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The Role of Charge and Retention in Effective Wet End Management

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ABSTRACT

The development of paper machines, increasing machine speeds with new, mostly low basis weight and/or high ash content paper grades, as well as the fact that several trends regarding process items have increased the sensitivity of papermaking. At the same time, papermakers are looking for flexibility in the production line. We can say that with all PMs, the biggest benefits with the lowest capital spending can be achieved by focusing on improved wet end management.

In order to manage wet end chemistry on a paper machine, our goal is to control subprocesses through which we can influence the operation of the entire wet end with maximum effect. Key measurements and controls are

- white water consistency control which is the most effective way to control retention.
- charge demand measurement and control which takes care of concentration of the anionic material entering to PM.
- ash measurements and controls which are deeply related to retention and paper quality.

This paper presents and concentrates to two of these key controls: retention and charge. The purpose of charge control is to give the process control the tools to react to changes caused by amount of dissolved and colloidal material incoming to wet end system. It is called coagulation or fixing control. Retention control is then taking care of retention aid flow to the process by responding any changes seen in white water consistency. It is called flocculation control.

Each of these solutions separately, and even more effectively all together, stabilize the wet end operations and so greatly improve the produced paper quality and machine runnability. Practical results will be presented and they are referring to the latest mill cases.

We have developed the first wet end measuring system in the late 1980s and control solutions based on this modern measuring technology were completely updated in 1990s. This paper introduces the principle, operation, and results of our unique wet end analyzers (retention and charge) which are at the level of automation solutions as a part of paper machine quality control. Especially our newest member of the platform, on-line charge analyzer has reached and set new standards to the on-line charge monitoring.

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1. Wet End Management

By wet end management we aim to have stable total and ash consistencies and basic chemistry in paper machine short circulation. Stability is very important because it is directly connected to paper machine runnability and quality of produced paper. The way of doing is as much proactive process management as possible. Stability can be achieved by new process solutions, automation and advanced control systems based on key measurements, together with effective and optimized chemical usage /1/. The biggest benefits at the lowest cost can be achieved by focusing on improved wet end measurements and automatic controls based on them.

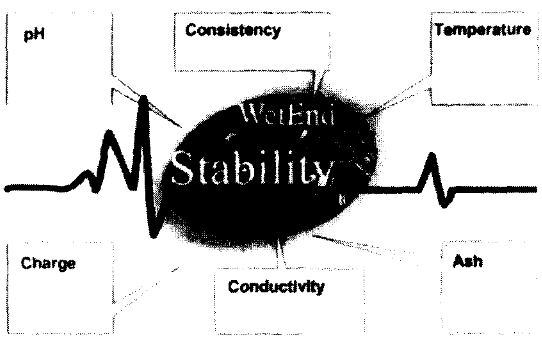

Fig. 1. The main componeuts affecting wet end stability.

1.1 Key measurements

Key measurements affecting wet end stability are shown in Fig. 1.

Consistency variation in the short circulation has a direct impact on paper quality (MD and CD) and break tendency.

Ash variability in wet end affects paper quality (strength, optical properties and porosity). Accordingly uneven distribution of ash (MD and CD) generates problems on paper machine and in coating and printing.

pH affects all chemical reactions at the wet end, especially charge level and efficiency of additives and chemicals. Sudden changes may cause paper machine runnability problems.

The ability to control the interactions of charged particles, such as fibers, fines, fillers and dissolved and colloidal material is the cornerstone of the wet end stability. In a way charge management takes care of papermaking key mechanisms like coagulation, flocculation and sizing.

Conductivity indicates the amount of dissolved inorganic material that is potential to form deposits. Conductivity is a measure of the system cleanliness.

Considerable temperature variations should be avoided due to their impact on reaction kinetics, deposition, formation and drainage.

1.2 Control concept principles

The practical wet end management can be divided into several subprocesses that can be presented in three main groups: consistency, ash, and chemistry. It is very important to separately pay attention to each subprocess, because they might have different process dynamics (e.g. ash vs. fiber consistency). The management of these main groups is based on continuous measurements and automatic control, Fig. 2.

Our target is to measure and control the key subprocesses in stock preparation and wet end area, through which we are able to influence the performance of the paper machine with maximum effect. Another main principle is combining feedback and feedforward control solutions to provide the most responsive controls possible (as much proactive as practical).

