

Mill experiences with conversion of a Kamyr digester to modified continuous cooking

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After modifying a Kamyr single-vessel hydraulic digester to operate with the MCC process, Consolidated Papers, Inc. in Wisconsin Rapids, Wis., raised its pulp strength a total of 12%, improved bleachability of the pulp, and improved the bonding capabilities of the pulp, thereby increasing runnability on the paper machines.

Modified continuous cooking (MCC) has been proven in Kamyr two-vessel hydraulic and vapor-phase digesters.^{1,2} Until two years ago, it had not been attempted in a single-vessel hydraulic digester. Consolidated Papers, Inc. (CPI) is operating a Kamyr single-vessel hydraulic softwood digester with a unique version of modified continuous cooking. Strictly striving for an increase in pulp strength at the same K number, temporary changes were made to the digester in July, 1987. The cooking zone was divided into two sections: a co-current zone and a countercurrent zone. The results being very positive, the initial changes have been made permanent. Other modifications also have been made to the digester to improve the overall operation. Here we discuss our experiences with the conversion, problems we encountered and how they were solved, and the results obtained.

Preliminary expectations

The single-vessel hydraulic digester started up in April of 1985. Softwood pulp produced in this digester is bleached to an 80-82 GE brightness and used to make lightweight coated grades for which strength properties are important. It was for this reason that CPI considered modifying the continuous digester to operate with MCC and hopefully achieve the strength increase that had been

found at other mills and in the laboratory.^{1,2} However, since this would be the first single-vessel hydraulic digester equipped for MCC, there was some concern as to how the digester would react, especially in the winter when most of the chips are frozen and fines can create chip column movement. This usually happens when chips are not properly steamed in the chip bin. Another concern was that since the digester was not originally designed to operate with MCC, the countercurrent cooking time would be three times longer than the co-current time. New and existing continuous digesters designed for MCC typically have cooking zones with equal times.

Digester conversion

The conventional single-vessel hydraulic digester is shown in Fig. 1. The various screens in the digester have been labeled as screens A, B, and C for simplicity. Screens A and B are normally the upper cooking circulation and lower cooking circulation, respectively. Screen C is normally used as the digester extraction. All of the white liquor is charged to the feed system when cooking in the conventional mode.

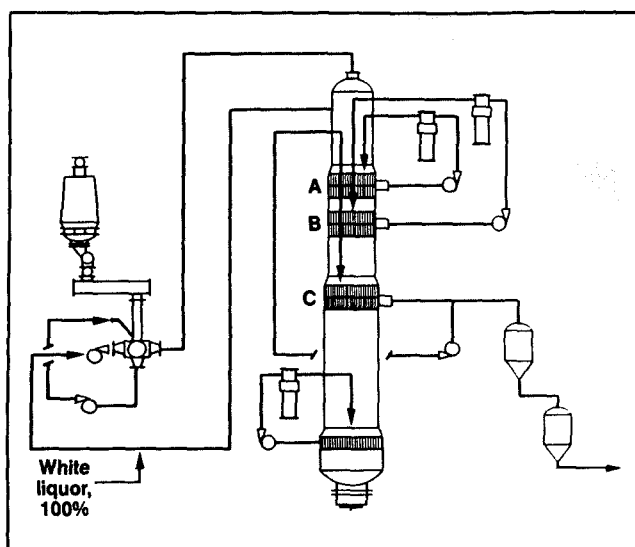
Piping and valves were added to allow the digester to operate in the MCC mode (Fig. 2). Note that screens B and C have swapped functions; screen B is now the extraction screen, and screen C is used for the MCC cooking circulation. The old lower cooking circulation heater and pump are used for this circulation. The quench circulation discharge in the central pipe above screen C is used to complete the MCC circulation. White liquor addition is possible in three locations: to the suction of the upper cooking circulation pump, to the suction of the MCC circulation pump, and, as before, to the feed system.

¹Backlund, E. A., Tappi J. 67(11): 62(1984).

