Retention of precipitated calcium carbonate in old corrugated container furnishes

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ABSTRACT

Filler does not have traditional use in linerboard manufacture. Recent research and mill experience show that moderate use of filler in linerboard can be beneficial. Addition of precipitated calcium carbonate (PCC) filler in recycled old corrugated container (OCC) furnish will improve appearance and printability and save fiber materials without noticeable sacrifice of strength. Stickies and wax will be less problematical when using PCC in OCC. This work studied PCC retention and fines retention in three different OCC furnishes. Different retention systems investigated included cationic polyacrylamide, anionic polyacrylamide, microparticle, and nonionic poly(ethylene oxide) plus phenol/formaldehyde resin. Results showed that the latter is the most effective retention system.

Application:

Nonionic poly(ethylene oxide) plus phenol/formaldehyde resin is an effective retention system for PCC and fines in OCC.

USE OF RECYCLED FIBERS HAS increased dramatically in recent years. With current environmental awareness and legislation, this trend should continue. Among all the paper grades recycled, old corrugated container (OCC) is the largest secondary fiber source. The U.S. paper industry reused 20.1 million tons of OCC in 1997 (1). Besides the common difficulties faced in the recycling industry, such as the high operating costs, low fiber yield, and poor physical properties, residual stickies and wax in the recycled furnish are also serious problems with use of OCC. In the United States, the estimate of wax in corrugated board is an average of 0.7%. After recycling, the average wax content in recycled OCC is still as high as 0.05%–0.15% (2). Such residual contamination will significantly affect the wet-end operation in manufacture of container board. Because fillers have a high specific surface area, they can often act as a control material for stickies to clean the wet end by adsorbing interfering substances or adhering to the particle surfaces of stickies to reduce their tack.

Additions of fillers to a furnish have a long history in the paper industry. With transition of the papermaking process from acidic to neutral or alkaline, precipitated calcium carbonate (PCC) as a filler has received increasing attention in recent years. Most recently, PCC has had a very successful introduction into recycled container board as a fiber extender *(3)*. No significant reduction in paper strength occurs when PCC content in paperboard is less than approximately 5% by weight *(3)*. Although preliminary results showed many advantages when using PCC in recycled OCC, the retention of PCC in this type of furnish has never been studied.

Besides the stickies and wax mentioned above, additives originally present in OCC such as retention aids, strength aids, and sizing agents may potentially carry over into the recycled furnishes. Chemicals used in repulping, dispersion, and deinking and some foreign contaminants may also be present. These components generally exist as "anionic trash" and will significantly influence the wet end chemistry of papermaking and especially the first pass retention *(4)*. An investigation on PCC and fines retention in OCC is therefore a topic of interest for papermakers. It is the main focus of this research.

MATERIALS

The experiments used three OCC furnishes. Two furnishes came from liner board mills in Georgia. Furnish from mill 1 is 100% recycled OCC without additional refining. Furnish from mill 2 contains 70% OCC and 30% mixed office waste (MOW) without additional refining. A third furnish resulted from repulping the preconsumer container board purchased from a commercial moving service. The container board was soaked overnight in water and disintegrated in a pulper at 9% consistency at neutral pH. All the furnishes were diluted to a 0.5% consistency with subsequent pH adjustment to 8 before the retention experiments. **Table I** lists some physical properties of the furnishes.

Table II gives information about retention aids in this study. Cationic polyacrylamide (CPAM) 1, CPAM 2, anionic polyacrylamide (APAM) 1, silica, and coagulant were from chemical company 1. CPAM 3, APAM 2, and bentonite were from chemical company 2. Nonionic poly(ethylene oxide) (PEO) came from a laboratory supply company in powder form. Water soluble phenol/formaldehyde resin (PFR) came from chemical company 3 with a solids content of 46%.

