Pressure screening: changes in pulp properties in the screen basket

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ABSTRACT

A pilot-scale pressure screen was used for experiments on changes in pulp properties in the screen basket. Pulp properties were found to undergo changes in both the axial and radial directions with respect to the screen basket. The axial change takes place because small particles pass through apertures readily, while large particles tend to remain inside the basket. The radial variation in pulp properties occurs because the water, flowing radially, compresses the fiber network close to the screen plate as water and fines pass through. According to the probability theory of pressure screening, the properties of the pulp also change in an axial direction in the accept chamber. These changes affect the capacity and efficiency of the pressure screen.

Application:

Experiments on the axial and radial changes in pulp properties in the screen basket offer insight as to how the pressure screen functions.

PRESSURE SCREENING AFFECTS paper quality. Although paper quality is determined primarily on the paper machine, the foundation for high quality is laid during pulping and stock preparation. An understanding of the changes in pulp properties is necessary in evaluating the pressure screen.

BACKGROUND

Not only does pulp quality affect the product quality, but it also affects the runnability of the machine. Breaks can occur in the paper web or at the coating blade as a result of shives or other impurities in the pulp (*1–3*). Before the paper web, these impurities have passed through at least two screenings: (a) either a brownstock screening for chemical pulp or a groundwood screening for mechanical pulp, and (b) headbox screening on the paper machine. In the probability theory of pressure screens, the amount of debris in the accepted pulp is assumed to change with the debris in the feed pulp (*4*), and this assumption is valid for all practical purposes.

Moreover, the properties of the pulp undergo changes in screening, both in the axial and radial directions with respect to the screen basket. The pulp is affected in the axial direction by virtue of the fact that small particles have a high probability of being accepted, whereas large particles tend to stay in the screen basket longer. This change in pulp properties leads to a comparable change in the properties of the accepted pulp (*5*). In addition, the pulp properties undergo changes in the radial direction of the screen basket. Changes in the radial direction arise from the radial flow of water. Both axial and radial changes in pulp properties affect the capacity and efficiency of screening.

EXPERIMENTAL DESIGN

In these experiments, we used a pilot-scale pressure screen to screen both a bleached kraft pulp and a groundwood pulp. The apparatus allows us to sample pulp from the feed chamber, the screen basket, the surface of the screen, and the reject chamber. We analyzed fiber length and consistency, along with freeness and paper properties in the case of the groundwood samples. **Figure 1** is a chart of the way the equipment is set up, showing the feed in the axial direction of the screen basket, which has a foil-type rotor.

The work was accomplished in three series of experiments. In the first series, experiments were carried out to determine the consistency, freeness, and papermaking properties of the groundwood pulp at different points inside the screen. Additional experiments were run to ensure that the results were valid and did not depend on the fiber type or screening conditions. Experiments in the second series were carried out to determine the effects of fiber type (kraft vs. groundwood). In the third series, we considered the effects of less aggressive conditions on the screen surface, using a slower tip speed for the foil.

All the pulp properties measured are presented relative to those of the feed pulp. The normalized format compensates for the error derived from small changes in feed pulp properties. The formula for normalized consistency, for example, is

$$N_i = (C_i/C_f) \times 100\% \qquad (1)$$

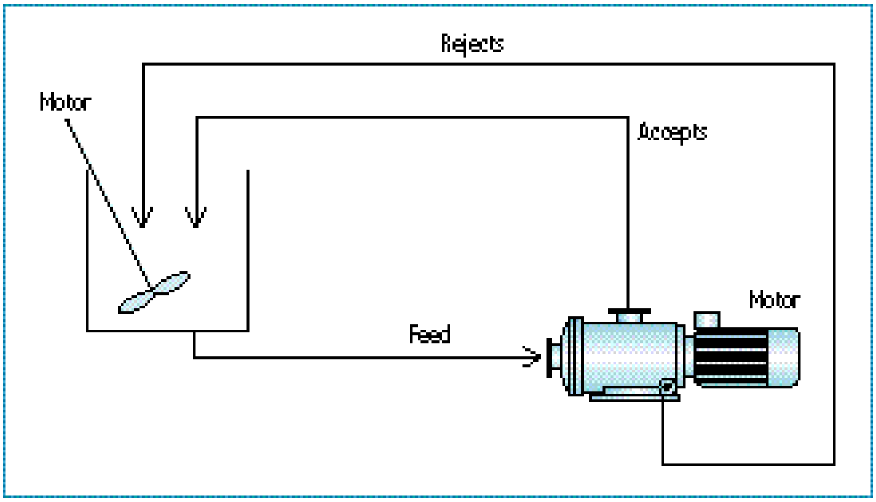
where

N_i = normalized consistency
C_i = consistency of the sample
C_f = feed consistency.

