New fiber-line control concept improves mill performance

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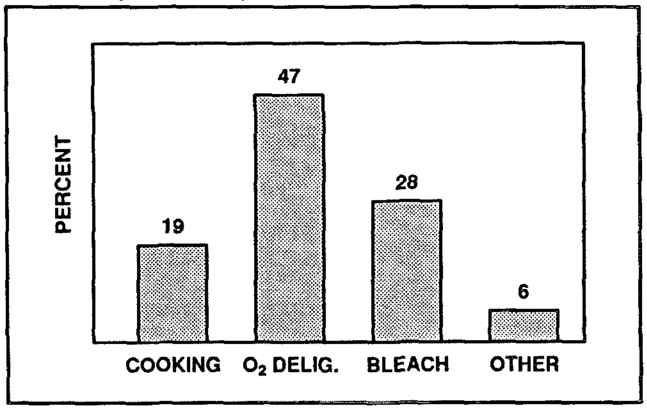
Application of a pulp lignin measurement system for control of kraft and sulfite pulp fiber lines has improved fiber-line operations, reduced bleaching chemical use (particularly chlorine), and reduced production of off-quality pulp.

The main purpose of the pulp fiber line is to delignify wood chips to produce the desired quality of pulp at the required brightness for its end use. For years the industry has relied upon hourly or even less frequent off-line tests of kappa number or a similar lignin determination (such as K-number) procedure to ascertain the level of delignification at several points along the fiber line. The kappa or K-number test also served to judge the quality of control and has been used for feedback control for some stages of the fiber line. It is typically included on the hourly log and is prominent in operating summary reports on the economics of the fiber line in the conversion of chips to bleached pulp. The yield of pulp (supervised by the kappa tests) from the purchased wood is essential to the economics of any pulping operation. In recent years, government and public concern over the environmental effects of effluents from the mill also has caused consideration of more precise methods of controlling the pulp fiber line.

Today an on-line analyzer, the STFI OPTI-Kappa, is available to make critical measurements in the pulp fiber line. Over 40 installations of this analyzer exist on both kraft and sulfite bleached and unbleached lines, with sample points throughout the fiber line (**Figs. 1 and 2**). This paper will review only the application of this analyzer since its design and development have been previously reviewed (*1*). Its application has been driven over the last several years by the industry's need to reduce the environmental impact of effluents coming from the pulp mill. Although this has been the driving force in its application, the potential to use the measurement to improve quality, reduce operating costs, and provide consistent operating data has been a major contributing factor to the acceptance of the OPTI-Kappa.

1. Percentage of sample points in each area of the fiber line



OPTI-Kappa technology in the pulp fiber line

The OPTI-Kappa technology that is now being applied to the pulp fiber line can be compared to the revolution that occurred in paper machine control in the 1950s and early 1960s. Prior to this time, paper machines were controlled based on the operator's experience and the results of a basis weight tear sheet taken at the end of each reel. Following World War II, the introduction of a basis weight sensor using radioactive isotopes gave reliable and continuous measurement of the basis weight and allowed control within the reel. Further control improvements and economic benefits were realized when on-line moisture measurement became possible and both the moisture and the dry fiber (bone-dry weight) of the sheet could be measured simultaneously and controlled independently.

Kappa analysis equivalent to bone-dry weight on the paper machine

The measurement and control of kappa number (lignin content) is comparable to the measurement of the bone-dry weight of a sheet in the paper mill. The on-line measurement of kappa provides the ability to determine the true chemical demand of the fibers and its delignification throughout the fiber line. However, the pulp flow also contains varying amounts of dissolved lignin that also consume chemicals. By sensing the dissolved lignin in the pulp liquor, independent control of each variable is possible, just as moisture measurement allows independent control of fiber and moisture on the paper machine. A correlation of the paper and pulp measurements is

