



4. Drainage of bleached chemical pulp as a function of CPAM addition for two values of pH



5. WRV of refiner mechanical pulp as a function of CPAM addition for two degrees of substitution



6. WRV of refiner mechanical pulp as a function of CPAM addition for two values of pH

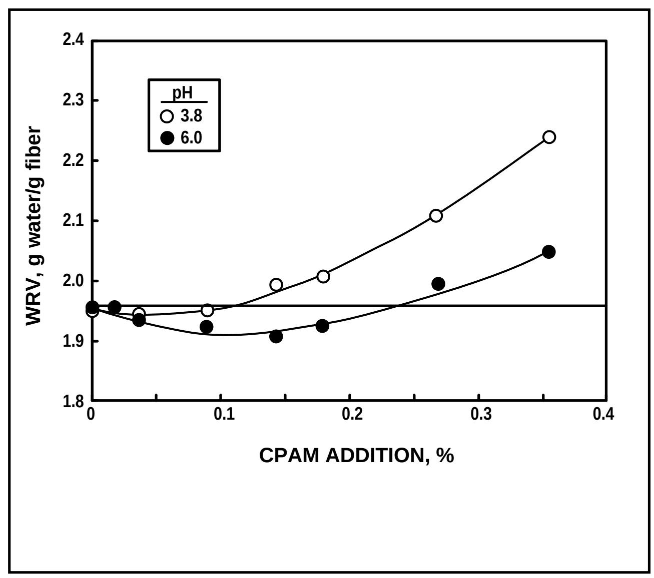


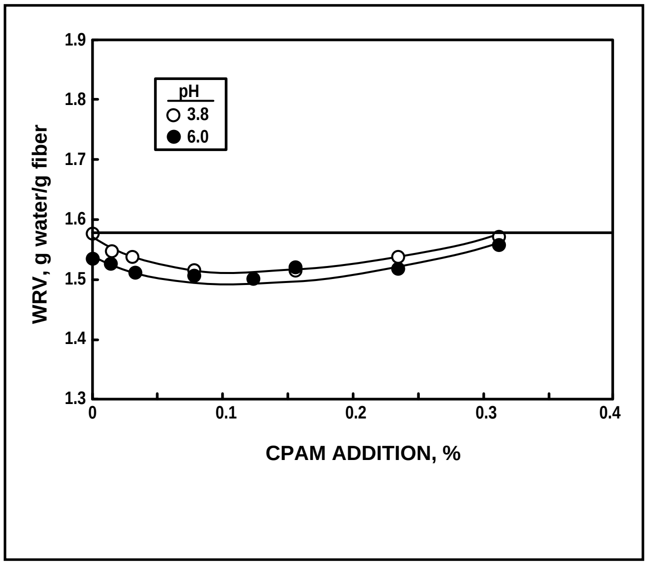
Figure 8 shows that PEI does not increase the WRV of the mechanical pulp. This is due to the mode of action of PEI. Unlike a polyacrylamide polymer, PEI induces flocculation by a patch-charge mechanism. Flocs formed by this mechanism have a compact structure containing less water.

The increase of the WRV at high addition levels of CPAM and at low pH suggests that a web can have a lower drying efficiency under such conditions. This has an important implication for board manufacture where the dryer often limits the machine speed due to the high thickness of the board.

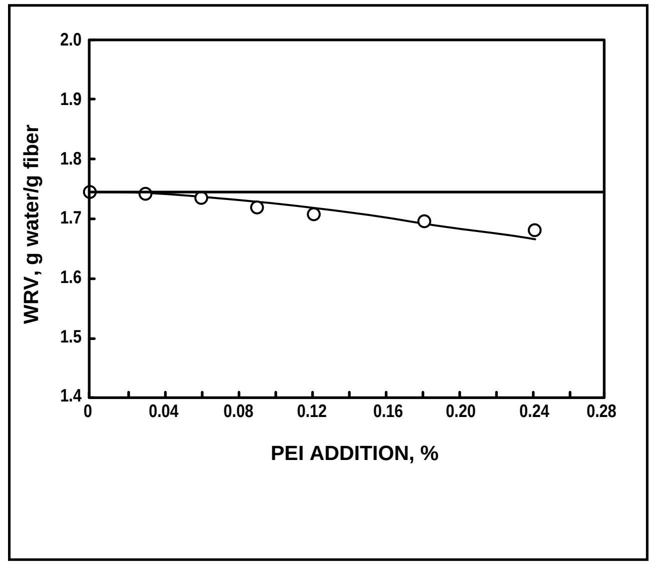
The WRV increase also adversely affects rosin sizing and strength. The interfacial water next to pulp fibers due to the high WRV is an energy barrier. This barrier prevents bonding among fibers, size, and polymers.

