# Controlling filler retention in mechanical grades

## There was significant improvement in retention with no effect on sheet qualities

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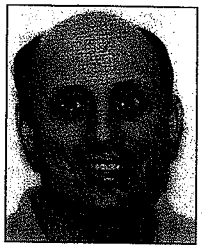

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THE MAIN TRENDS in production of mechanical grades of paper are: increased filler contents; higher brightness; lower basis weight; increased content of recycled pulp; and, the introduction of calcium carbonate as a filler with the necessary move to neutral pH conditions. Increased filler content increases the importance of a well-functioning and well-controlled retention program.

Chemically assisted retention, contrary to mechanical filtration, allows fillers to be incorporated in a way that reduces two-sidedness, dusting and other surface problems. In the absence of alum, retention programs consist mainly of polymeric retention aids. These polymeric materials provide agglomeration of furnish elements through one of the three basic mechanisms — coagulation or charge neutralization, patch formation, and bridging flocculation.

Molecular weight and charge density of a retention polymer are the two most important factors affecting the mechanisms of their action. Low molecular weight and high charge cationic polymers called coagulants operate mainly through the charge neutralization and/or patch formation mechanism. The principal mode of action of high molecular weight polymers (flocculants) is bridging flocculation.

Development of new retention programs includes: selection of the appropriate retention polymers; sequencing of their addition; and, determination of feeding points to achieve the most advantageous contribution from the three basic mechanisms. Optimizing feeding points permits targeting a specific fraction of furnish, based on its relative concentration. Feeding retention aids, starch and high molecular weight flocculants to the filler is one of the possible feeding strategies [1,2]. Little if any on-machine information exists about such applications, especially for low molecular weight polymers (coagulants).

The flocculation of papermaking furnish can have a decided impact on retention, drainage and formation of the produced paper. The response of any given system to application of retention polymers will depend on the characteristics of the furnish and the effectiveness of the retention polymers. Even for one particular paper machine, both these factors may change quite quickly and cause an abrupt change to the operation of the paper machine with a consequent loss of runnability and paper quality.

Some important factors affecting operation of the wet end of paper machine are:

- pulp type;
- fibre length distribution;
- bleaching process;
- fines and filler content;
- pH;
- conductivity; and
- anionic trash level.

On the microscale, the most important sources of variability in the wet-end are:

- the magnitude of colloidal repulsive forces that have to be overcome ($\zeta$-potential);
- surface area and surface properties of the furnish elements;
- chemical factors, possible side reactions of retention polymer and its conformation in solution. These chemical factors and their impact are discussed in the following two paragraphs.

The degree of variability can be much higher in the production of mechanical grades of paper than in fine paper applications. Bleaching with no washing, along with varying dosages of brightening chemicals, cause pronounced changes to the chemical environment of the wet-end of the paper machine. For example, on one machine, changes in cationic demand from 400 µEq/L to 1500 µEq/L were observed. In particular, hydrogen peroxide bleaching due to its oxidative character and high pH, is known to generate high levels of anionic, colloidal and soluble, materials that significantly affect the wet-end of the paper machine. The nature of the materials generated during the hydrogen peroxide bleaching of mechanical pulps has been discussed extensively in the literature. Early papers attributed increased levels of anionic trash in peroxide bleached pulps to the presence of various oligomeric forms of silicates [3-5]. Recent work by Thornton, however, suggests that at least 50% of these anionic substances are organic products of oxidation of wood components [6-7]. Whether their nature is organic or inorganic, the anionic and polymeric characters of these substances make them reactive toward retention polymers. These reactions reduce the effectiveness of polymers and generate a variety of products whose properties and effect on paper machine operation depends on charge, molecular weight and the degree of crosslinking of both the retention polymer and the anionic trash component.

Changes of pH observed for any bleaching technology will result in varied degrees of ionization of substances that contain an acidic function having a pKa value close to the pH of the machine operation. Carboxylic groups (–COOH) have a pKa close to the pH of so-called acid paper machines (pH = 4 to 6). Variations in pH cause significant changes to the total amount of anionic charge present in

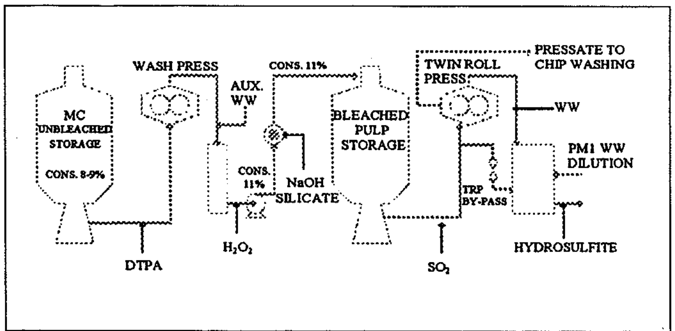


FIG. 1. Process flow of bleaching plant at Irving Paper, Saint John, NB.