Retention control is in most cases the heart

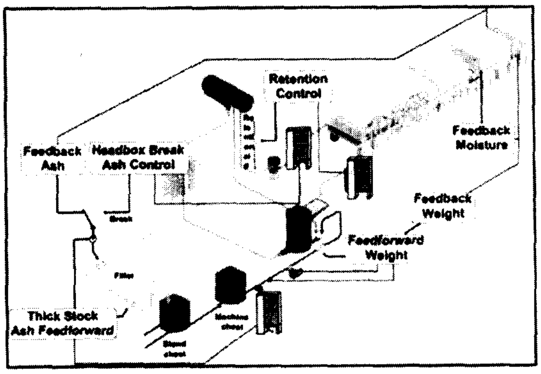

Fig. 2. Modern Papermachine Quality Controls.

of the wet end management. In practice controlling the white water consistency with retention aid controls it.

Stabilizing cationic demand of white water mainly controls wet end chemistry. This will prepare optimal conditions for other chemical additions like retention aids and so further improve retention control. Our target is to first take care of coagulation then flocculation.

2. Analyzer Platform

Continuous on-line measurements are an absolute must for effective wet end control. Automatic control concepts cannot be designed on the basis of spotwise process information provided by laboratory analyses; they require measurements that give reliable and accurate data on the key variables and allow the study of process operation and dynamics, interactions and causalities of the numerous variables. Thus, continuous and comprehensive process data and its accurate analysis are essential tools in the management and development of the paper production process.

The requirements that the various measurements must meet are dependent on how they are applied, Fig. 3. In comparison to their modern counterparts, the first available wet end measurements were simple in design and principle, and only able to measure one single variable, but in their time they were sufficiently reliable to be useful.

They fulfilled the criteria of continuity, they provided trends, and thus gave an idea of the process dynamics. However, their long-term accuracy and reliability were not up to the challenge of automatic control.

The next steps were special sensors that measured simultaneously two or three key variables. These sensors possessed more

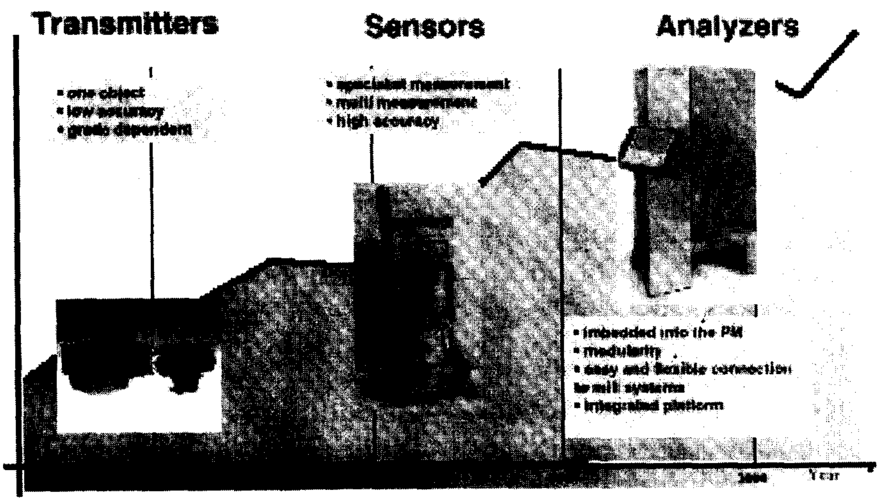

Fig. 3. Wet End Measurements based on requirements.

sophisticated measurement and self-diagnostics capabilities, and consequently also their measurement accuracy, selectivity and stability were far superior to the first generation. These technological advances enabled the construction of various unit control solutions.

The most modern measurements are designed to be extensively integrated into the process they measure, even in the paper machine itself, as necessary in each application. They are constructed, as analyzers that contain the "intelligence" needed for independent operation, as well as comprehensive self-diagnostics to ensure reliability. Successful integration into the process is facilitated by their flexible interfacing with mill systems. The modular measurements can be easily combined into one unit, ensuring a tailor-made solution that best meets the needs in each case. For the first time, a flexible and powerful measurement package capable of effective process control is now available—a Wet End Management system.

