

Fiber length fractionation of TMP using pressure screens

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THERMOMECHANICAL PULP (TMP) can be separated into fractions based on fiber length. Each fiber fraction can then be treated separately to achieve the best possible performance in the recombined pulp. Modern pressure screens can divide TMP into fiber length classes, and the results are promising, as recent studies show (1, 2). In fiber screening, short fibers pass through a screen plate, but the long fibers are retained on its surface. A successful screening produces a reject stream of long fibers and an accept stream of short fibers.

There are several ways to hinder the long fibers from passing through the screen plate. Adjustments are made by changing the hole size, the rotor speed, or the aperture velocity (3, 4). The problem with these options is that water passes through the screen plates more easily than does the pulp, leaving a thick reject pulp in the bottom of the screen. As the reject pulp thickens, operating problems arise. In addition, the mass reject rate increases at a constant volumetric rate.

In this work, we used pressure screens to separate TMP into distinct fiber length classes according to Bauer-McNett. Specifically, we split an ordinary TMP of 150–200 mL CSF into Bauer-McNett fractions of +14, 14–30, 30–50, and –50. The objective was 100% clean fractions, both in the reject stream and in the accept stream.

It was not an option to increase the reject rate to keep the accepts

clean. To do so would contaminate the reject stream with the accept fraction.

EXPERIMENTAL DESIGN

The practical work of screening and refining was performed at the New Zealand Forest Research Institute in the PAPRO Pilot Plant. For pressure screening, PAPRO has two Ahlström F1 pressure screens, which were installed in 1993.

The pulp used for screening was a two-stage TMP produced in the Jylhävaara, single-disk, SD50/36 refiner. This pulp had a freeness of 170 mL CSF. The raw material consisted of Norwegian spruce logs transported from Norway to New Zealand in a refrigerated container. **Table I** shows a typical Bauer-McNett distribution for the feed pulps used during these trials.

Baskets of two different types of construction were compared:

- Drilled holes and smooth surface
- “Wedge wire baskets” — that is, wedge-shaped bars (or wires) welded together, forming a profiled surface with long, narrow (and also wedge-shaped) slots.

For the baskets of smooth surfaces with drilled holes, the hole diameters were 1.40, 1.20, 1.00, and 0.80 mm. For these baskets, the pressure screens were operated at aperture velocities of 0.6 m/s and 1.0 m/s at volumetric reject rates of 15%, 30%, and 45%.

The two wedge wire baskets both had slot widths of 0.15 mm, and

ABSTRACT

Pressure screens were used to divide a Norwegian spruce TMP furnish into fractions that corresponded in fiber length to Bauer–McNett classes. Two kinds of baskets were tested. Smooth-surface, drilled-hole baskets were tested for the effects of hole size, aperture velocity, reject rates, and screening configuration. Wedge wire baskets with profiled surfaces and narrow slots were tested for the effects of profile height, rotor speed, aperture velocity, reject rate, and screening configuration. A sharp fractionation was accompanied by a high degree of reject thickening and a propensity for screen plugging. To limit plugging, keep the accept rate high, and separate fibers sharply by length, the screening process was configured for multiple-stages.