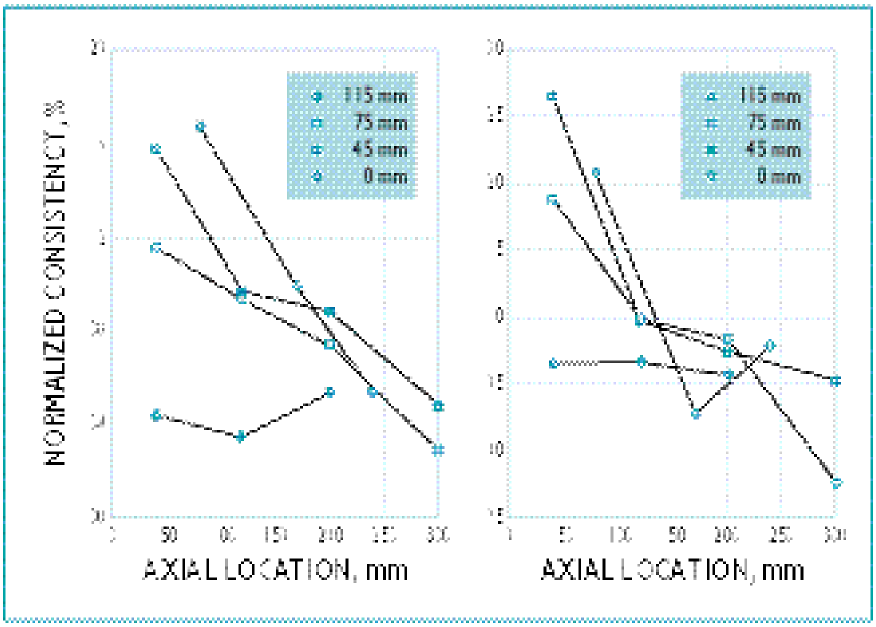
RESULTS

Consistency distribution in the screen basket

For both pulps tested, the consistency changed markedly in both the radial and axial directions of the basket, as shown in **Fig. 2**. In the radial



1. Diagram of the pilot screening system, showing the feed in the axial direction of the basket.



2. Normalized consistency distributions in the screen basket for both the groundwood pulp (left) and the bleached kraft pulp (right).

	Correlation factor Consistency	Correlation factor Freeness
Apparent density	-0.91	-0.96
Tensile strength	-0.93	-0.95
TEA	-0.82	-0.85
Stretch	-0.76	-0.78
Tear strength	0.73	0.70
Elastic modulus	-0.61	-0.61

TEA = tensile energy absorption.

I. Correlation of handsheet properties with consistency and freeness

direction, it mainly increased from the center of the screen (curve for 115 mm) towards the surface (curve for 0 mm). The gradient was large at the beginning of the screen basket, and it diminished towards the reject chamber. In the graphs, the axial location of 0 mm denotes the front end of the screen basket.

In the axial direction, the consistency was highest at the beginning of the screen basket and was lowest towards the reject chamber. Axial consistency distributions near the screen plate varied between the groundwood pulp and the kraft pulp. As the figure shows, the plot was an almost straight downward line for groundwood, but the curve was V-shaped for bleached kraft.

Freeness distribution in the screen basket

The freeness distribution in the screen was similar to the consistency distribution. The correlation coefficient between freeness and consistency in the screen basket was 0.99 for groundwood. **Figure 3** shows an example of the freeness distribution.

Fiber length distribution in the screen basket

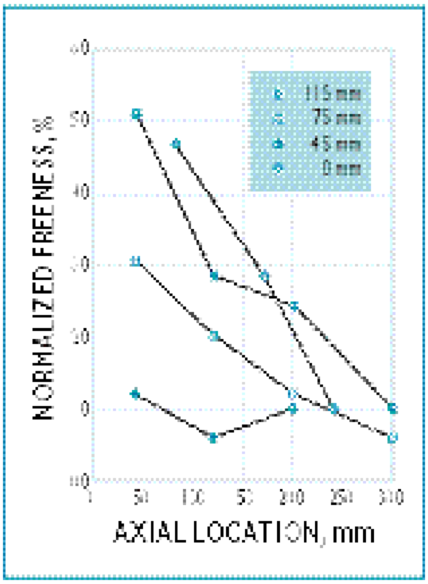
Fiber length was measured in length-weighted form. Its distribution in the screen basket followed the patterns found for consistency and freeness. The correlation factor between fiber length and consistency for groundwood was 0.91. For bleached kraft, the correlation factor between fiber length and consistency was 0.93. Examples of the fiber length distribution are reproduced in **Fig. 4**.