State of art analyzers that we have developed for the wet end: the modular kajaaniRMi and kajaaniCATi, and the specialized kajaaniMCAi consistency transmitter. The first two have been designed as part of a modern paper machine concept, and they form the core of the Wet End Management platform. Both of them are built in a similar frame and 80% of their components are the same. The user interfaces are identical, too; as an example, both analyzers can be controlled using the same PC software. The unique feature of these three measuring devices is that they each represent wholly different measurement technologies—microwave, optical, and electrochemical—yet they can be seamlessly integrated into a single measurement system.

The measuring principle of the kajaaniRMi has been refined from the one used in the trusty Kajaani RM-200 /2/. Its measuring module registers several optical properties of a sample, and applies the obtained data to calculate models that best describe each of the measured variables. The core measurements of kajaaniRMi are total and filler consistency, complemented by flocculation, brightness, fines content, and turbidity.

Consistency measurements must be continuous—not only reading the measurement result several times per second but also measuring the sample continuously, in real time. To achieve this we need an in-line measurement or an on-line measurement with continuous sample through-flow. Results show that the measuring accuracy is at least equal to paper quality measurements.

The charge control loop is slower than that of retention control loop. The kajaaniCATi (utilizing streaming current detector) measures cationic demand by titrating a new result about every 10 minutes—shown to be a suitable interval for charge control applications. kajaaniCATi can be used to measure the charge density in different places in a paper machine. The restrictions are the sample consistency <1% and conductivity <500 mS/m /3/.

The result of polyelectrolyte titration with streaming current end point detection depends on polyelectrolyte type (molecular weight, quaternary or tertiary ammonium group), titration speed, titration type (direct or back), sample treatment (whole sample, filtrate, centrifuged, settled, diluted), initial reading drift control, sample temperature, the cleaning of the cell, and the implementation of the electrical circuit board. Thus deviation from laboratory measurements, especially regarding offset, can be quite high. Surprisingly, quite good correlation is usually observed, if same type of polyelectrolyte is used; but far more important is the ability of an on-line instrument to measure trends reliably. Because every circle is iden-

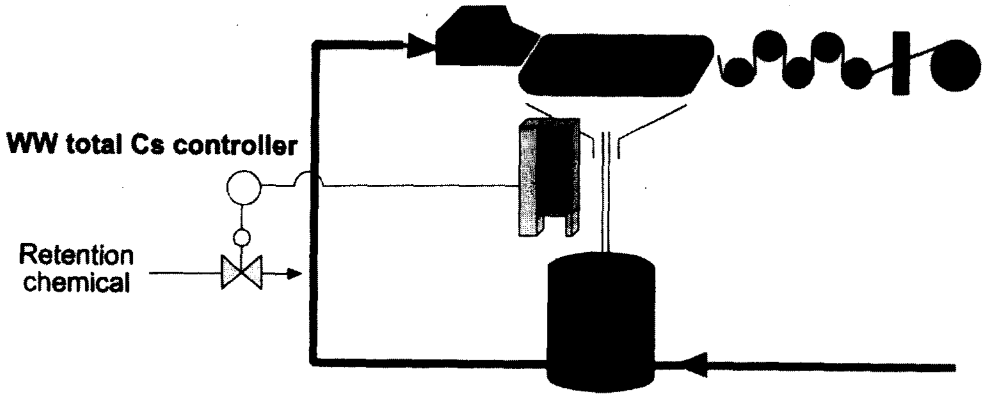

Fig. 4. White water consistency control system: retention control.

tical in an on-line instrument, the standard deviation is better than in laboratory.

An additional Chemistry Module—with pH, conductivity, and temperature measurements—can be assembled in both the kajaaniRMi and kajaaniCATi analyzers.

3. Improvements with Control Solutions

3. 1 Consistency control

The majority of the poorly retained material is contained in the white water flow and returns from there to the headbox. The retention of these critical components is improved by adding retention chemicals. Reducing total consistency variations in white water will also stabilize consistencies in the entire wet end, and this in turn is reflected in a more stable retention. The most effective way to stabilize wire retention is by controlling white water consistency with the retention aid flow. Retention is controlled indirectly, through the total consistency control of the white water; the principle is presented in Fig. 4. Algorithm is a cascaded control system where the inner loop is retention aid flow controller and the outer loop is consistency controller.