Furnish source	Mill 1	Mill 2	Board
CSF, mL	580	400	675
Fines content, %	13.9	22.1	13.9
Original pH	7.2	7.0	6.6
Charge density of filtrate passing 200-mesh screen*, µeq/L	–77.6	–130	–68.9
Charge density of filtrate passing filter paper*,µm	-17.6	-34.6	-18.4

*Filtrates are from 0.5% pulp suspension

I. Physical properties of recycled OCC furnishes

Symbol	Chemical composition	Molecular weight	Charge density
CPAM 1	Cationic polyacrylamide	Very high	Low
CPAM 2	Cationic polyacrylamide	Very high	Low
CPAM 3	Cationic polyacrylamide	High	Low
APAM 1	Anionic polyacrylamide	Very high	Low
APAM 2	Anionic polyacrylamide	Medium	Low
Bentonite	Anionic bentonite	-	-
Silica	Anionic silica sol	-	-
PEO	Poly(ethylene oxide)	8 x 106	-
PFR	Phenol/ formaldehyde resin	13,000	-
Coagulant	Cationic polyamine	Low	High

II. Chemicals used for retention

PCC was a commercially available scalenohedral calcite filler product with an average particle size of 1.3 µm and specific surface area of 12 m^2/g. Amphoteric starch for dry strength was a commercially available material. Alkyl ketene dimer (AKD) emulsion for sizing came from mill 2.

EXPERIMENTAL

Pulp furnish was first diluted to a consistency of 0.5% and adjusted to a pH of approximately 8 with NaOH solution. The prepared furnish (500 mL) was poured into a dynamic drainage jar (DDJ) and stirred at 1000 rpm. A 200-mesh wire for DDJ was used unless otherwise noted. Next, 5% PCC (based on dry fiber weight) was added. After stirring for 30 s, retention aids were added. For dual-component retention systems, different addition sequences were used as given in the figure legends. A fixed ratio of polymer to microparticle of 1:5 was used for the microparticle retention system. For the PFR and (PEO) system, a fixed PEO/PFR ratio of 2:1 was used. Dry strength starch at the dose of 10 lb/ton and AKD sizing agent at the dose of 8 lb/ton were used only for the furnish from mill 2 to achieve an environment closer to the mill situation. When starch and AKD sizing were used, the addition sequence of the additives was PCC, starch, retention aid(s), and AKD. The first 150 mL filtrate from DDJ was collected 15 s after the retention aid(s) was added. PCC and fines retention were measured. The calcium concentration was analyzed by potential titration using ethylenediaminetetraacetic acid tetrasodium salt (EDTA) as a titrate. The end point of the titration was measured using a voltmeter equipped with a calcium-selective electrode and a glass pH reference electrode. The drainage rate test followed the same procedures as the retention test but the stirring stopped before filtrate collection. Drainage rate was expressed as the amount of filtrate collected in the first 25 s. Zeta potential was measured using a commercially available instrument.