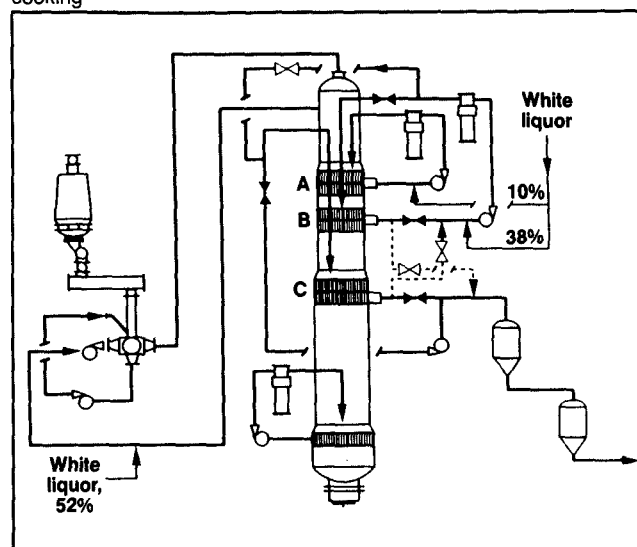
²Kortelainen, V. A. and Backlund, E. A., Tappi J. 68(11): 70(1985).

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1. Conventional single-vessel hydraulic digester



2. Single-vessel hydraulic digester converted to modified continuous cooking



I. Justification trials

1988	Process	T85	Standard deviation	Tear	Mullen	Digester K no.
January	MCC	2.86	0.15	2.89	84.8	23.5
February 9-29	Semi-MCC	2.67	0.10	2.60	87.9	22.7
March 1-10	Conventional	2.54	0.11	2.47	88.3	23.6
March 11-April 25	MCC	2.84	0.13	2.75	87.3	23.4

Optimization

In this digester, the co-current cooking time at a design production rate of 360 bone-dry tons/day is only 25 min, and the countercurrent cooking time is 80 min. The first objective after switching over to MCC was to determine the optimum white liquor split to the three addition points. Since lignin condensation would occur when there is an insufficient amount of alkali present during any part of the cook, we attempted to maintain the same residual in both the downflow liquor and the upflow liquor at the extraction screens (screen B in Fig. 2). The target residual of 0.5–0.7 lb/ft³ effective alkali as Na₂O did not change. By altering the switching valve sequence at screen B, individual samples of downflow liquor and upflow liquor were taken and tested. This was done several times with various white liquor splits until both downflow and upflow liquor residuals were within the target range. The optimum split was determined to be 57% to the feed, 10% to the upper circulation, and 33% to the MCC circulation (57–10–33). However, we have since changed the split to 52–10–38 without any adverse effects on pulp quality or black liquor residuals.

While optimizing the white liquor splits, we also found that white liquor charges of less than 25% to the MCC circulation resulted in high K numbers. This was due to the fact that white liquor was being extracted before

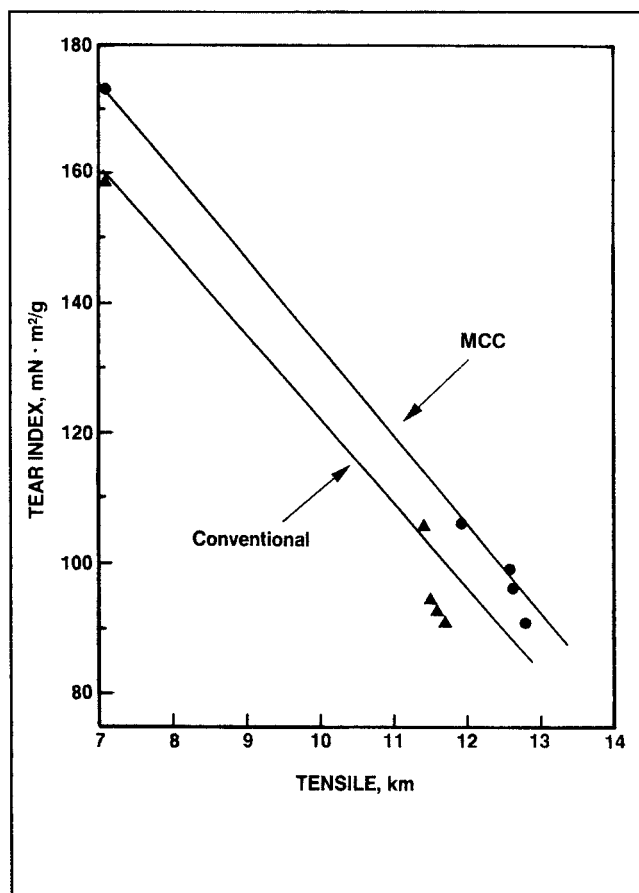
having time to react with the wood in the very short co-current cooking zone. Evidence of this was seen in higher extraction residuals. Therefore, the white liquor charge to the MCC circulation had to be increased.