This control solution optimizes the retention program by using always only the necessary amount of chemicals, and by eliminating underdosing and overdosing situations. It also pinpoints potential problems in the process: retention chemical make-up and dosing system, pulp refining, mixing and broke dosing, It is the last watchdog before the furnish turns into paper, and it can be used to fine-tune the papermaking process. Fig. 5 shows results from a PM where white water consistency control was put on automatic control.

As can be seen the difference between automatic and manual run is clear. The automatic control is able to keep the white water consistency very stable and the effect of this can be also seen as much more stable headbox consistency and total and ash retention. So by controlling white water consistency we are able to stabilize the whole short circulation.

More stable wet end means more stable dry end. Example of that can be seen in Fig. 6. Basis weight and moisture are much more stable when retention control is on.

Statistically control results have been studied by comparing the standard deviations of important measurements for the same grade runs with and without automatic white water consistency control. Typically from 5

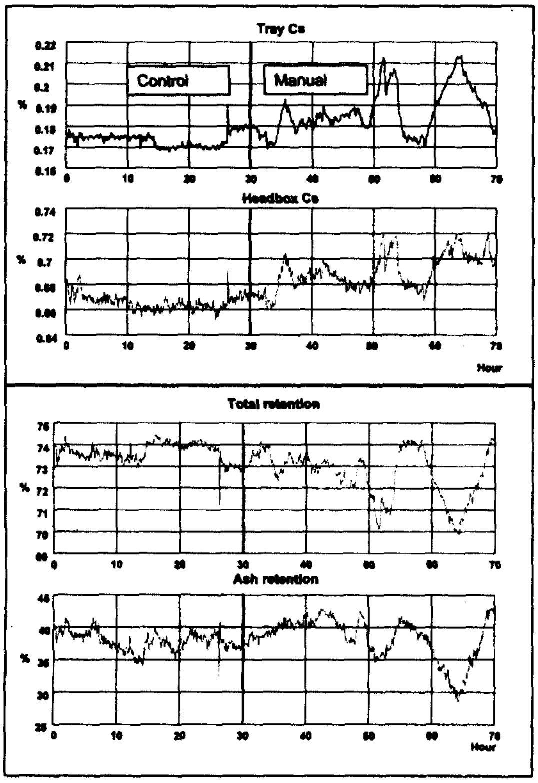

Fig. 5. White water consistency on manual and automatic control and its effect to headbox consistency, total and ash retention.

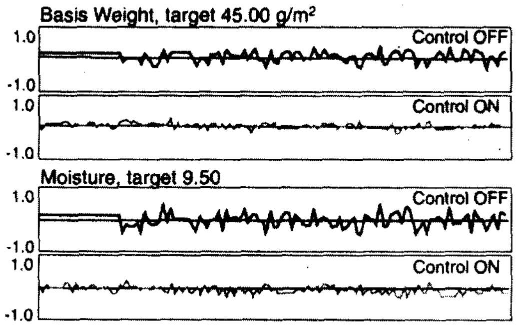

Fig. 6. Basis weight and moisture with and without white water consistency control.

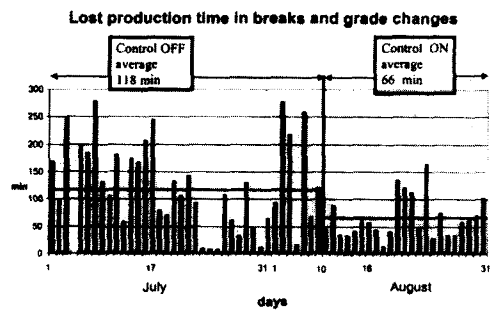

Fig. 7. The reduction in lost production time after white water consistency control.

to 10 manual vs. control run pairs are collected and studied in each individual paper or board machine. The average relative results of the comparison are shown in Table.

As the Table shows, the control periods

	News	SC	LWC	Fine	Board
WW Total Cs	-80%	-68%	-57%	-80%	-71%
Basis Weight	-30%	-19%	-14%	-9%	-5%
Paper%	-	-	-	-	-38%
Ash	25%	20%	22%	22%	

show great improvement both in wet and dry end stability, which means better runnability and improved paper quality. Also the relative improvements in different type of machines seem to be very similar.