Distributions of papermaking properties in the screen

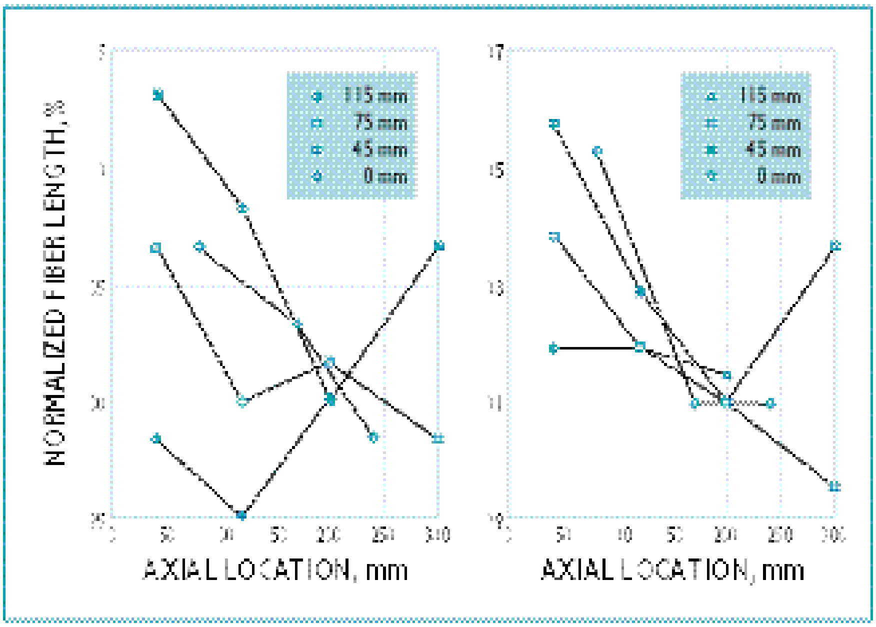
The papermaking properties of the pulp samples are shown in Figs. **5–9**. The correlations of these properties with consistency and freeness were negative, with the exception of tear strength. The apparent density and tensile strength of the test sheets correlated best. Tensile energy absorption, stretch, tear strength, and elastic modulus showed moderate correlations with consistency and freeness. These correlation factors are presented in **Table I**.

DISCUSSION

Impurities in pulp are normally segregated out on the screen plate, as reflected in the high values for consistency and freeness in the rejected pulp (*6*). In these experiments, however, we used prescreened pulp. The



3. Normalized freeness distribution in the screen basket for the groundwood pulp.



4. Normalized length-weighted distributions of fiber length in the screen basket for both the groundwood pulp (left) and the bleached kraft pulp (right).

effects of impurities were mostly eliminated, and the screen plate was kept clean of any debris that could form a barrier layer. In addition, the absence of debris, together with the relative low feed consistencies, made it feasible for us to take samples reliably from within the screen basket. Screening was based only on the passing probability of fibers, and the screening phenomena were relatively clear and easy to consider.

There were probably some sampling errors occasionally. The trends in all the experiments were so distinct, however, that the results can be regarded as valid, even if somewhat unexpected.

Changes in the axial direction

Pulp was at its highest in consistency, freeness, and fiber length at the initial stage of the screen basket. This outcome points to a dewatering effect, with long fibers remaining on the screen plate while mostly water and fines readily flowed through. Interestingly, pulp consistency in the screen basket was always greater than in the feed pulp, even near the feed point some 115 mm from the screen surface. This effect proves that dewatering was initiated in the feed chamber or even at the end of the feed pipe.

Dewatering at the initial stage was quite pronounced in these experiments because the feed was axial and the feed chamber was unusually short. Consequently, the fiber suspension did not reach a sufficient tangential velocity before it reached the screen basket. As a result, insufficient turbulence was generated at the screen surface, bringing about crowding of fiber flocs in that area. These phenomena emerge in Fig. 2 as high consistency of groundwood and kraft pulp at the initial stage of the screen basket.