Resulting strength improvements

The value used to characterize intrinsic pulp strength at CPI is called T85, which is the disintegrated tear value at a mullen or burst of 85. With conventionally cooked pulp, the average T85 for a two-month period prior to switching to MCC was 2.66. After switching to MCC, we immediately saw an increase in the T85 value to 2.85—a 7% increase. We also noted that the pulp was “harder to refine” and, because of this, the disintegration time was changed from 15 min to 30 min. Also, the variability in T85 values decreased significantly, and test results were more repeatable.

In February and March of 1988, comparative trials were run to determine if it was economical to permanently convert the digester to the MCC process. Results are shown in Table I. The first line shows data from January 1988, where the pulp was cooked with the MCC process. Beginning on February 8, the digester was switched back to conventional cooking, but the white liquor was still added at three locations. We will call this method “semi-MCC,” where we do not get the benefit of countercurrent

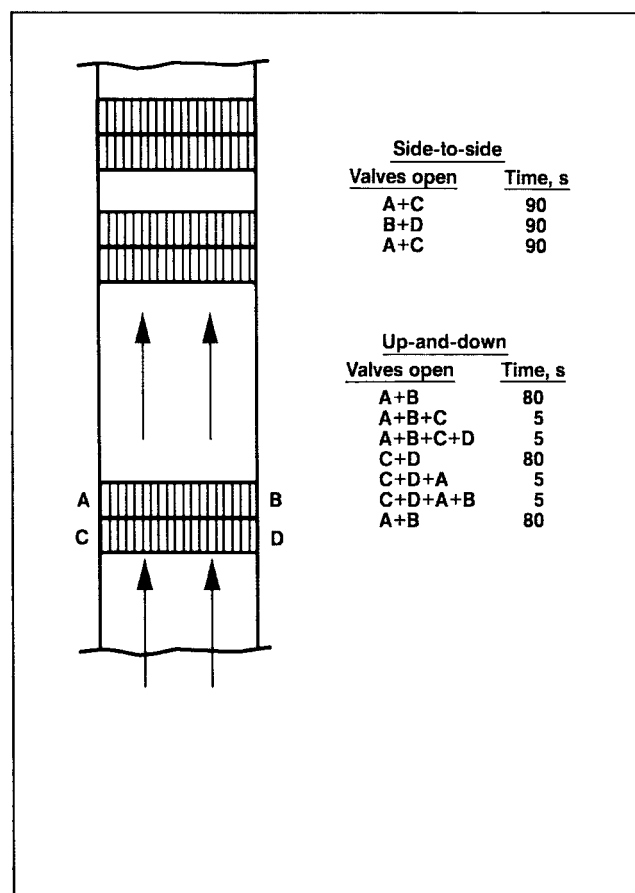
3. Tear vs. tensile for unbleached mill pulps



cooking but where the alkali profile is still evened out. Then, starting on February 29, all of the white liquor was added to the chip feed, which is the standard conventional cooking method. And finally, on March 10, a switch was made back to MCC. The results from this set of trials confirmed the original results, clearly showing a pulp strength increase for the MCC operation. For these trials, the "semi-MCC" operation showed a 6.7% strength improvement and the full MCC operation a strength increase of 12.2%, compared to the March 1–10 baseline conventional cooking period. The baseline conventional period had slightly lower than normal strength, which may account for the magnitude of the strength change (12.2%) as compared to the slightly lower initially realized improvement (7%). Results of a T-test indicate that the T85 averages are statistically significant within a 95% confidence interval.

Within a two-day period, pulp samples were taken when the digester was operating with MCC and then was switched to conventional cooking. Results of tear vs. tensile relationships are shown in Fig. 3 for these unbleached pulps. TAPPI testing methods were used. The tear index is about 9% higher at the same tensile for the MCC pulp compared to conventional pulp.