A stable wet end and more uniform paper web means less breaks and production losses. In Fig. 7 is an example of improved runnability in a paper machine after the white water consistency control was put on.

Before the average lost production time was 118 minutes a day and after the control was put on the lost time was decreased by 41% to 66 minutes. The machine speed was also 1.7% higher during control runs.

3.2 Basic chemistry monitoring

A continuous charge measurement is an absolute must for charge control. A *charge demand* type measurement indicates how much cationic or anionic material the sample requires in order to reach the neutral state. This information can be used directly when searching for the correct chemical dosage levels, and it particularly helps to avoid the risk of over-cationizing. This principle is widely accepted as having practical applications to describe and control the papermaking process.

The charge density taken from the filtrate of coated broke thickener varies a lot depending on what kind of rolls are fed into

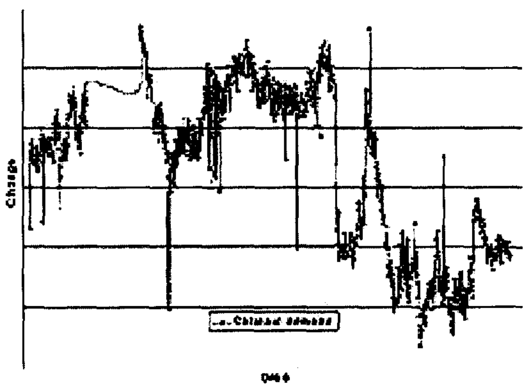

Fig. 8. Cationic demand variation in coated broke.

pulper and what is the consistency of the broke tower, Fig. 8. If this variation is not controlled by fixative addition, the retention and white water consistency of the machine will always fluctuate.

Charge control is especially important on paper machines where the target is to run the process close to zero charge, on machines using mechanical pulp (CTMP, TMP, GW, DIP) or having many grades. Usually the level of bleaching (peroxide) varies and thus the amount of anionic trash. Changes in pulp mixture or DIP itself can also cause large variation on the system charge state.

Fig. 9 shows how in a fine paper process the charge reversion can easily happen. At the beginning of third grade change (second arrow) the system has been on positive side. The grade near the neutral state does not use optical brighteners (which in this machine are negatively charged), instead cationic surface starch is dosed into process.

On one case the studied machine had white water consistency control that maintains a stable white water total consistency by automatically changing the retention aid flow. As Fig. 10 demonstrates, cationic demand and retention chemical flow correlates closely with each other. This is a good

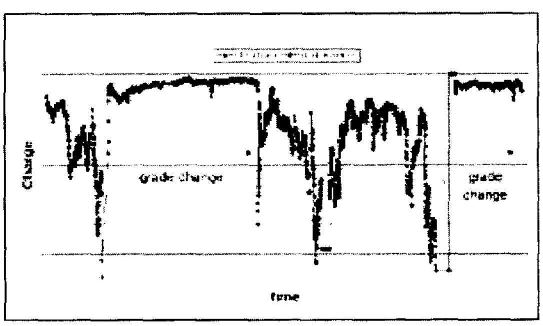

Fig. 9. Grade changes and charge density.

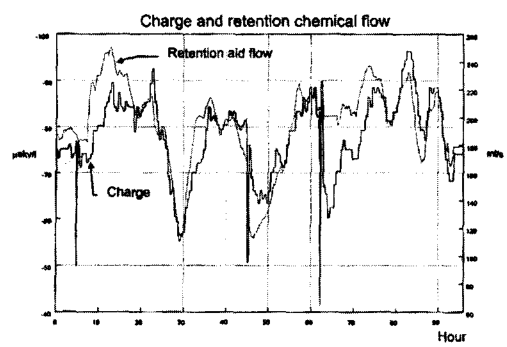

Fig. 10. The correlation of retention aid flow and on-line cationic demand measurement.

example of how changes in charge influence the dosage of other chemicals, such as retention aid: its action, and hence the required amount, changes when cationic demand changes. If there had been a constant retention aid flow in l/min, then the effective retention aid flow would have changed and caused fluctuation of white water consistency.

3.3 Control of cationic demand

To have more stable cationic demand, an automatic control was made for this machine. The control system involves cationic demand measurement from the white water, and the chemical (coagulant) used for charge control was added to several places before short circulation. The control system in this case consists of "main" and "assistant" controllers that control the chemical flow to the different addition points based on cationic demand measurement and coated broke dosage.