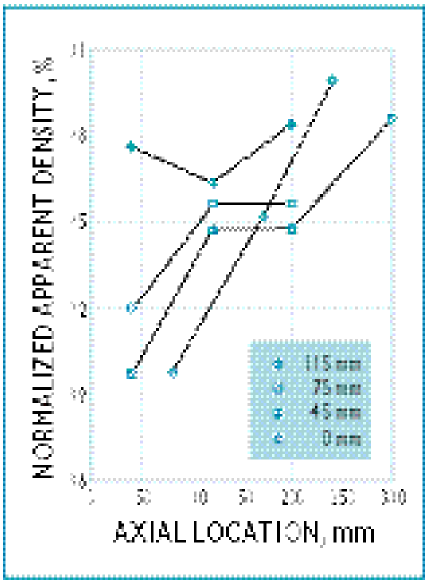
We observed a gradual change in groundwood pulp properties and consistency in the axial direction of the screen basket. At each radial distance from the screen surface, the change was similarly oriented, but the effect was weaker at greater distances.

The explanation may be that the increase in tangential velocity and turbulence towards the reject end dispersed the flocs and caused more and more long fibers to pass through the apertures. Fewer long fibers accumulated, and the fiber network loosened. As a result, consistency and pulp properties changed gradually in the axial direction.

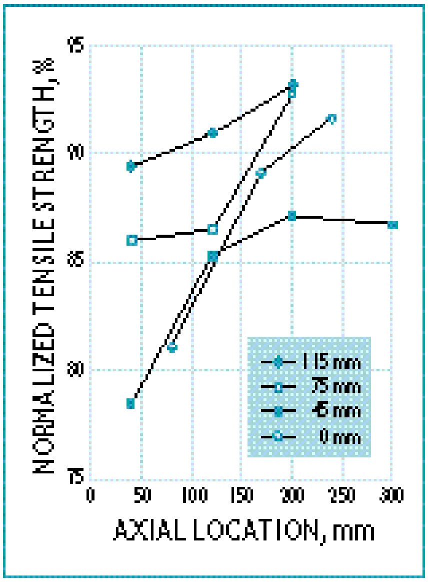
Had we used pulp with more debris, more fibers would have accumulated, and consistency and freeness would have increased towards the reject end of the screen. The distributions for consistency and freeness would probably have been V-shaped.

The behavior of the bleached kraft pulp differed from that of the groundwood pulp only at the back end of the screen surface. The flow guides in the reject chamber reduced the tangential velocity of the pulp, enhancing its flocculation on the screen plate as a result of insufficient turbulence. On the other hand, the low tangential velocity also strengthened the suction effect, or the negative pressure pulse induced by the foil. This suction produced a backflow of water and fines from the accept chamber into the screen basket (7).

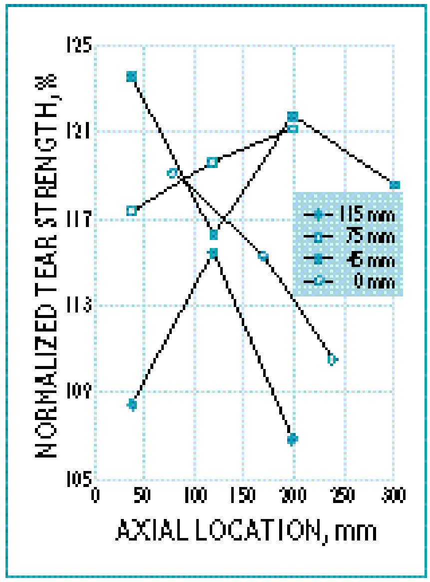
In the case of the long-fibered kraft pulp, flocculation overcame this backflow. With the short-fibered groundwood pulp, the backflow of groundwood fines is evident in apparent densities of the test sheets, as presented in Fig. 5. The apparent density on the screen surface was higher than elsewhere in the screen



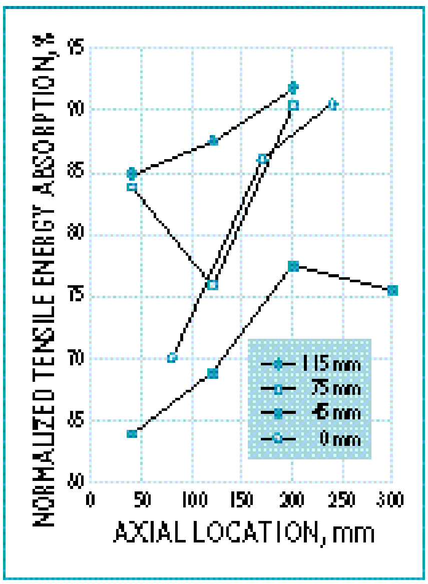
5. ***Normalized apparent density distribution in the screen basket for the groundwood pulp.***