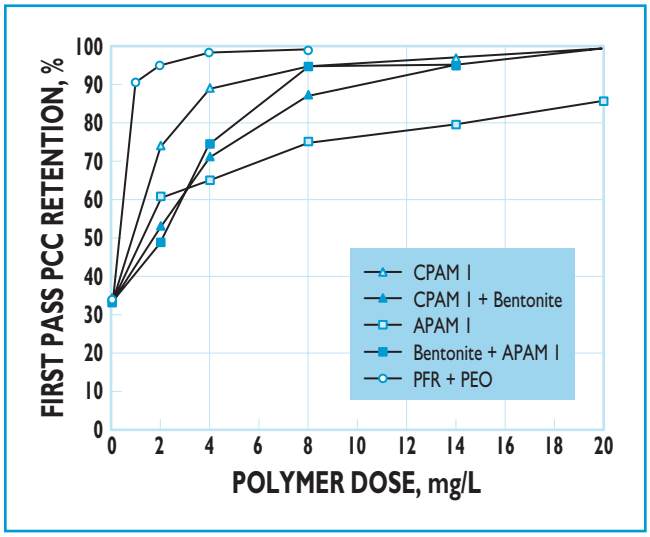
RESULTS AND DISCUSSION

OCC from mill 1

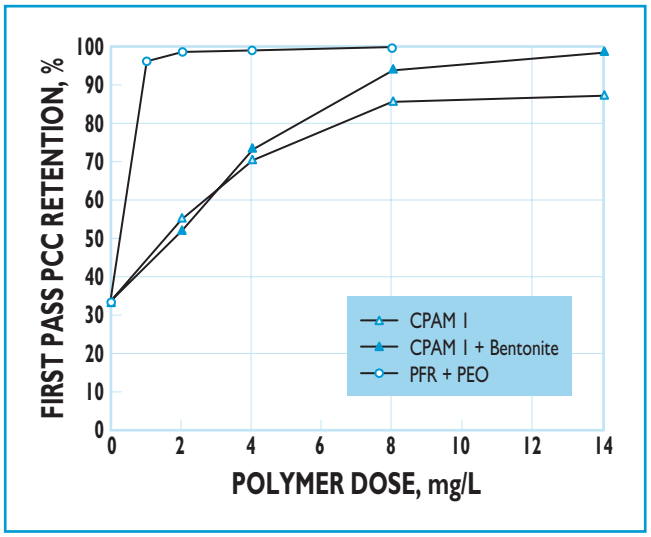
Figure 1 shows the effect of different retention aids on the first pass retention of PCC in OCC from mill 1. The best retention results occurred with the PEO/PFR system. This is especially true at low polymer addition levels. One ppm PEO that is equivalent to 0.4 lb/ton gave a 90% first-pass retention of PCC. High retention was also possible with cationic PAM and a combination of CPAM and bentonite. A higher polymer dosage was necessary. The microparticle retention system of cationic PAM plus bentonite did not work well for this furnish. At lower dosages, the retention results from this microparticle system are even poorer than that from the single cationic polymer. The least effective retention system is the single anionic PAM. This agrees with previously published results *(5)*. The addition of bentonite after anionic PAM improved the retention remarkably.

Although the mechanism of improved filler retention using a combination of these two negative systems is not clear, one possible explanation is the formation of microparticle bridging. To form such bridging, the APAM first adsorbs onto fiber and fines surfaces due to van der Waals forces to form negative parches. When bentonite was added, the bentonite microparticles bridged the fibers and fillers through adsorbed APAM molecules. Two types of forces may contribute to the interaction between negatively charged bentonite microparticles and APAM molecules. These are the van der Waals force and hydrogen bonding between the acrylamide groups on PAM and the aluminol groups on bentonite.

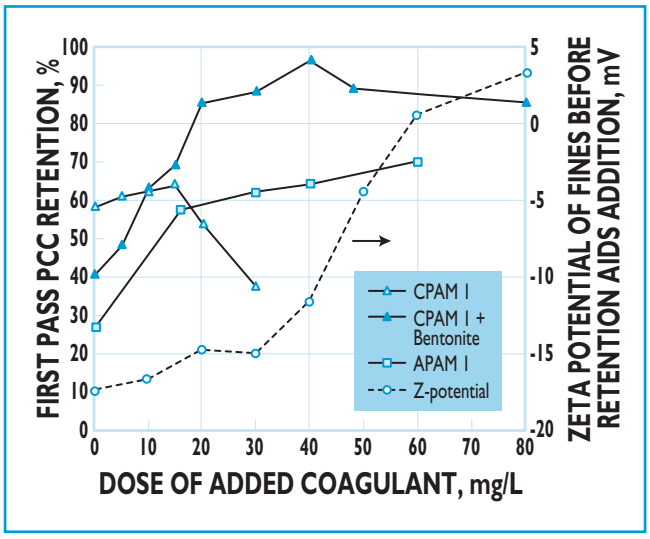
The anionic trash in the furnish could be the major reason for the poor performance of the CPAM and its combination with bentonite. To study the effect of anionic trash on the performance of CPAM, the soluble anionic trash was removed by washing the furnish thor-