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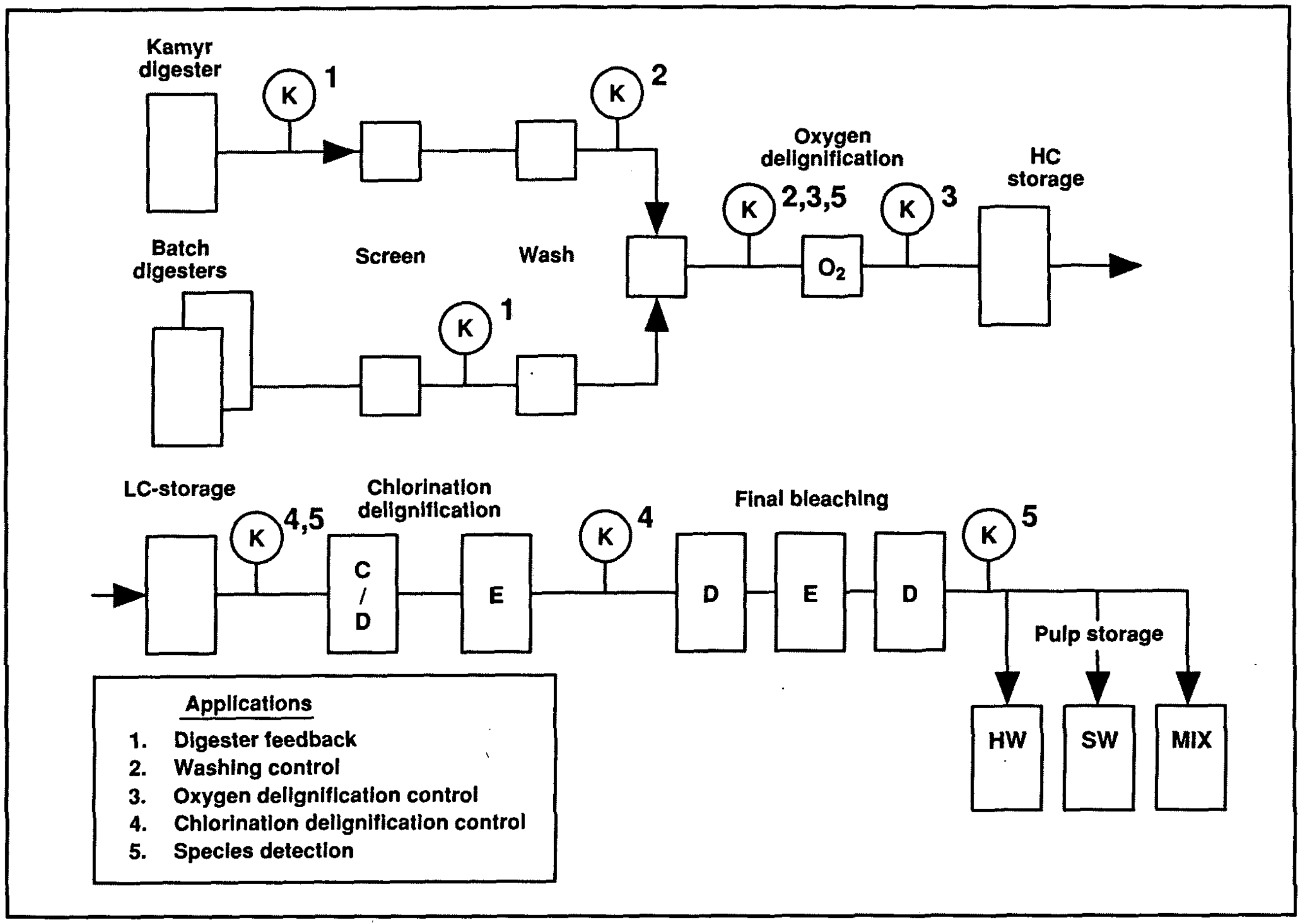
2. Typical OPTI-Kappa sample points



indicated below:

- Total lignin = basis weight
- Dissolved lignin = moisture content
- Kappa number = bone-dry weight.

Kappa analyzer uses

Managing chemical application

Separation of the pulp variables is important for optimizing the fiber line. The kappa measurement indicates the level of delignification of the wood and is used to optimize the control of the processes for cost, quality, and production. By applying bleaching chemicals based on the amount of lignin present, the level of AOX, dioxin, furans, and chloroform development will be consistent, and tests should be repeatable (*2*).

Since the optimal chemical addition varies based on the incoming kappa number, the chemicals can be applied continuously, based on the desired chlorine multiple, kappa multiple, or both, as the incoming lignin conditions change. The CD stage may be run with varying dioxide substitution, with sequential addition, and without a measurable chlorine residual when using feed-forward chlorine multiple control.

By using an on-line kappa sensor to measure before and after a delignification stage or stages, measurement of the lignin drop across the stage may be calculated and used to manage the chemical application. This approach ensures that the pulp does not exceed the delignification limit, which could cause viscosity problems or excessive chemical use.

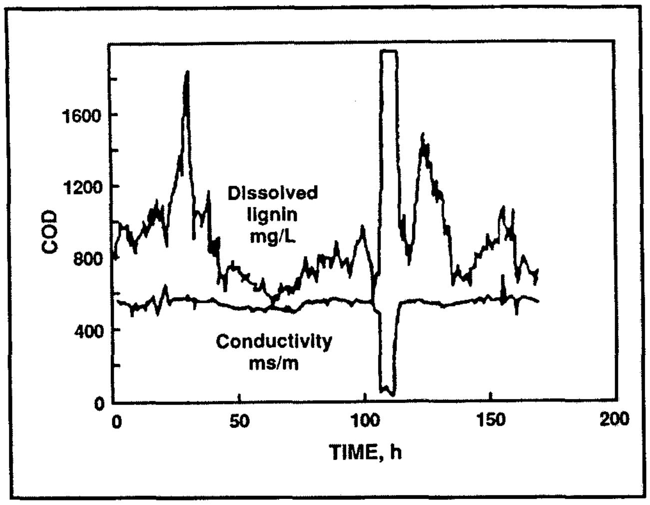
Dissolved lignin measurement

Using the dissolved lignin measurement, control of washing operations can be improved. The dissolved lignin (carry-over) measurement is also useful in sensing washer operation changes in the pulp as it enters the bleach plant, where it may require a different chemical dosage. In oxygen delignification, the level of the dissolved solids may have a detrimental impact on the selectivity of the delignification (*3*). By sensing the dissolved lignin of the incoming pulp, changes in the dissolved solids can be indicated and control actions taken to avoid long periods of unacceptable pulp quality.