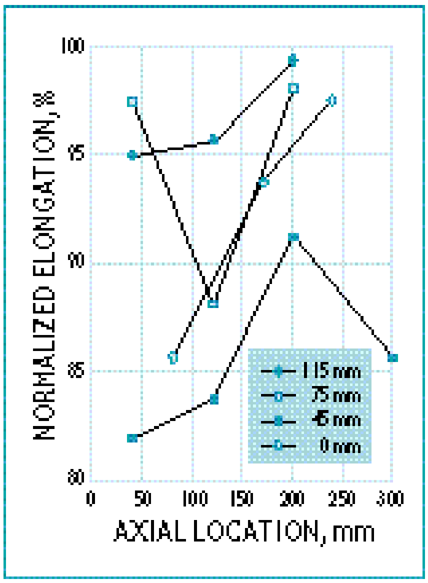
6. ***Normalized tensile strength distribution in the screen basket for the groundwood pulp.***



7. ***Normalized tear strength distribution in the screen basket for the groundwood pulp.***



8. ***Normalized tensile energy absorption in the screen basket for the groundwood pulp.***



9. ***Normalized elongation distribution in the screen basket for the groundwood pulp.***

basket. This increase points to more fines, evidently derived from the accept chamber.

Changes in the radial direction

In addition to the axial change in pulp properties, a clear change in the radial direction was indicated. The compression of the fiber network increased from the center of the basket towards the screen plate. This change was caused by centrifugal force to some extent, but it occurred mainly because the screen plate restrained fibers from passing through the apertures, while water and fines flowed freely.

In other words, the compression force exerted by the radial flow of water increased as the fiber network drew closer to the screen plate. This compression, along with dewatering of the fiber network, altered the proportions of the fiber fractions in the pulp.

Handsheet properties

These phenomena were corroborated by the papermaking properties of the test sheets. Both axial and radial changes in papermaking properties occurred in the screen basket and on the surface of the screen. A good correlation was found between each papermaking property and consistency or freeness. (As consistency and freeness decrease, tear strength decreases, but tensile strength and apparent density increase.)

This outcome is explained by the proportion of fines, because fines mainly determine the papermaking properties of groundwood by virtue of their bonding ability (*8*). The good correlation between consistency and papermaking properties may offer a way to use online consistency monitoring alone to predict the properties of mechanical pulp after pressure screening.

Axial vs. tangential feed

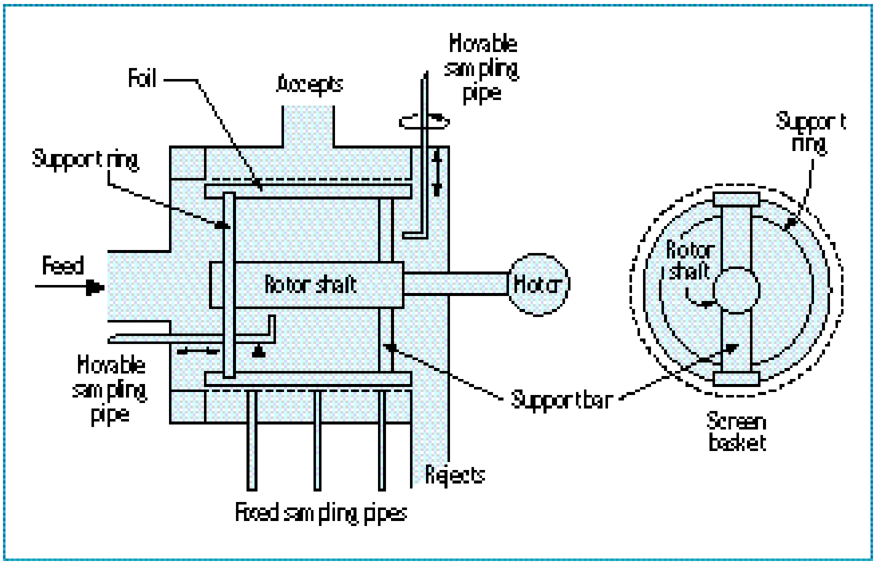
These experiments were performed with a pressure screen that had an axial inlet. However, the same phenomena would probably occur in a screen with a tangential inlet if it had a feed chamber the same length. The initial tangential velocity of the feed pulp is 0 m/s for an axial inlet and about 1–2 m/s for a tangential one. Concerning the foil tip speed, which may be 10–20 m/s, we can presume that the tangential velocity distribution in the screen basket is practically the same, whether pulp is fed tangentially or axially.