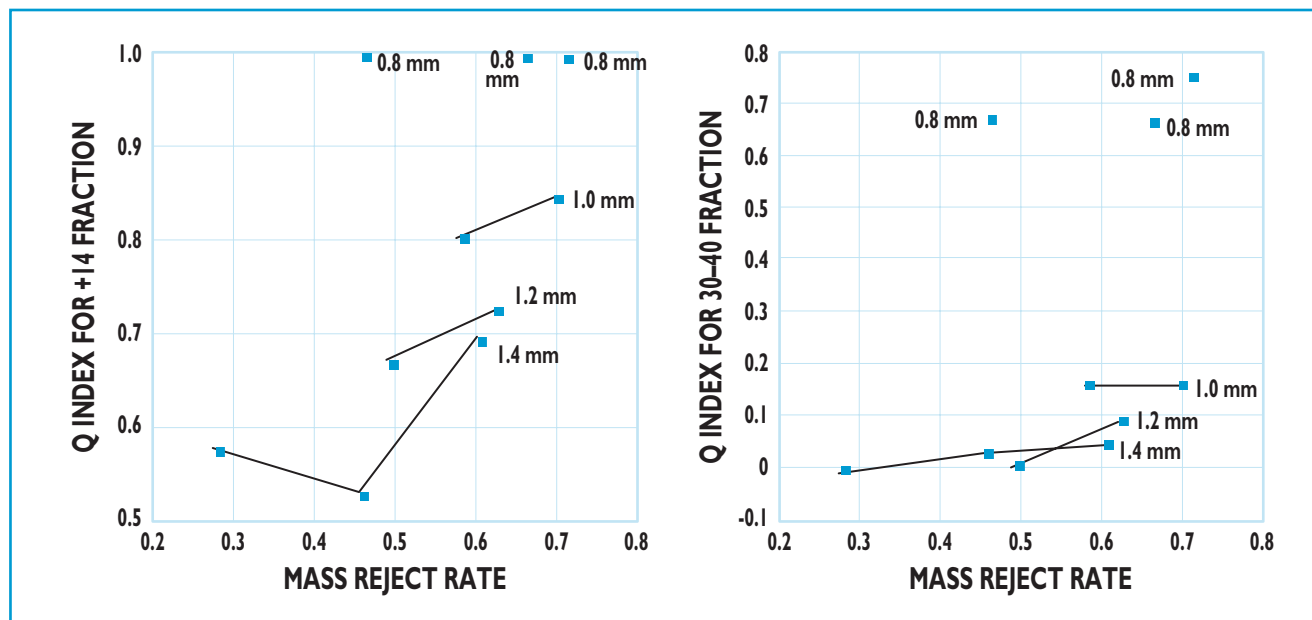
Application: Operating conditions of pressure screens can be optimized to separate mechanical pulp fibers successfully into fiber length classes.

the profile heights were 0.3 and 0.6 mm. These baskets were examined at volumetric reject rates of 15% and 45%, aperture velocities of 0.15, 1.0, and 2.0 m/s, and rotor tip speeds of 13, 18, and 22 m/s.

A minimum feed consistency of 1.5% was required to ensure that enough fiber was available for refining from both the accept and reject streams.

DEFINITIONS OF TERMS

The Q index is a measure of the sharpness of fractionation. A Q index of 1 means a perfect, sharp fractionation, whereas a Q index of 0 means no fractionation at all. The Q index for fraction x is the share of fraction x in the accept stream divided by the share of fraction x in the reject stream.



1. *Q* index values for the +14 fraction and the 14–30 fraction for screens consisting of holes drilled through smooth surfaces. (Hole diameters are indicated in millimeters.)

Fraction	%
Retained on:	
14 mesh	30.1
30 mesh	16.1
50 mesh	10.8
100 mesh	10.2
200 mesh	7.6
Passing through:	
200 mesh	25.2

1. Typical Bauer–McNett distribution for the feed stream

As an example, if the accept stream consists of 10% of +14 fraction and the reject stream consists of 20% of +14 fraction, then

$$Q_{+14} = 1 - (0.1/0.2) = 0.5$$

The volumetric reject rate, R_v , is the volumetric flow in the reject stream divided by the volumetric flow in the feed stream.

The reject thickening factor, RTF , is defined as the reject consistency divided by the feed consistency. Depending on the feed consistency, the RTF value describes how “heavily” the screen is working. A feed con-

sistency of 1.5% and an RTF of 3 coincides with a reject consistency of 4.5%. A reject consistency of 4.5% usually requires the addition of dilution water and means the screen is prone to plug.

The mass reject rate, R_m , is defined as the mass flow of pulp (oven dry) in the reject stream divided by the mass flow of pulp (oven dry) in the feed stream.