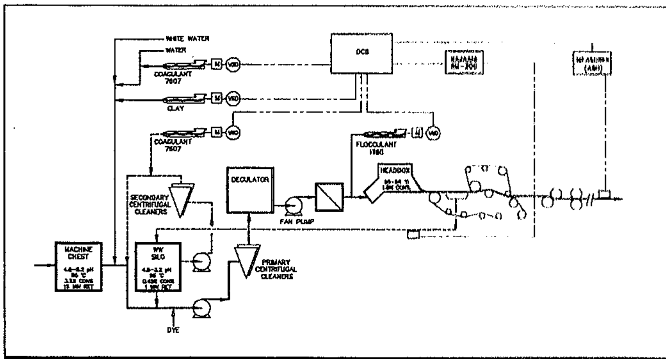


FIG. 2. Flowchart, PM 1. Irving Paper.

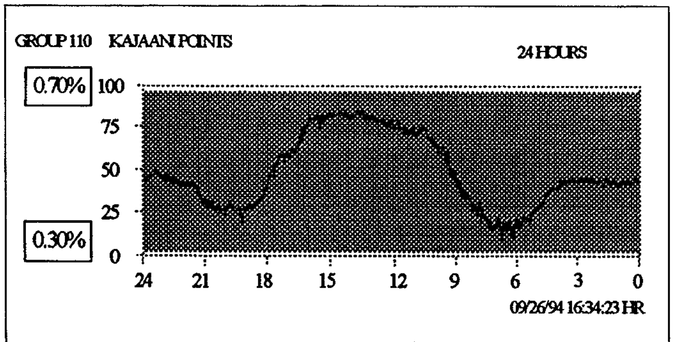


FIG. 3. The variation in white-water consistency before installation of on-line control.

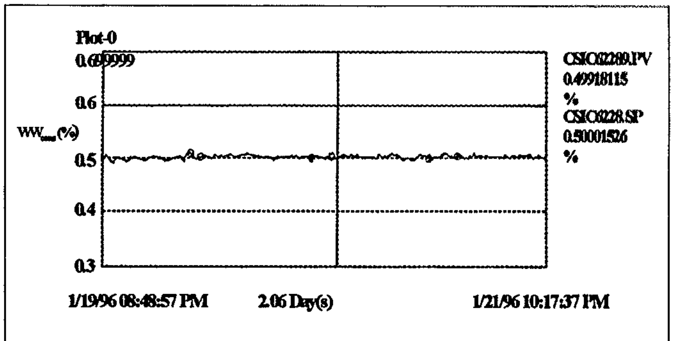


FIG. 4. White-water consistency after on-line control was implemented.

TABLE I. Effect of twin roll press operation on pulp quality and retention efficiency.

| | Twin roll press – ON | Twin roll press – OFF |
|---|---|---|
| COD (ppm $O_2$) | 1500-2000 | 3500-4000 |
| Cationic demand (µEq/L) | 1200-1700 | 2500-2700 |
| Conductivity (mS/cm) | 0.7 | 1.9 |
| Relative retention costs | 60% | 100% |

the system. Changes in pH may also affect the amount of cationic charge of some unquarternized cationic polymers.

Conductivity, being a measure of concentration and mobility of ionic species in solution, can also vary significantly. An increased salt content results in suppression of the double layer of the colloidal materials and leads to agglomeration. On the other hand, increased conductivity will also change the conformation of polymeric retention aids and reduce their effective length in the solution. This effect will obviously reduce the effectiveness of polymers acting through the bridging mechanism. Changing content of ions may also have an effect on the surface properties of particles and affect (increase or decrease) adsorption of the polymer. In general, changes in salts concentration are one of the sources of instability in paper machine retention and drainage [8-12].

This paper presents the work done at Irving Paper to optimize the filler retention:

- reduction and stabilization of cationic demand;
- on-line control and monitoring of the retention program; and
- application for pre-treatment of filler with a coagulant and its impact on retention and sheet quality.