CONCLUSIONS

Pulp properties undergo changes in both the axial and radial directions with respect to the screen basket. The axial change takes place because the probabilities vary for fiber fractions passing through the screen. Small particles readily pass through the screen, whereas large particles tend to stay inside the basket longer.

At the initial stage of screening, the turbulence on the screen plate is not sufficient to prevent fibers from flocculating. Most of the long fibers are caught up in flocs and do not pass through in the accept stream. If the pulp is prescreened, these flocs are dispersed on the screen plate as turbulence increases, and there is a gradual decrease in the number of long fibers towards the reject end of the screen. However, if the debris level is high enough, then debris accumulates, and consistency and freeness increase towards the reject end of the screen.

The radial variation in pulp properties is mainly attributable to the radial flow of water through the fiber network, which compresses the fiber network against the screen plate, while water and fines pass through. A good correlation exists between papermaking properties, consistency, and freeness. Consequently, consistency measurements could be used to predict paper quality from pressure screening data in a given mechanical pulp process.



10. Sampling system and rotor type used in the experiments.

MATERIALS AND METHODS

The pulps used were bleached Scots pine (*Pinus sylvestris)* kraft pulp and Norway spruce (*Picea abies*) groundwood. The kraft pulp had an average length-weighted fiber length of 2.09 mm, and the groundwood pulp had an average length-weighted fiber length of 0.62 mm. The drainability, or freeness, was 700 mL CSF for bleached kraft and 50 mL CSF for groundwood.

The experimental work was performed with a pilot-scale pressure screen with an axial feed and a foil-type rotor. The pressure screen was connected to a stock preparation pilot system, as illustrated in Fig. 1. The feed, accept, and reject lines were equipped with pneumatic ball valves, each with an aperture that had a constant opening time.

The foil was 50 mm wide and 14 mm thick. The screen was equipped with a wedge wire screen basket with a slot width of 0.15 mm, a contour height of 0.82 mm, and a slot pitch of 15°. The diameter of the screen basket was 300 mm, and the axial length was 300 mm. The feed chamber and reject chamber were each 90 mm long. The reject chamber was equipped with static flow guides to reduce the tangential pulp velocity.

The pressure screen was also equipped with axial and radial sampling pipes 10 mm in diameter. These movable pipes allowed us to sample pulp from the feed chamber, the screen basket, and the reject chamber. In addition, there were three fixed sampling pipes located on the surface of the screen. **Figure 10** shows the locations of these sampling pipes.

Figure 10 also shows the specially constructed rotor that allowed the sampling pipe to be inserted in the screen. The front end of the rotor was designed with a circular support without inner bars so that pulp samples could be taken from within the screen basket. Each pulp sample was tapped at the same flow rate, about 14 L/min, with sampling controlled by manual ball valves. Sampling was started only when screening had reached an acceptably steady state.

Each sample was analyzed for consistency and freeness in the laboratory according to SCAN-M1:64 and SCAN-M4:65. Test sheets were made according to SCAN-M5:76 but with a grammage of 74 g/m² instead of 60 g/m² to obtain better retention of fines. The properties of the test sheets were analyzed according to SCAN-M8:76. Fiber length was measured with the Kajanni FSA fiber length analyzer according to TAPPI T 271 om-98.

The feed pressure in the experiments was 200 kPa, and the feed rate was 15 L/s. The fiber concentration in the feed was around 9.5 g/L (0.95%) in the tests on groundwood and about 5.4 g/L (0.54%) in those on bleached kraft. In experiments for determining fiber length, the rotor frequency was 10 s^{-1}, which corresponds to a foil tip speed of 9.4 m/s. In these experiments, the volumetric reject rate was 12% with groundwood and 25% with bleached kraft. In experiments from which handsheets were made and papermaking properties were determined, the volumetric reject rate was 25%, and the rotor frequency was 15 s^{-1}, corresponding to a foil tip speed of 14.1 m/s. The stock temperature for the tests was approximately 30°C. **TJ**

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