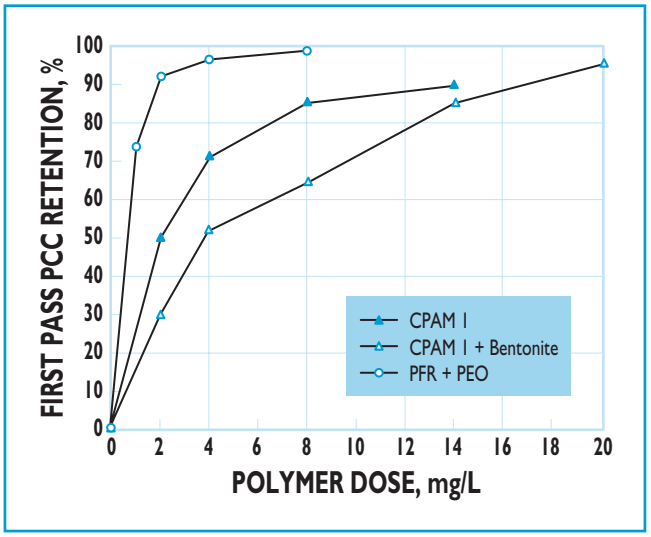
1. PCC retention for OCC from Mill 1



2. PCC retention for washed OCC from Mill 1



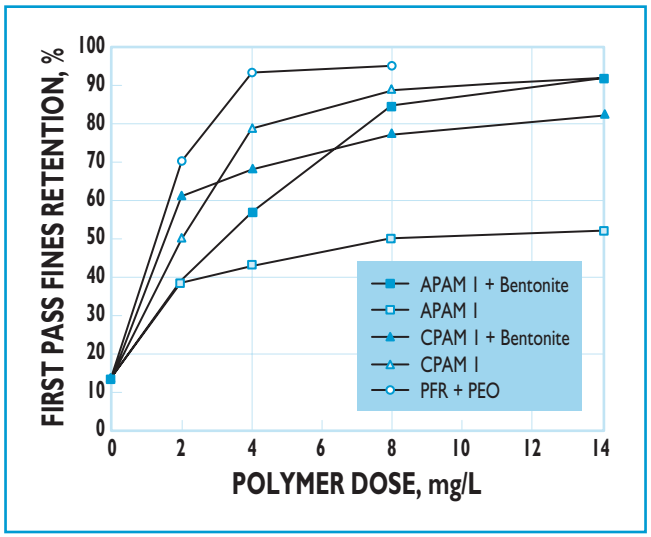
3. Effect of coagulant addition on the retention of PCC at a constant 1 mg/L retention polymer addition



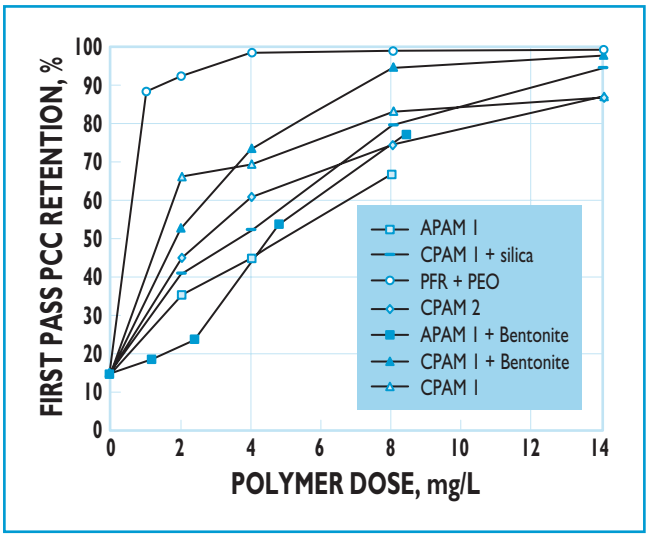
4. PCC retention for OCC from Mill 1 using 100-mesh wire