## RESULTS

**Peroxide bleaching:** Figure 1 presents the schematic diagram of the bleaching plant in Irving Paper. The TMP can be bleached with hydrogen peroxide, sodium hydrosulphite, or a combination of both. An important element of the design includes the use of a twin roll press to create a barrier reducing the influx of anionic materials to the paper machine system. Our earlier surveys performed in mills that use hydrogen peroxide bleaching showed that the cationic demand of the filtrate (Millipore 0.45 µm) from a pulp sample represents up to 90% of its total cationic demand. Therefore, separating the pressate from the thick pulp should result in significantly less contamination on the paper machine. This is clearly demonstrated in Table I, which compares pulp COD, cationic demand (CD) and the relative costs of retention with the twin roll press in operation and without it. Retention costs are estimated based on the flow of chemicals required to achieve the same bottom tray white-water consistency.

**Paper machine operation:** PM 1 at Irving Paper produces soft-calendered, filled grades of paper. The first pass retention and sheet ash control strategies in this mill are based on the measurement of the white-water consistency with a Kajaani RM200 in the wet-end and Measurex ash sensor at the dry end, Fig. 2. The main objectives of these control strategies are to minimize variations in the paper machine wet-end conditions and to stabilize sheet ash levels. With this in mind, the mill has also done a significant amount of work addressing the thick stock composition and consistency control. We will not discuss this work in this paper, but would like to stress the importance of this area in an overall effort to stabilize the paper machine operations.

**Retention system:** The mill uses a dual polymer program based on a low molecular weight, high charge cationic polymer (coagulant) and a high molecular weight, cationic polymer (flocculant). Significant improvements were made between mill and supplier in the polymer makedown and delivery systems to ensure the elimination of upsets due to variability in the concentration or feed rates of the polymers. We will not discuss this in detail, but would like to emphasize the importance of such things as proper filtration of flocculant solution, good quality make-down and dilution water, constant flow of dilution water, etc. The

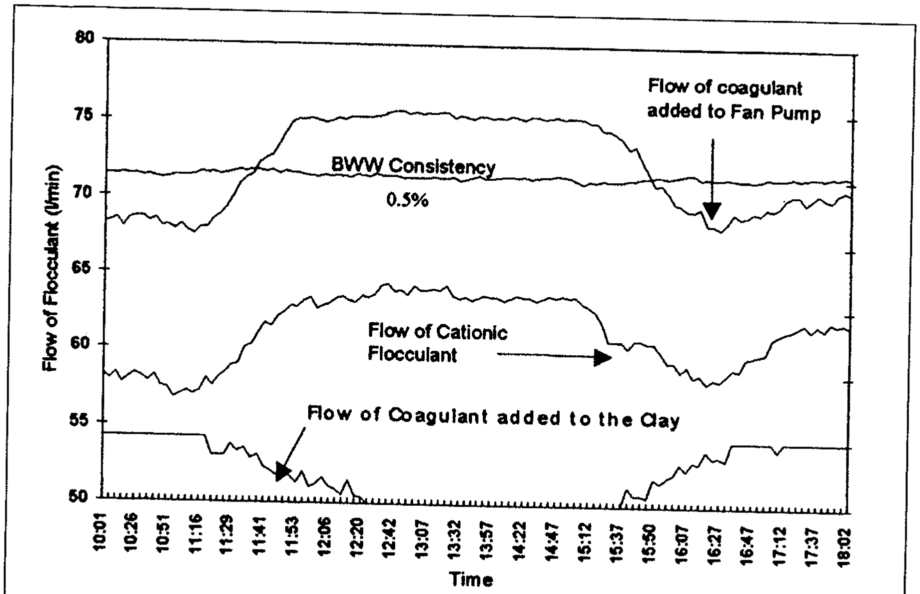


FIG. 5. The effect of clay precoagulation.

feed points of both polymers, Fig. 2, are typical for a dual polymer program. The coagulant is applied to the suction side of the primary fan pump and the flocculant to the headbox pipe after the pressure screens.

**On-line retention control:** The control of the retention program is based on the strategy of keeping a stable target bottom wire white-water consistency. Figure 3 shows the variation in the white-water consistency observed before application of an on-line control strategy.

An earlier trial with an on-line charge demand titrator (Mutek PCT10) showed that an increase in cationic demand and a coinciding increase in conductivity was a primary trigger of lower retention periods. Therefore, the strategy of controlling the bottom wire white-water consistency is based on changing the flow of both polymers, flocculant and coagulant. This approach proves to be more effective and safer to formation than a response based on changing the flow of flocculant only. The ratio of coagulant to flocculant is increased with higher flocculant dosages responding to the increased necessity for charge neutralization.