The actual control system must, of course, be different for different kinds of paper machines, depending on the chemicals available for control and the main sources of cationic demand disturbances.

Fig. 11 shows a typical example of control operation. During normal run the control keeps the charge level within ±5 units of the set point. Another major benefit of automatic charge control is that it enables optimum, stable conditions for other chemicals, such as retention aid. With steadier charge in the wet end, other chemical dosages can be optimized more easily.

Moreover, it has been very beneficial that the machine operators are no longer forced to constantly follow the charge measurement and adjust the chemical flow. The automatic control will do that for them using only the necessary amount of chemical and thus chemical savings are achieved.

Charge measurement and control mean easier startups and grade changes, because the danger of changes in charge around the zero point can be monitored and avoided.

Also here both the white water consistency control and cationic demand control are on automatic. As the graph shows, both controls are able to keep their respective controlled variables very near the set point. The graph includes two grade changes, with a change of white water consistency setpoint in both. For each main paper grade this mill has a different optimized setpoint for white water consistency. As can be seen from the changing chemical flows, both controls have to work to keep charge and consistency stable at the setpoint. So neither of them makes the other dispensable—both are clearly needed.

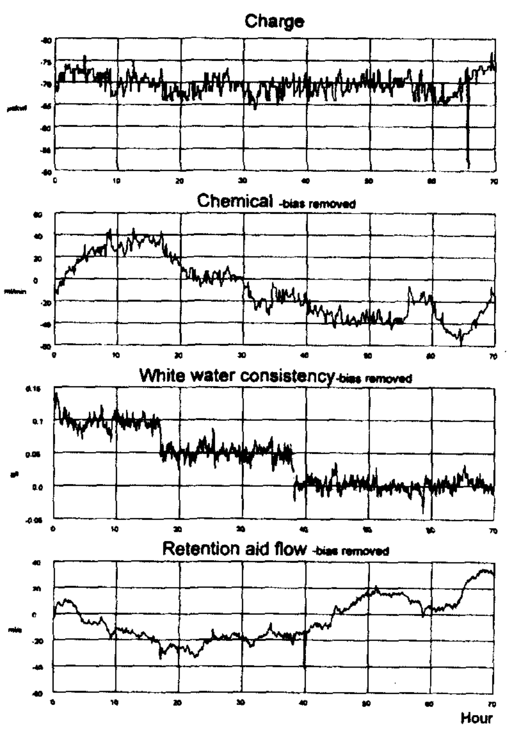

Fig. 11. Automatic control of white water consistency and cationic demand.

Even when used alone, white water consistency control is a powerful tool that compensates for a variety of disturbances. However, the effect of the retention chemical used in consistency control is always limited.

The following example, Fig. 12, compares the effect of a drop in coated broke flow on white water consistency control with and without charge control.

Without charge control the consistency decreases, the consistency controller reacts to this by decreasing retention aid flow and the consistency gets back to set point. With charge control on, the consistency control does not see this disturbance at all. Disturbances caused by broke—particularly coated broke—can be eliminated more efficiently.

With cationic demand control, the coated broke no longer causes such large changes in white water consistency. This makes the task of the consistency controller easier, consistency remains closer to set point in all situations—more efficient optimization of consistencies and quality.

Cationic demand control clearly helps the consistency control by eliminating disturbances and preparing optimum conditions for the retention chemical. But cationic demand control alone can not maintain a stable white water consistency, as demonstrated by Fig. 13.

In this graph the cationic demand is on automatic control all the time whereas white water consistency control is on manual from 13 h to 30 h. During that period the white water consistency is not stable, and even the cationic demand seems vary more. Very obviously an automatic consistency control is absolutely necessary for stable white water consistency.

Both controls—white water consistency and cationic demand—are effective and useful as independent solutions.