RESULTS AND DISCUSSION

Drilled-hole baskets: hole size and the mass reject rate

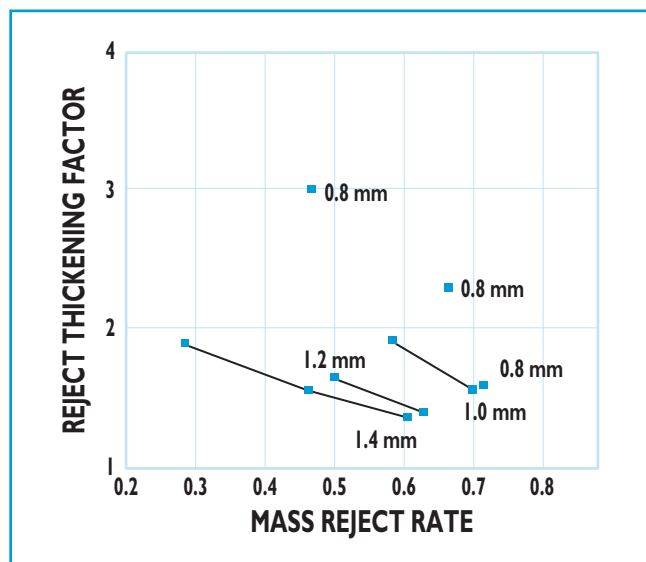
Figure 1 shows Q index values at different reject rates for the +14 and 14–30 fractions. The velocity through the apertures was about 1 m/s, varying from 0.9 m/s to 1.1 m/s.

As the graphs show, the Q index for the long fiber fractions increased with decreasing hole size. Generally, the Q value decreased with decreasing reject rate. The basket with 0.8-mm openings gave almost perfect fractionation of the +14 fraction, but it was fed with a furnish different from that of the other baskets. It received accept pulps of lower consistency, pulps from which some of the long fiber had already been removed.

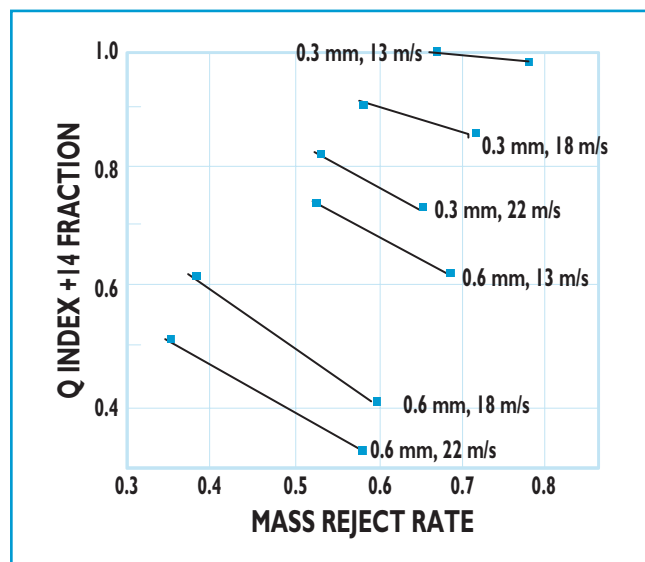
The trends for the 14–30 fraction were more or less the same as for the +14 fraction. The Q index values were generally lower, indicating that it was more difficult to separate the 14–30 fraction than the +14 fraction. The fibers in the 14–30 fraction are shorter than those in the +14 fraction (5), and they pass more easily through the screen basket apertures. The only drilled-hole basket that gave reasonable Q values for the 14–30 fraction was the one with 0.8-mm holes.

For the 30–50 fraction, the Q values were too low to give a useful fractionation, for all of the tested baskets. The maximum Q index for this fraction was 0.5, a value obtained for both the smooth-surface basket with drilled holes of 0.8 mm and the wedge wire basket with a profile height of 0.3 mm.

Figure 2 shows that the reject thickening increased as the reject rate was decreased. It also shows that the baskets with the small hole sizes gave the highest reject thickening. These baskets were also the baskets that gave the best separation, or the highest Q index.



2. Reject thickening factor vs. mass reject rate for the baskets of smooth surfaces with drilled holes (velocity through the aperture = 1 m/s). (Hole diameters are indicated in millimeters.)



3. Q index values for the +14 fraction vs. mass reject rate for different profile heights (mm) and different rotor tip speeds (m/s) for the wedge wire baskets (aperture velocity = 1 m/s).

Wedge wire baskets: profile height, the mass reject rate, and the rotor speed

Figure 3 shows Q values at different reject rates for the +14 fraction. Increasing the profile height and rotor speed reduced the fractionation, giving smaller values for the Q index. This decrease was caused by the increased turbulence and fiber disorder around the apertures.