Figure 4 shows the typical bottom wire white-water consistency after the on-line control was introduced. This degree of stability is possible despite changes in basis weight, sheet filler level and broke content.

**Precoagulation of filler trial:** The paper machine system diagram, Fig. 2, shows an additional feed point for the coagulant — the dilution water for the delaminated clay. This application of coagulant, clay precoagulation, allows for preferential treatment of the surface of clay particles leading to increased retention levels. The precoagulation of the clay results in some destabilization of the clay slurry and an increase in particle size. Both effects have to be kept in mind if such application is considered. Overdosing coagulant at this point may fully destabilize the slurry and cause feeding problems.

On PM 1, the typical dose of coagulant to the dilution water of delaminated clay is about 2 kilograms per tonne (kg/t) based on clay solids. To evaluate the effect of clay pre-treatment with coagulant on the retention and sheet quality, a one-day trial was performed on PM 1.

**Trial protocol and data collected:** The trial started with 2 kg of coagulant per tonne of clay added to the dilution water of delaminated clay. The bottom tray white-water consistency was operated on control with a consistency setpoint of 0.5%. After a stabilization period, the coagulant was removed from the filler dilution water. The effect on retention was monitored in terms of change of flow of retention polymers required to keep the white-water consistency at 0.5%. At the end of the trial, the flow of coagulant to the filler was restored.

Throughout the duration of the trial, the sheet properties were closely monitored by collecting quality lab data - brightness, opacity, tensile, tear and NUI. Additionally, MK Systems measured the formation of the sheet samples using the MK formation tester.

Samples of headbox stock and white-water were collected to measure consistencies, first pass retention (FPR), first pass ash retention (FPAR) and water chemistry data — pH, cationic demand and conductivity. The distribution of filler in the sheet was measured using scanning electron microscopy. The degree of two-sidedness

TABLE II. Sheet properties, retention and cationic demand during the pre-coagulation trial (shaded background represents period with no precoagulation of filler).

| Time | Brightness % | Opacity % | NUI | MK form index | Cationic demand White-water µEq/L | Cationic demand Headbox Neg/2 | FPR % | FPAR % |
|---|---|---|---|---|---|---|---|---|
| 10:31 | 64.8 | 94.2 | 10 | 10.9 | | | | |
| 10:41 | | | | | 637 | 388 | | |
| 11:01 | | | | | 663 | 385 | 50.1 | 23.8 |
| 11:21 | 64.9 | 94.1 | 10 | 11.2 | | | | |
| 12:22 | 64.5 | 93.7 | 11 | 10.9 | | | | |
| 13:17 | 64.3 | 94.4 | 9 | 10.5 | | | | |
| 14:12 | 64.4 | 94 | 8 | 10.9 | | | | |
| 14:27 | | | | 10.9 | 637 | 379 | 51.4 | 25.6 |
| 15:07 | 64.3 | 94.3 | 8 | 10.2 | | | | |
| 15:22 | | | | | 663 | 404 | 48.3 | 21 |
| 15:56 | 64.1 | 92.8 | 10 | | | | | |
| 16:32 | | | | | 650 | 388 | 47.6 | 23.1 |
| 16:52 | 64.5 | 92.9 | 9 | 11.5 | | | | |
| 17:22 | | | | | 683 | 418 | 47.4 | 23.2 |
| 17:47 | 65.6 | 92.4 | 8 | 11.3 | | | | |

in filler distribution was evaluated by electron dispersive spectroscopy (EDS) to measure the relative amount of inorganic filler components (Al, Si) on each side of the sheet. Z-direction filler distribution was measured using the sheet splitting technique. Additionally, during the trial, an on-line flocculation monitor was installed to monitor the degree of flocculation of the headbox stock. This was an initial experiment in our search for an on-line headbox flocculation measurement which can serve as an indicator of sheet formation.

**Trial results:** Figure 5 shows how adding coagulant to the delaminated clay affected the flow of the retention polymers required to keep white-water consistency at 0.5%.

It is clearly seen that a significant increase in the flow of retention polymers (by approximately 10%) coincided with the removal of coagulant from the clay feed point. The reverse effect was observed when feeding coagulant to the clay was reinstated. Table II presents sheet quality properties, as well as retention and water chemistry data collected during the trial.