oughly with water and filtering using a filter paper until the charge density of the filtrate reached zero. The fines content of the washed pulp was 10.42%—lower than that of the unwashed pulp. The charge density of the filtrates from a 0.5% washed pulp furnish passing the DDJ changed from –77.6 µeq/L to –40 µeq/L. **Figure 2** shows the PCC retention for the washed pulp. In these washed pulp furnishes, the retention induced by the cationic flocculent and microparticle system was still much lower than those induced by the PEO/PFR at lower addition levels. Comparing with the results from the unwashed furnish, no increase in the retention efficiency of cationic PAM and microparticle retention system was found. The anionic trash in the furnish is probably not the major reason for the poorer performance of the CPAM and the microparticle system in these particular finishes.

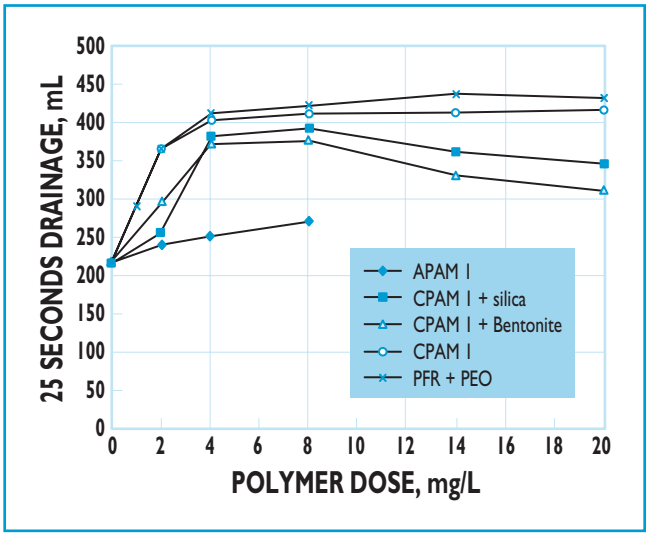
To test this phenomenon further, cationic coagulant was added to neutralize the anionic trash in the unwashed pulp before the addition of 1 ppm cationic PAM (1 ppm CPAM + 5 ppm bentonite for the microparticle system). For the single cationic PAM, **Fig. 3** shows that the coagulant addition has only a slight positive effect on the retention at low addition levels. It has a negative effect at