Altering the rotor speed made it possible to get the baskets with profile heights of 0.3 mm and 0.6 mm to perform in roughly the same way in regard to fractionation. The highest rotor speed combined with the lower of the two profile heights gave approximately the same fractionation as the lowest rotor speed combined with the higher profile. Figure 3 also shows that the Q index increased as the reject rate was decreased. The same effect for the Q index for the +14 fraction was found at high rotor speeds by Repo and Sundholm (1).

An increasing Q index with decreasing reject rate is opposite to the trend found with the baskets with smooth surfaces and drilled holes.

Figure 4 shows steeper lines than those of Fig. 2, indicating that the

increased reject thickening caused by a decreased reject rate was more pronounced for the wedge wire baskets than for the drilled-hole baskets. This difference may be that the narrow slots in the wedge wire basket provide more barrier screening than the drilled-hole baskets provide. Barrier screening means that the particle cannot pass through the aperture under any circumstances because the aperture is too small.

The attempt to force the fibers through the basket favored the passage of water more in the wedge wire baskets than in the drilled-hole baskets. The dewatered fiber mat inside the wedge wire basket may have served as an additional screen plate layer, making it even more difficult for the long fibers to pass through the screen plate.

Q index vs. mass reject rate

Figure 1 showed that the Q index decreases with decreasing mass reject rate for drilled-hole baskets. Figure 3 showed, conversely, that the Q index increases with decreasing mass reject rate for the wedge wire baskets. The reason for this apparently fundamental difference between the drilled-hole baskets and wedge wire baskets is that the reject thickening factor increases much

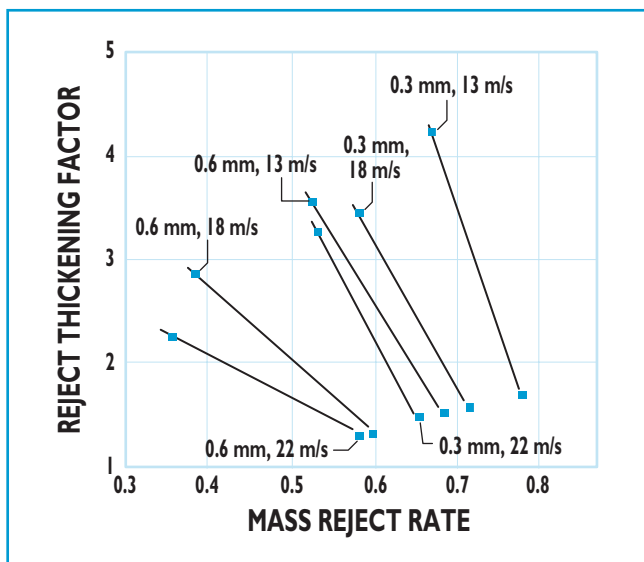
more rapidly for the wedge wire baskets than for the drilled-hole baskets when the mass reject rate is reduced.

To make a fair comparison of the relationship between R_m and Q index for drilled-hole and wedge wire baskets, the comparison has to be done at a constant RTF value. This condition is important because the reject thickening indicates how "heavily" the screens operate.

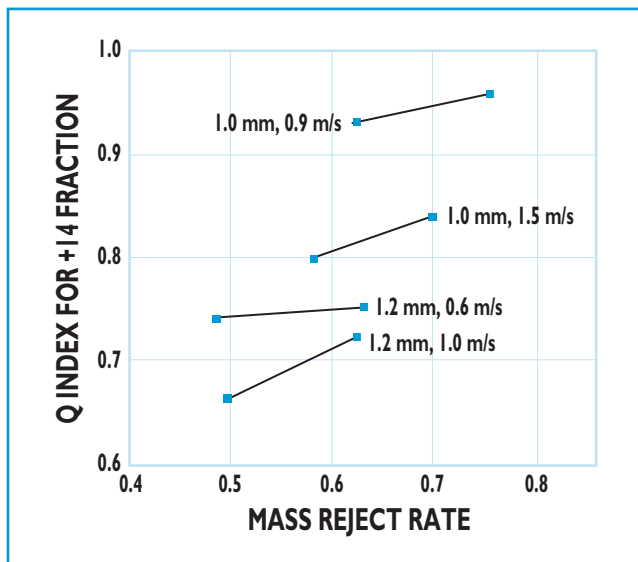
For example, suppose one of the screens has less reject thickening than the other. If the Q index and the mass reject rate are the same for both, what does that tell us about the screen? It indicates that the screen is not working as hard, figuratively speaking, in screening out the long fibers. Therefore, it is possible to reduce the hole size for this basket, keeping the mass reject rate the same. To do so would be to improve the Q index at the higher rate of reject thickening.