None of the sheet quality parameters show a significant change due to precoagulation of the clay slurry. NUI measurements might suggest some improvement of formation with removal of clay precoagulation. This was not confirmed by measurements performed in the MK Systems lab with its formation tester. According to the MK Systems report, formation throughout the trial was essentially unchanged.

The z-direction filler distribution was obtained from the sheet splitting experiments. No significant change in filler distribution was observed due to filler pretreatment with coagulant. This data was confirmed by SEM-EDS analyses of sheet samples performed in the Nalco corporate analytical lab, Naperville (Analytical No. 457794-457796). For the three studied samples (procoagulation on - reel 2205; off - reel 2208; and on again - reel 2213) the observed amount of two-sidedness remained between 15 and 25%. Within the error of the technique no difference was found. Also, the amount of filler in the sheets was found to be essentially equal. Finally, according to the analytical report, all three samples showed comparable levels of filler agglomeration.

It should be noted that homo-agglomeration of clay particles may in some cases cause undesired effects like loss of the opacifying effect of the filler. The application of precoagulation of filler would not be recommended for $TiO_2$ with its scattering coefficient being so different from any other component of the furnish. In this case, the formation of $TiO_2$-$TiO_2$ agglomerates would result in the formation of unproductive interfaces, from point of view of light scattering. We strongly recommend initial lab handsheet work or a short on-machine evaluation if such application is planned.

**Monitoring of the headbox flocculation:** In the overall wet-end control strategy, a real limitation of a retention program is reached if the required dosage of retention polymers needed to achieve the desired retention causes formation problems. Measuring the degree of flocculation on-line and relating it to sheet formation could allow for early recognition of potentially bad formation conditions.

With this in mind, the MK Systems flocculation monitor was tried during the precoagulation trial. The unit was installed on the approach pipe to the headbox. The measured flocculation index showed good response to the factors known to affect the degree of flocculation. No significant changes in the flocculation index were observed during the precoagulation trial (flocculation index 55-59 indicated very uniform floc distribution in the headbox). At the end of the trial, the target white-water consistency was changed from 0.50% to 0.45%. This resulted in a significant drop in the flocculation index from 55 to 49. The NUI and MK formation tester examination of the paper produced indicated that this change in the flocculation index did not result in formation problems. To establish a flocculation index — formation relationship, a longer flocculation monitor trial is planned.

## CONCLUSIONS

To achieve stable operation of a paper machine wet-end requires very thorough control over the inputs — furnish, additives, retention polymers, water chemistry. The application of a twin roll press in the TMP bleach plant significantly reduces and stabilizes the influx of detrimental substances to the paper machine.

On-line control of a dual polymer retention program, based on bottom wire white-water consistency, significantly improves paper machine operation.

Precoagulation of delaminated clay increases the efficiency of its retention, with no apparent impact on sheet quality.

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**Résumé:** Sur la machine à papier numéro un (PM1) de l'usine de la société Irving, nous utilisons de la pâte thermomécanique (PTM) blanchie à l'hydrosulfite et au peroxyde d'hydrogène pour produire des catégories de papier légèrement calandré. Nous avons employé des teneurs en kaolin délaminé qui ont atteint les 16 pour cent. Un bon nombre d'améliorations ont été apportées au procédé en vue d'améliorer la stabilité dans la partie humide de la machine à papier. Le contrôle de la rétention en direct, le contrôle de la demande cationique et le prétraitement de charge au moyen de coagulants ont permis d'accroître l'efficacité de la machine à papier. Nous faisons état ici des résultats d'essais sur machine en termes d'évaluation des impacts de la précoagulation de la charge sur la rétention, la qualité de la feuille et la floculation dans la caisse d'arrivée. Ces résultats font voir des améliorations importantes dans la rétention sans incidence mesurable sur les aspects qualitatifs de la feuille.



**Abstract:** Paper machine No. 1 (PM 1) at Irving Paper uses hydrosulphite and hydrogen peroxide bleached TMP to produce soft-calendered grades. Delaminated clay content of up to 16% has been used. A number of process improvements have been introduced in order to improve stability in the wet-end of the paper machine. On-line retention control, control of cationic demand, and pre-treatment of filler with coagulant have increased the efficiency of the paper machine. The results of the on-machine trial evaluating the impact of filler precoagulation on retention, sheet quality and headbox flocculation are presented. The results showed significant improvement in retention with no measurable impact on sheet quality aspects



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