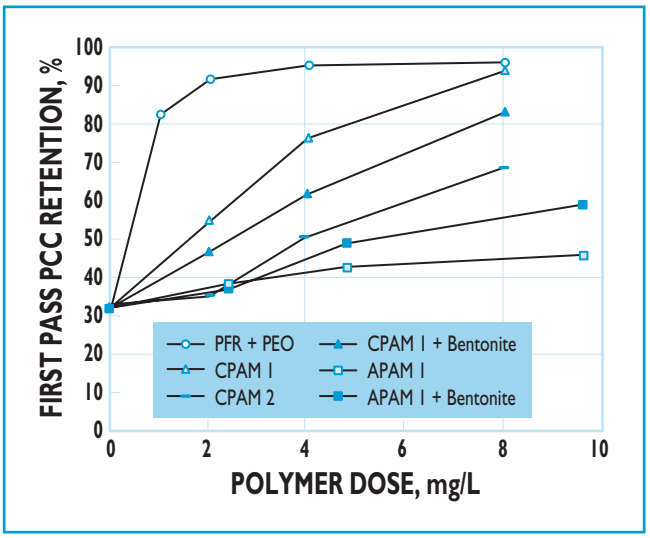
5. Fines retention for OCC from Mill 1



6. PCC retention for OCC from Mill 2



7. Effect of retention aids addition on the drainage rate



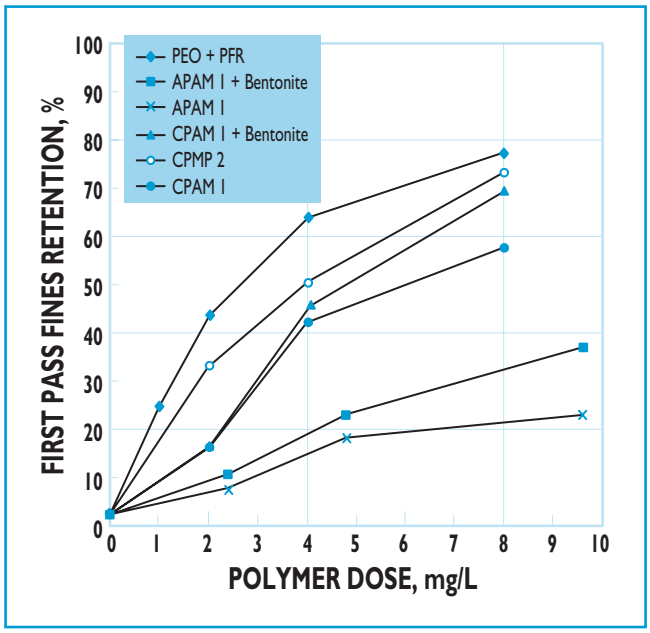
8. PCC retention for OCC repulped in the laboratory

higher addition levels. The reason is obviously that certain anionic charges on the PCC and fines are necessary for the cationic PAM to function effectively. The effect of coagulant addition on the microparticle system is significant. PCC retention increased with increasing coagulant addition to a high coagulant level (40 ppm). This result suggested that the microparticle system needs more coagulant to achieve the best result than the single cationic flocculant does.

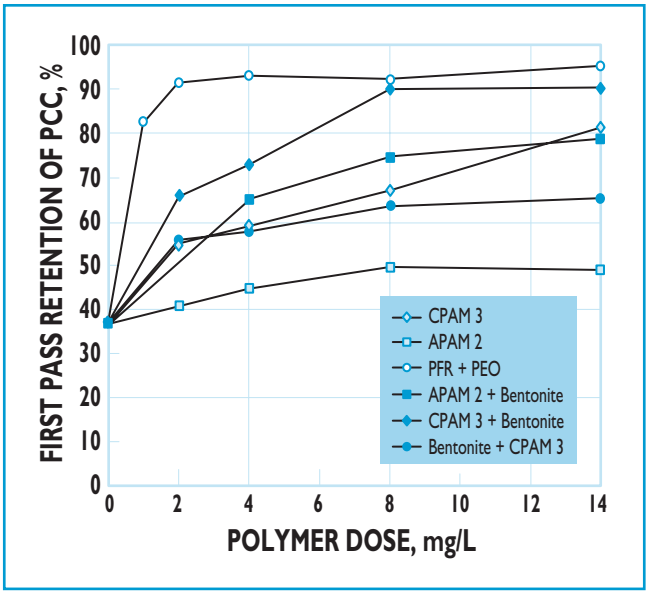
Figure 3 also gives the zeta potential of the DDJ filtrate as a function of coagulant concentration before retention aid addition. At the coagulant addition level where the best retention occurred, the particles in the system were still negatively charged. Combining with the results from the washed pulp, the negatively charged anionic trash in the system seems to have a complicted effect on the retention efficiency of the microparticle system. It has a smaller effect when using a single CPAM. This prompted additional study of the retention mechanism of the microparticle system.

Although the addition of coagulant improved the PCC retention when using a CPAM and microparticle system, high retention was not possible even at high coagulant addition levels. The coagulant addition also has a positive effect on retention when using a negatively charged APAM.