4. MCC circulation switching valve sequences



Operational observations

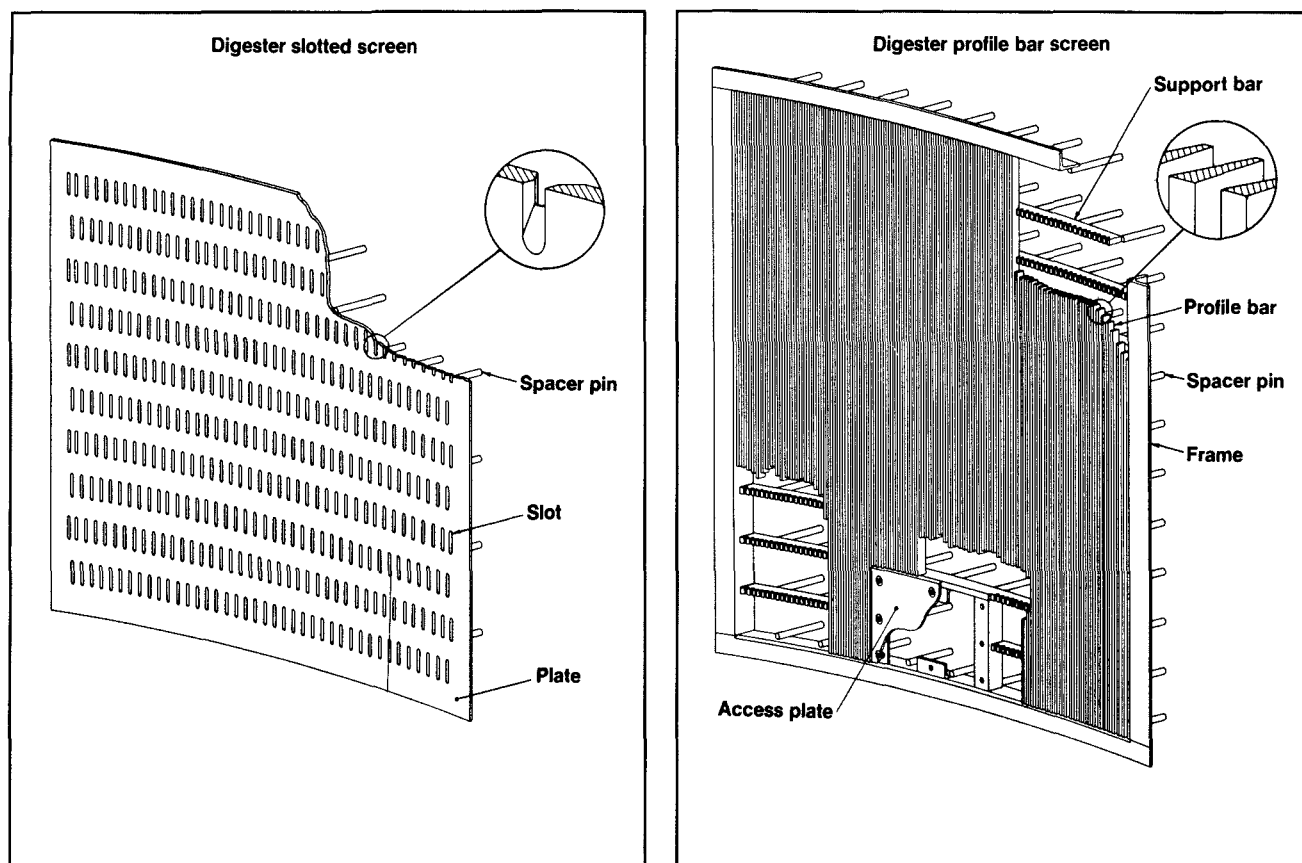
Top circulation temperature

Immediately after switching over to MCC, we noticed a 7–10°F temperature increase in the top circulation (TC) line, which resulted in some pulsation of this line. The higher temperature was caused by a reduction in the charge of white liquor, which normally provides a source of cooling for the TC loop. Some weak black liquor addition (30–125 gal/min) to the chip feed system was required to keep the TC line cool. Eventually, a line was run from the flash liquor pump so extracted liquor from the digester could be added instead. The drawbacks to adding black liquor are that the extraction flow must be increased, and steam requirements are higher. Therefore, white liquor coolers were added in April 1988 to cool the white liquor to the feed system by 40°F. This eliminated the necessity to add black liquor to the feed system.