For the machine in this work, the CPAM and bentonite system was the drainage aid for the middle plies. The addition level of CPAM was 0.16% on fiber. Laboratory evaluation and machine trials established this level. There was a trial to determine the impact of CPAM reduction on machine production and board qualities. During this trial, the addition level of CPAM was 0.11% and then 0.08%. This reduction slowed drainage at the wet end and caused the wet press moisture to increase by 1.5% and then by 1%. The inter-

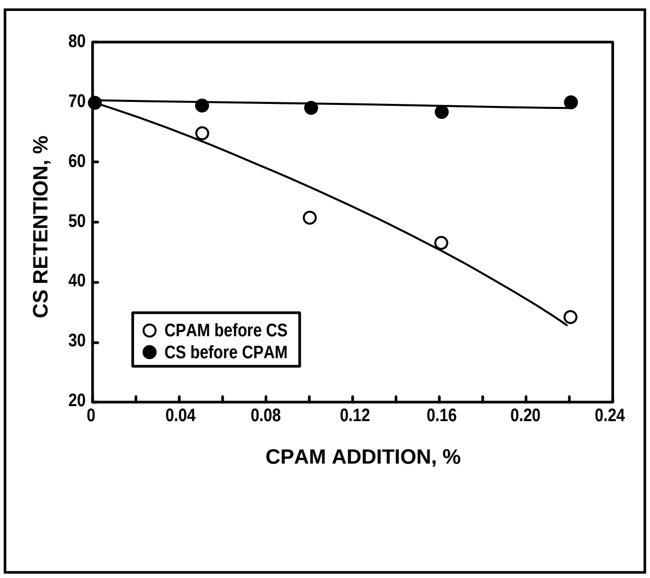
7. WRV of bleached chemical pulp as a function of CPAM addition



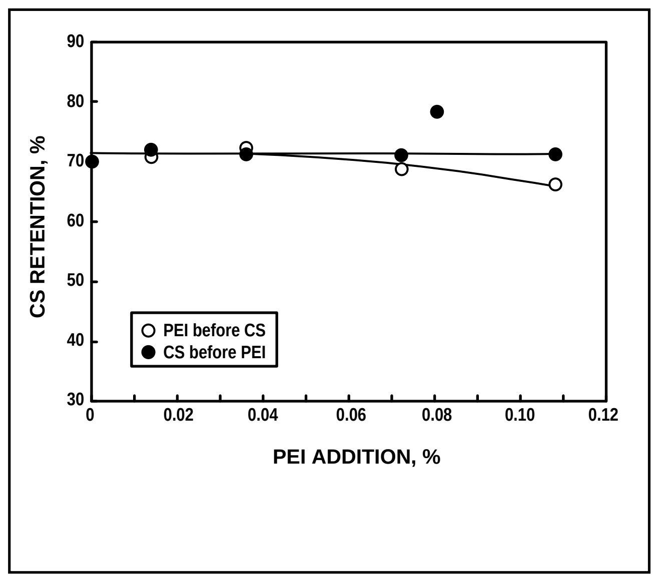
8. WRV of refiner mechanical pulp as a function of PEI addition



9. Effect of CPAM on the retention of CS in refiner mechanical pulp



10. Effect of PEI on the retention of CS in refiner mechanical pulp



nal bond between the second and third middle plies increased by 15% and then 25%. The reduction of CPAM addition improved sizing degree measured by 3-min Cobb test. This allowed a size flow reduction of 10%.

Interference with cationic starch

On many paper machines, the finished sheet strength requires improvement. Adding chemical strength aids either at the wet end or at the size press can accomplish this. CS is a popular wet-end strength aid because of its economical price.

To achieve the expected strength advantages economically, efficient adsorption of starch on furnish components is imperative. High adsorption of starch will also decrease any problems caused by unretained starch.

Figure 9 shows that CPAM could significantly reduce the starch retention provided the addition into the paper stock was before the starch. **Figure 10** indicates there was only a slight effect with PEI. At the 0.16% addition level on the board machine, CPAM gave a reduction in starch adsorption of 24%. The corresponding reduction with 0.06% PEI was only 1.5%.

CPAM or PEI addition before CS can obviously compete with the starch for the available adsorption sites on fibers. One question remains, however. Why does the highly cationic PEI show much less interference with starch adsorption?

On No. 1 machine, the initial attempts to use CPAM and bentonite system to replace PEI as the drainage aid gave unsatisfactory results. One suggestion was that reduced retention of CS added after CPAM for strength development caused this. Unretained starch accumulated in the system during the white water recycling reducing the effectiveness of CPAM in improving drainage. Since moving the starch addition point before the CPAM addition, the CPAM and bentonite system has functioned successfully.

Conclusions

According to laboratory results and mill experience, CPAM is an effective drainage aid in mechanical pulp either singly or with bentonite. CPAM application in mechanical pulp, however, showed characteristics not seen in chemical pulp or with use of PEI. These characteristics related to problems experienced at the mill.

This work led to the following conclusions:

- The optimum dosage of CPAM does not depend on the cationic charge and pH with chemical pulp. It does depend on these factors for mechanical pulp.
- CPAM reduces the WRV at low addition levels. At high addition levels, CPAM can increase the WRV of mechanical pulp. This may reduce the total efficiency of CPAM as a drainage aid. There is no increase in WRV for chemical pulp and with PEI.
- CPAM reduces the adsorption of CS, if it is added before the starch. PEI does so only slightly.

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