Table II shows that the Q index will decrease with decreasing mass reject rate for both the drilled-hole baskets and the wedge wire baskets if the comparison is based on a reject thickening of 1.5.

Table II also shows that drilled-hole baskets apparently give a better fractionation at given R_m and RTF val-



4. Reject thickening factor vs. mass reject rate for different profile heights (mm) and rotor tip speeds (m/s) for the wedge wire baskets (aperture velocity = 1 m/s).



5. Q index values for the +14 fraction vs. mass reject rate for different aperture velocities (m/s) and hole diameters (mm) for drilled-hole baskets.

	Holes, mm	Profile, mm	Rotor speed, m/s	R_m	Q_{14}
Drilled holes	1.4	...	...	0.53	0.6
	1.2	...	...	0.58	0.7
	1.0	...	...	0.72	0.85
	0.8	...	...	0.73	1.0
Wedge wire	...	0.6	22	0.53	0.37
	...	0.6	18	0.58	0.45
	...	0.3	22	0.65	0.75
	...	0.3	18	0.72	0.88

II. The relationship between the mass reject rate and Q index values for the +14 fraction at constant reject thickening factor (RTF = 1.5)

ues than do wedge wire baskets. However, this conclusion cannot be claimed with certainty because the results for the wedge wire baskets and drilled-hole baskets are derived from samples from two feed pulps from two different refinings. The two pulps are not necessarily equal even though both pulps were from Norwegian spruce logs refined under process conditions as similar as possible. As mentioned, the results for the drilled-hole baskets with 0.8-mm holes were obtained from the screening of an accept pulp; therefore, the results for this pulp also cannot be compared directly.

For the drilled-hole baskets, the volumetric reject rate settings during the trials were 45%, 30%, and 15%. The settings at 15% usually failed because of plugging (with the exception of the 1.4-mm holes). The baskets worked easily at 30% volumetric reject rate (2.1–2.2% reject consistency), suggesting that the reject consistency limits for

the drilled-hole baskets were reached well below 30% R_v . More closely spaced data points are needed to determine the precise limit.

The wedge wire baskets could be operated at a volumetric reject rate of 15% R_v at most rotor speeds (up to 3.8% reject consistency). In these cases, however, the screen was very close to plugging. Therefore, it is more likely that a thick reject stream can be processed without plugging through wedge wire baskets with profiled surfaces than through smooth-surface baskets with drilled holes.

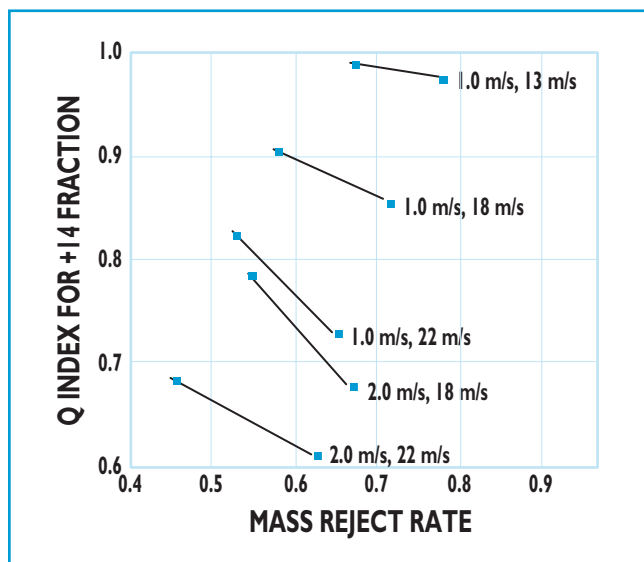
Smooth-surface, wedge wire baskets were not tested during these trials. Consequently, it is not possible to determine whether it is the slotted shape of the aperture or the profiled surface of the basket which acts more to defend the screen against plugging. In our shared opinion, however, the profiled surface of the basket protects more against plugging. A profiled surface imparts a further mixing of the pulp, extending protection against plugging to pulps of higher consistencies.