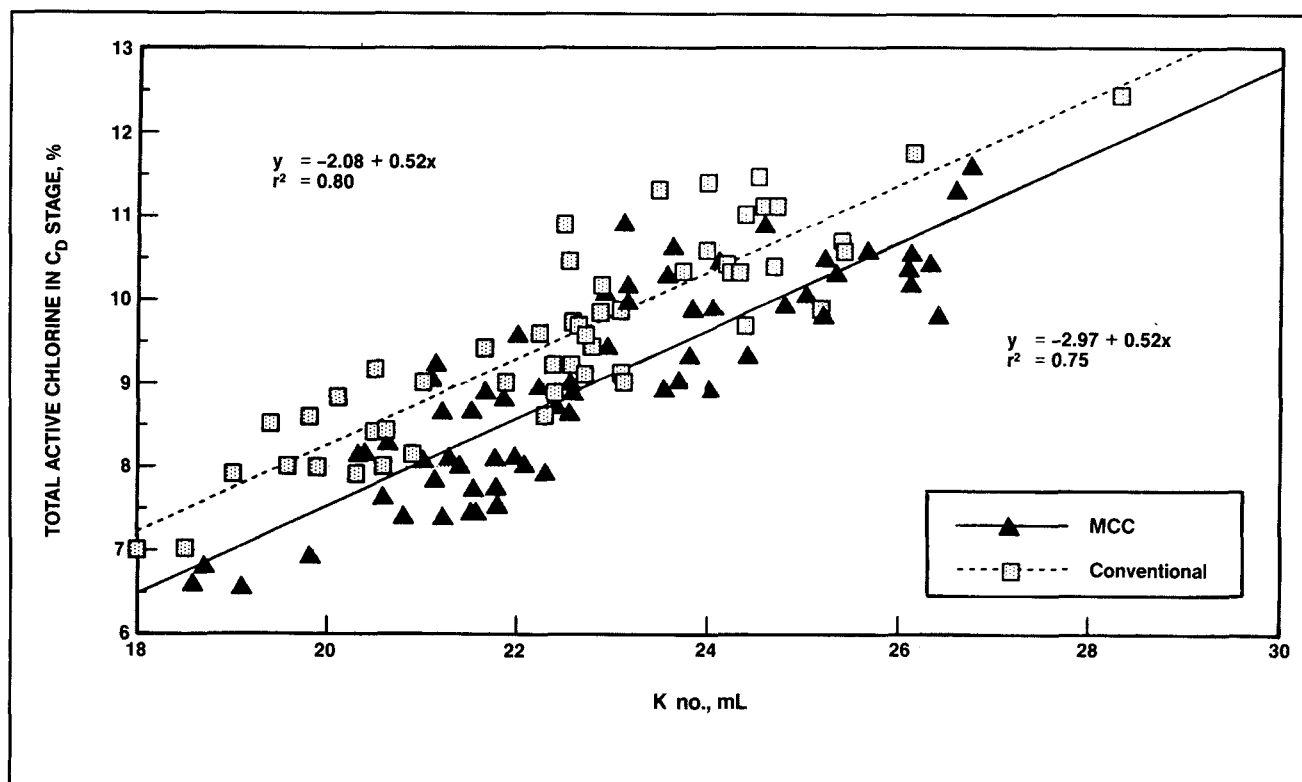
Screen plugging

At times during MCC operation, some minor screen plugging problems developed at the MCC circulation screens. This was indicated by a high differential pressure across the screens and circulation flow limitations. A new switching sequence was devised for the four switching valves changing from the normal side-to-side sequence to an up-and-down sequence. Figure 4 illustrates both

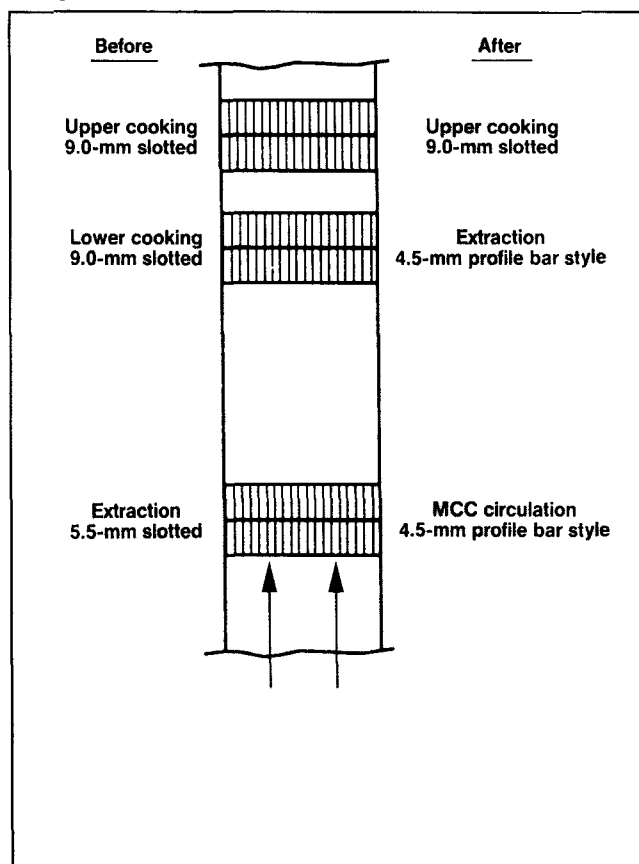
6. Digester slotted screens were replaced with profile bar screens.