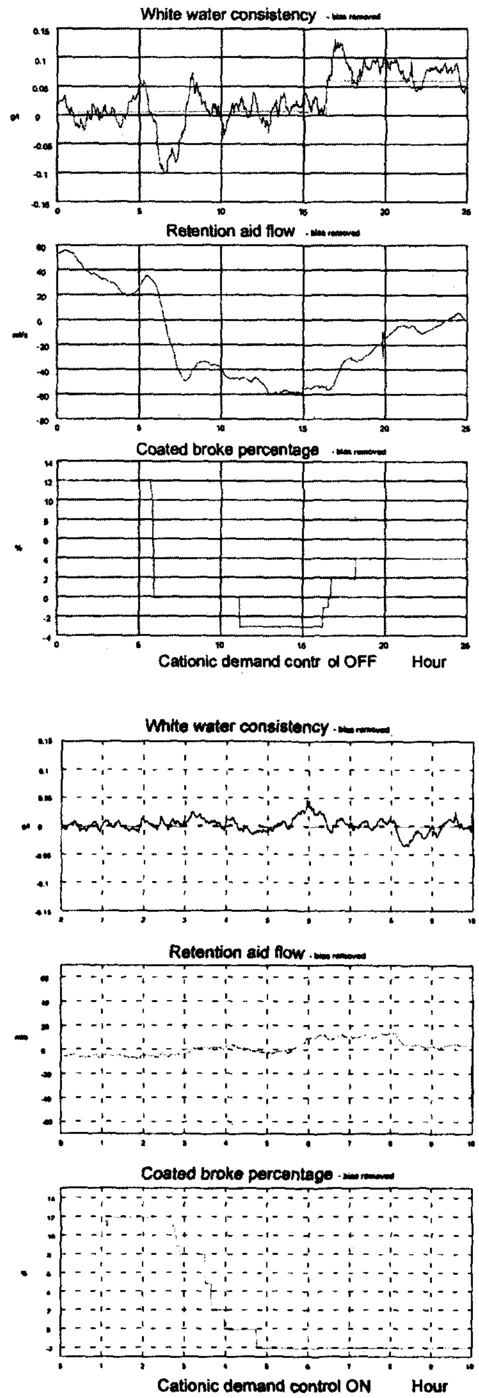

Fig. 12. White water consistency control during a coated broke change, without and with automatic cationic demand control.

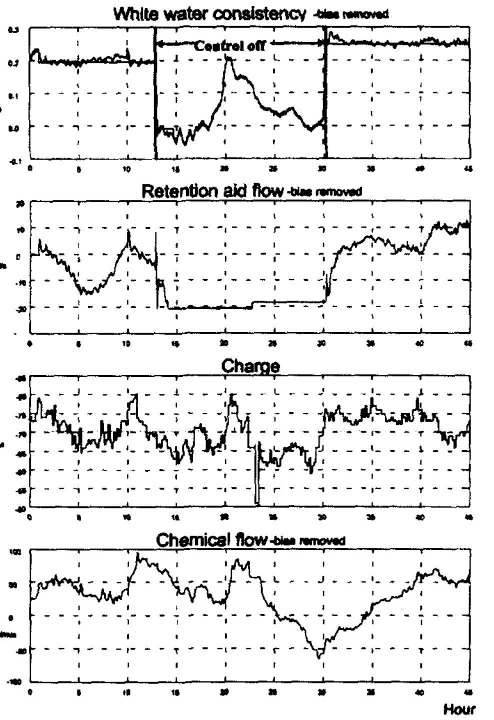

Fig. 13. White water consistency control on automatic and on manual, white water cationic demand control on automatic.

However, cationic demand control by itself does not guarantee a stable white water consistency; to achieve stable retention, white water consistency control is needed. Cationic demand control helps the consistency control by preparing optimum chemical conditions for the retention chemical program. The controls support each other, and usually the best results are achieved when using a combination of the two. With these controls, big and sudden variations in charge and consistency can be avoided. This means improved runnability.

4. Conclusions

A new wet end management concept (WEM) has been developed, based on the measurement and control of key process variables. We have at hand a wholly new wet end quality management system. It is based on new family of industrial wet end measurements integrated to paper machine. These measurements are at least as reliable and capable as the dry end quality monitoring systems.

Retention control, based on white water consistency control, is highly effective way to stabilize consistencies of whole short circulation. Charge control enables optimum, stable conditions for other chemicals. For example it makes the task of the white water consistency control easier, and when used in combination, these two controls provide a powerful tool that stabilizes the short circulation at an optimum white water consistency and minimum retention chemical dosage levels. The result is remarkably improved PM runnability, efficiency, and product quality.

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