The PCC retention obtained from DDJ with a 200-mesh wire (76 µm) is



9. Fines retention for OCC repulped in the laboratory



10. PCC retention for OCC repulped in the laboratory

much higher compared with an actual paper mill situation. Because of these high retention values, the minor difference among the efficiency of different retention systems may be masked and become insignificant. To investigate if the wire pore size of the DDJ would influence the relative efficiency of different retention systems, a 100-mesh (150 µm) wire was used to repeat some experiments. **Figure 4** shows the results. Although the absolute PCC retention values from 100-mesh wire are lower than those from 200-mesh wire, the general trends agree with each other. The PCC retention results from the PEO/PFR system are still much higher than those from single cationic PAM and its combination with bentonite.

Figure 5 shows the fines retention from different retention systems using 200-mesh wire. Similar to the situation of PCC retention, the best fines retention occurred with the PEO/PFR system. Poorest retention was with the single anionic PAM.

OCC from mill 2

Figure 6 shows the PCC retention results for the recycled furnish from mill 2. Similar to the results obtained from the furnish of mill 1, the PEO/PFR system induced the best retention. Anionic PAM gave the poorest result. The retention efficiency of CPAM 1 is near that of the microparticle system of CPAM 1 plus bentonite. A combination of cationic PAM 1 plus anionic silica microparticle is less effective than a cationic PAM 1 and bentonite combination. Besides the smaller particle size of a silica compared with bentonite, the higher anionic charge of silica particles may not be desirable for this application. The retention induced by CPAM 2 is much lower than that induced by CPAM 1. According to the vendors, both CPAM 1 and CPAM 2 have very high molecular weight and low charge density. The colloidal titration showed that the charge density of CPAM 2 is higher than that of CPAM 1. Cationic PAM should flocculate anionically charged particles through a bridging mechanism. If the charge density of the CPAM is too high, adsorbed polymer molecules will adopt a flat configuration with short loops and tails that may be too short to catch other particles. The flocculation efficiency will therefore be lower.

Figure 7 shows the effect of different retention aids on the drainage rate. PEO/PFR, CPAM, and the microparticle system gave a significant improvement in drainage rates, but the effect of APAM on drainage rate was minor.

OCC repulped in the laboratory

Preconsumer corrugated container board was repulped in the laboratory, and the PCC and fines retention for this furnish was investigated. **Figures 8 and 9** gives the results, respectively. For both PCC and fines retention, the efficiency of different retention systems is similar to that discussed above for the OCC furnishes from two paper mills. Two other polyacrylamides, CPAM 3 and APAM 2, were also tested for this furnish. Figure 10 shows that PEO/PFR is still much more effective than other retention systems. An advantage of cationic PAM plus bentonite over single CPAM system was noticed. The addition order of cationic PAM and bentonite had a remarkable effect on the retention efficiency. If the bentonite was added first, the retention was even less than the single CPAM system.

CONCLUSIONS

For the OCC furnishes used in this study, nonionic PEO/PFR is the most effective retention system for both PCC and fines retentions. Very high retention is possible with only a moderate amount of PEO addition. Retention results from the traditional microparticle system—cationic polymer and anionic microparticle—varies depending on the polymer and microparticle used and the order of chemical addition. No definite advantage of the microparticle system over the single cationic flocculant occurred. Removal of the soluble anionic trash in the furnish did not improve the performance of the cationic flocculant and microparticle system. Preaddition of highly charged cationic coagulant did enhance the retention efficiency of the microparticle system significantly to a level comparable with that of PEO/PFR. **TJ**

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LITERATURE CITED

1. McEntee, K., *Prog. Paper Recycling* 7(3):8(1998).
2. Back, E. L., *Tappi J.* 78(7):161(1995).
3. Haller, T. M., *TAPPI 1997 TAPPI Joint Engineering/Papermakers Super Conference Proceedings*, TAPPI PRESS, Atlanta, p. 191.
4. Yeager, R. L., *PIMA Magazine* 78(3):8(1996).
5. Krogerus, B., *TAPPI 1994 Papermakers Conference Proceedings*, TAPPI PRESS, Atlanta, p. 445