7. Cl_2 consumption vs. K number for conventional and MCC operation



5. Digester screens before and after conversion



switching sequences. Side-to-side switching was not effective because each row of screens is connected internally by a circumferential header. By changing to an up-and-down format, one row of screens was completely inactivated at all times to allow the chip plug to wipe the screens. This eliminated the screen plugging problems. The wash heater hot pen temperature was increased from 270°F to 300°F with the new switching sequence. This change minimized temperature swings to the MCC circulation heater since liquor from the lower row of screens is normally cooler than liquor from the upper row.

Corrosion

White liquor addition to the MCC circulation resulted in some corrosion of the mild steel circulation piping due to the increase in alkalinity. This was first noticed after about five months of operation with the MCC process. Leaks first developed at the suction and discharge of the MCC circulation pump. Repairs were made on the run, but leaks continued to develop on a monthly basis until short sections of pipe were replaced in these areas in March 1988. Also, the MCC circulation pump casing had to be replaced due to corrosion.

The second problem area was at the new tie-in to the quench inlet of the central pipe. Erosion was also a factor at this location because of high liquor velocities. Since leaks at this location could not be isolated until an isolation valve was added, the digester operation was temporarily switched back to conventional cooking.

Replacement of mild steel piping with stainless steel in the MCC circulation loop is being planned for the 1990 Labor Day shutdown.

Heater limitation

Since startup, this digester has been operated at production rates of 290–330 bone-dry tons/day, slightly below the design rate of 360 bone-dry tons/day, due to demands for softwood at the paper division. Recent higher rate trials have indicated that the MCC circulation heater has a limitation at production rates above 405 bone-dry tons/day, which is over 12% above design. This heater may have to be upgraded since future plans are to operate the digester at even higher production rates.

Screen replacement

Another major and significant modification to the digester in September 1988 was the replacement of two sets of existing slotted screens with new-style profile bar screens having more appropriate openings. Figure 5 indicates the slot sizes before and after the modification at both locations. Since the digester extraction is now in the same location as the old lower cooking circulation, these screens were changed from 9-mm slotted to 4.5-mm profile bar to minimize fiber entrained with the black liquor. Also, the MCC screens were changed from 5.5-mm slotted to 4.5-mm profile bar to minimize screen plugging and increase the circulation flow since the percentage of open screen area increased from 8.4% to 17.2%. This is illustrated in Fig. 6. With the new continuous-slot profile bar screens, the attainable MCC circulation flow was almost doubled, from 1.75 gal/min/bone-dry tons/day to 3.3 gal/min/bone-dry tons/day without any visible limitations. Results after these changes showed another clear 5% increase in the T85 strength index from 2.85 to 3.0, which most likely can be attributed to an increase in uniformity due to higher liquor circulation rates. Recently, the T85 index has been averaging at even higher values, often greater than 3.1.

Operating with MCC

Digester operators have commented that control of the digester is about the same with MCC or conventional cooking. The K number is controlled by the MCC circulation hot pen temperature while the upper circulation hot pen is kept constant. A constant liquor upflow is maintained in the wash zone and countercurrent cooking zone. The target K number is 22–24 and has not been reduced due to the desire for improved pulp strength. K number standard deviation has improved from 2.0 to approximately 1.7.

Prior to switching to MCC, the total white liquor charge was 18.0–18.5% active alkali as Na₂O on wood. This has been increased to 18.5–19.0% to maintain black liquor residuals in the digester extraction when operating on MCC.

Screenroom operators have commented that MCC pulp at higher K numbers is easier to process than conventional pulp at the same high K numbers. Data on rejects prior to MCC is not available, but recent testing has shown rejects in the primary screen feed are 0.3–0.6% at K no. 22–24.

There is some indication of reduced chlorine consumption for a given K number (**Fig. 7**), but the data scatter is too large to draw definite conclusions at this time.

Conclusions

By modifying the continuous digester to operate with MCC, the goal of an increase in pulp strength was achieved. There was less variability in pulp quality, and the pulp exhibited better bonding capabilities resulting in better runnability on the paper machines. □

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