Nevertheless, no clear conclusions can be drawn as to which design is better suited to yield a thick reject stream. The drilled-hole baskets were far from plugging at their lowest runnable reject rate (30% R_v). On the other hand, the wire baskets were close to plugging (15% R_v). Therefore, the results cannot be compared directly.

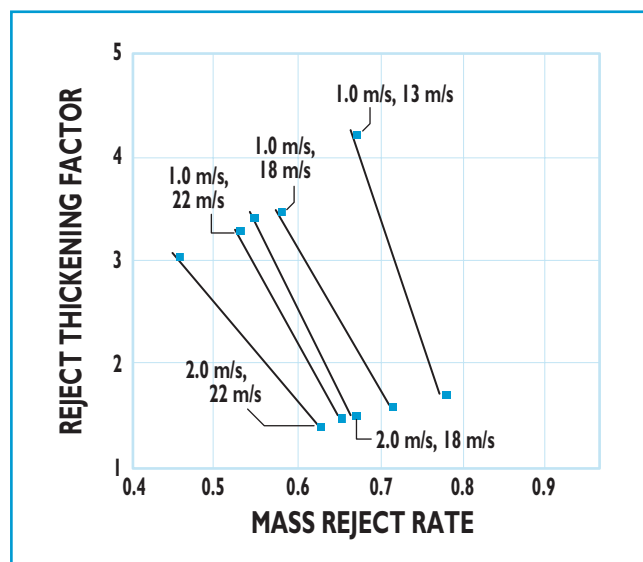
Figures 1–4 show that the conditions which gave the best fractionation in general also gave the highest values for the reject thickening factor.

Aperture velocity and rotor speed

Aperture velocity. For both types of baskets, an increase in the aperture velocity reduced the fractionation efficiency. These results are shown in Fig. 5 for the drilled-hole baskets and in Fig. 6 for the wedge wire baskets. At



6. *Q* index values for the +14 fraction for different aperture velocities (1.0 and 2.0 m/s) and different rotor speeds (13, 18, and 22 m/s) for wedge wire baskets with profile heights of 0.3 mm.



7. Reject thickening factor vs. mass reject rate for different aperture velocities (1.0 and 2.0 m/s) and rotor tip speeds (13, 18, and 22 m/s) for wedge wire baskets with profile heights of 0.3 mm.

the higher aperture velocities, the greater fluid drag drew the long fibers through the apertures proportionally more than it did the shorter fibers.

The aperture velocities and rotor speeds that gave the highest *Q* index values also gave the highest *RTF* values, as shown in Fig. 6 and in Fig. 7.

Figure 7 shows that a higher aperture velocity resulted in less reject thickening. At the same rotor speeds, the lines for aperture velocities of 1 m/s are to the upper right of those for velocities of 2 m/s. This graph may make it seem that an increased aperture velocity helps the screen to run more easily. Presumably, there would be less reject thickening and less risk of plugging.

If that were the case, then it should have been easy to obtain adequate performance with the settings of 2.0 m/s for aperture velocity and 13 m/s for rotor speed. It was possible to run at this rotor speed without plugging at the lower aperture velocity of 1.0 m/s. However, the combination of higher aperture velocity and this same rotor speed caused plugging for the wedge wire baskets.

Plugging by another mechanism.

So far, the type of plugging discussed has been caused by a thickened reject pulp blocking the passage between

the rotor and the screen basket. The type of plugging associated with the high aperture velocities was brought about by another mechanism. This type of plugging occurred several times during the trial. All of the instances had two circumstances in common. First, there was no warning of the approach of plugging by a thickening of the rejects. Second, plugging occurred when the aperture velocity was high and the rotor speed was low.

A theory for this sort of plugging has been proposed for smooth-surface baskets (3, 4). According to this theory, the movement of the rotor aligns the fibers parallel to the screen basket. The flow through the apertures drags the fibers out of parallel movement, turning the leading edge of a fiber down into the aperture. If the aperture velocity is increased or if the rotor speed is decreased, the change will allow more time for the fibers to turn and will increase the probability that long fibers will be accepted. The presence of too many long fibers in the apertures will finally cause the apertures to plug.

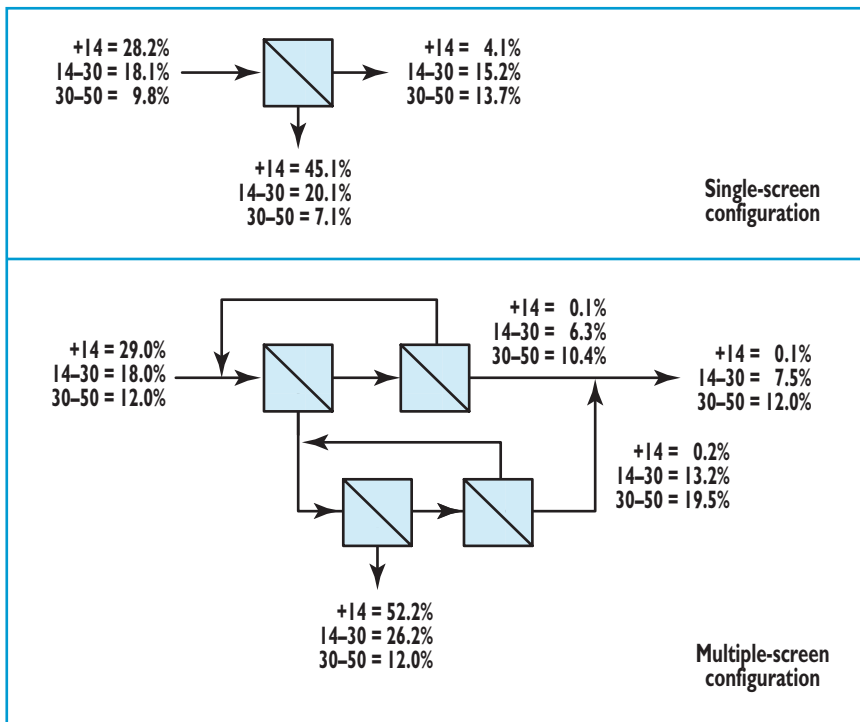
Rotor speed. For smooth-surface baskets, both decreased reject thickening and decreased *Q* index values have been observed when the rotor

speed has been reduced to less than twenty times the aperture velocity (2, 6). The basket finally plugged. For the wedge wire baskets with their profiled surfaces, in contrast to the smooth-surface baskets, a decrease in the rotor speed increases both the *Q* index and the reject thickening.

Smooth-surface, wedge wire baskets have not been tested during these trials. It is therefore not possible to prove which feature gives the increased *Q* index and reject thickening under reduced rotor speed. Is it the slotted shape of the aperture or the profiled surface of the basket?

From our point of view, the profiled surface contributes to this effect more than does the aperture shape. For a profiled surface, an increased rotor speed does not lead to greater alignment of the fibers along the screen plate. Instead, it leads to a more vigorous mixing of the fibers, more acceptance of long fibers, and less reject thickening.

However, at high aperture velocities, the same crowding of fibers within the apertures occurs for the wedge wire baskets as for the smooth-surface baskets with drilled holes. This degree of crowding is attributable to the increased acceptance of long fibers through fluid



8. Experimentally obtained results from a single-screen configuration and a multiple-screen configuration ($R_m = 58.1\%$ for the single-screen system and overall $R_m = 55.1\%$ for the multiple-screen system).

drag. Plugging at high aperture velocities will be particularly prevalent at low rotor speeds because the suction pulse will be too weak to keep the apertures clear of fibers.

For the profiled wedge wire baskets, increased rotor speed causes fiber disorder and the acceptance of long fibers. However, these two conditions will not lead to fiber crowding in the slots and to plugging of the screen. The reason may be that it is not the long fibers themselves which plug the apertures but the flocs created by them. Flocs are more likely to appear in the profiled wedge wire baskets when mixing is gentle (or when the rotor speed is low).

Although plugged apertures are detrimental to the efficiency of separation, excessive mixing of the stock in the screening zone is also undesirable. The influence of the rotor speed on the screen performance will depend on the rotor design and stock characteristics. If the rotor action is insufficient to prevent excessive plugging of the apertures, then the separation efficiency will

improve with an increase in the rotor speed. However, if the rotor action is already mixing the stock excessively, then further increases in the rotor speed will reduce the efficiency. [Differences in rotor design can also affect the screen performance (2).]

Multiple-stage screening

A sharp fractionation was usually followed by a high degree of reject thickening. If the following criteria had to be met during screening, a single screen would plugging:

- Sharp fractionation (such as a Q index greater than 0.95 for the +14 fraction)
- Maximum mass reject rate of 30%
- Minimum aperture velocity of 1.0 m/s to provide capacity
- Minimum feed consistency of 1.5% to meet capacity and dewatering constraints
- Two-stage TMP with a freeness of 150–200 mL CSF as feed pulp.

If the Q index has to be high to provide good fractionation, some of the other constraints have to be

relaxed to avoid plugging. Increasing the reject rate is the simplest and most effective response. Figure 2 and especially Fig. 4 show that reject thickening decreased rapidly when the reject rate was increased. Figures 1 and 3 show that good fractionation efficiencies could be achieved at high reject rates when the hole sizes were kept small (Fig. 1) or when the profile and the rotor speed were kept low (Fig. 3).

To bring the reject rate down to the desired target requires that the potential accept fibers be separated from the reject stream in a subsequent screening stage. The lower configuration in Fig. 8 illustrates such a case.

The screens in the multiple-screen configuration in Fig. 8 have smaller holes than has the screen in the single-screen configuration. The screens in the multiple-screen system run at higher mass reject rates. This arrangement will keep the reject thickening at the same level for all of the screens shown in Fig. 8. Both the single-screen and the multiple-screen configurations have overall mass reject rates of approximately 60% (in these particular runs).

Both mathematical models and practical trials show that the multiple-screen configuration gives a higher overall Q index than does the single-screen configuration at a given overall mass reject rate and a given reject thickening for each screen. A rule of thumb says (7, 8), "Never mix streams of different cleanliness, because mixing them will contaminate the cleanest one." This rule applies in the development of optimal multiple-screen configurations. However, with highly efficient baskets available (high Q values), it is possible to "feed-forward," as shown in Fig. 8. The multiple-screen configuration shown in Fig. 8 is beneficial despite a slight "contamination" of the primary-stage accepts by the secondary accepts.

This concept has probably also been considered by others, but the documentation is poor or nonexistent. These results show that the concept has advantages in terms of separating thermomechanical pulp into fiber length fractions based on Bauer-McNett classes.

CONCLUSIONS

With the baskets and a four-screen configuration as shown in Fig. 8, practical trials showed that it is possible to achieve an almost perfect fractionation of the +14 fraction. In other words, there was almost no +14 fraction in the accept stream. It is possible to achieve a reasonable fractionation of the 14–30 fraction (7.5% in the accept vs. 18% in the feed). However, it is not possible to achieve a useful fractionation of the 30–50 fraction.

The screening conditions that gave the best fractionation in general also gave the highest reject thickening. Improved fractionation (higher Q index values) could be obtained by reducing:

- Aperture size
- Profile height
- Rotor speed
- Aperture velocity.

Despite the decrease in reject thickening obtained by increasing the aperture velocity, this change in velocity gave no protection against screen plugging; rather, it led to plugging of the apertures.

For a drilled-hole, smooth-surface basket, Q values decreased when the reject rate was decreased. For a profile-surface, wedge wire screen, Q values increased when the reject rate was decreased. The price to pay for this increase in Q values is a reject stream that thickens more rapidly than it does for the drilled-hole, smooth-surface baskets at the same mass reject rate.

Multiple screening was required to avoid the problem of a high degree of reject thickening at high Q index values. Each screen worked at high reject rates, and accept fibers were recovered from the reject stream by subsequent screening stages. **TJ**

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