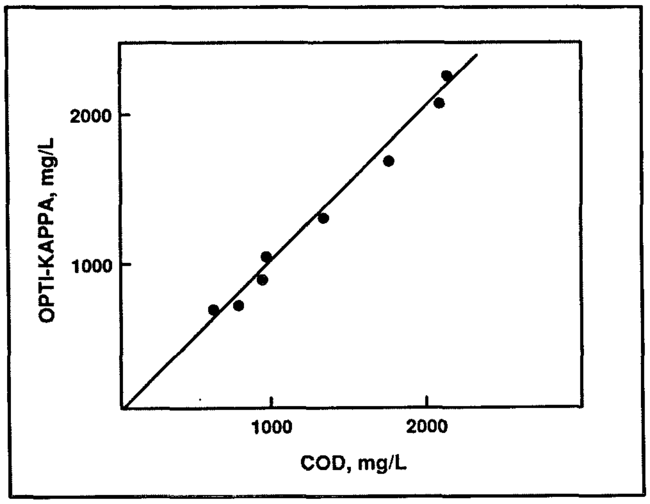
Modified cooking control

The level of dissolved lignin in the final stage of cooking is critical to the quality of the cook. Modified or extended cooking, where the ratio of the effective alkali to dissolved lignin is increased during the final stage of the cooking process, has shown substantial improvements in the viscosity and strength of pulp at the same kappa number when compared to conventional cooking (*2*, *4*). The on-line dissolved lignin measurement is useful to evaluate the changing lignin content. An on-line kappa measurement

3. Comparison of washer conductivity sensor reading with analyzer dissolved lignin (COD)



4. Correlation of analyzer dissolved lignin measurement with laboratory COD



in the blow line provides a continuously available result for quick feedback to minimize variations from target.

Reduce tester manpower

The application of the OPTI-Kappa to a fiber line will provide more consistent and reliable data regarding the variations in the fiber line. Since multiple sample points may be attached to a single analyzer, the normal kappa testing for an entire fiber line could be fully automated (Fig. 2). Data will not be biased and will be consistent with the sample time at the process.

Washer control and evaluation

The initial testing of the OPTI-Kappa sensor indicated that it could measure the performance of washing by measurement of the dissolved lignin in the liquor. The sensor, using a sampler designed to obtain precise amounts of the wash liquor, could be useful in evaluation and control of the washing operations in a pulp mill. The tests were carried out by STFI to determine how the OPTI-Kappa sensor related to typical measurements made for control of the washing operation (*5*).

In Sweden, the focus of washing control has shifted over the years from using dissolved inorganic matter, as estimated by soda loss analysis, to dissolved organic matter tested as chemical oxygen demand (COD) in the lab, as a measure of washing performance. This is consistent with the requirements of the Swedish regulatory authorities for reporting to be done in COD.

In many mills in North America, an on-line conductivity sensor, an indication of the dissolved inorganic matter, is used to determine the soda loss. Typically, a conductivity sensor installed in the drop leg from the last washer of a conventional three-drum line is used to indicate the concentration of inorganic matter in the liquor. Data from a test installation (**Fig. 3**) indicate that the trend in the dissolved lignin is similar but not identical to the trend in the conductivity sensor. At the significant peak in dissolved lignin, the conductivity signal responds in a directly opposite way. This is because the process was changed to have the pulp bypass the last washer. The conductivity sensor was reading just the wash liquor being fed to the washer while the OPTI-Kappa, located in the pulp stream, was indicating the unwashed pulp.

The same analyzer was calibrated in COD units and correlated to lab COD tests on a softwood line after a continuous digester (*5*). As expected, the on-line comparison was excellent (**Fig. 4**).

Feed-forward to oxygen and bleach plant control

An important use of the dissolved lignin measurement is as a feed-forward signal to compensate for extra chemical demand. In the first stage of a conventional bleach plant, there is no way to distinguish the extra lignin dissolved in the liquor; additional chemicals will be added as if the lignin was due to an increase in the kappa number of the pulp. By knowing the changes in both the dissolved lignin and in the kappa number, the precise chemical addition may be made.

For pulp fed to the oxygen reactor a change in the dissolved solids (lignin) can have an undesirable impact on the rate of delignification in the reactor as shown by Miller (*3*). If known, the flow of oxidized white liquor may be adjusted to avoid the upset and achieve the desired delignification.

Species detection

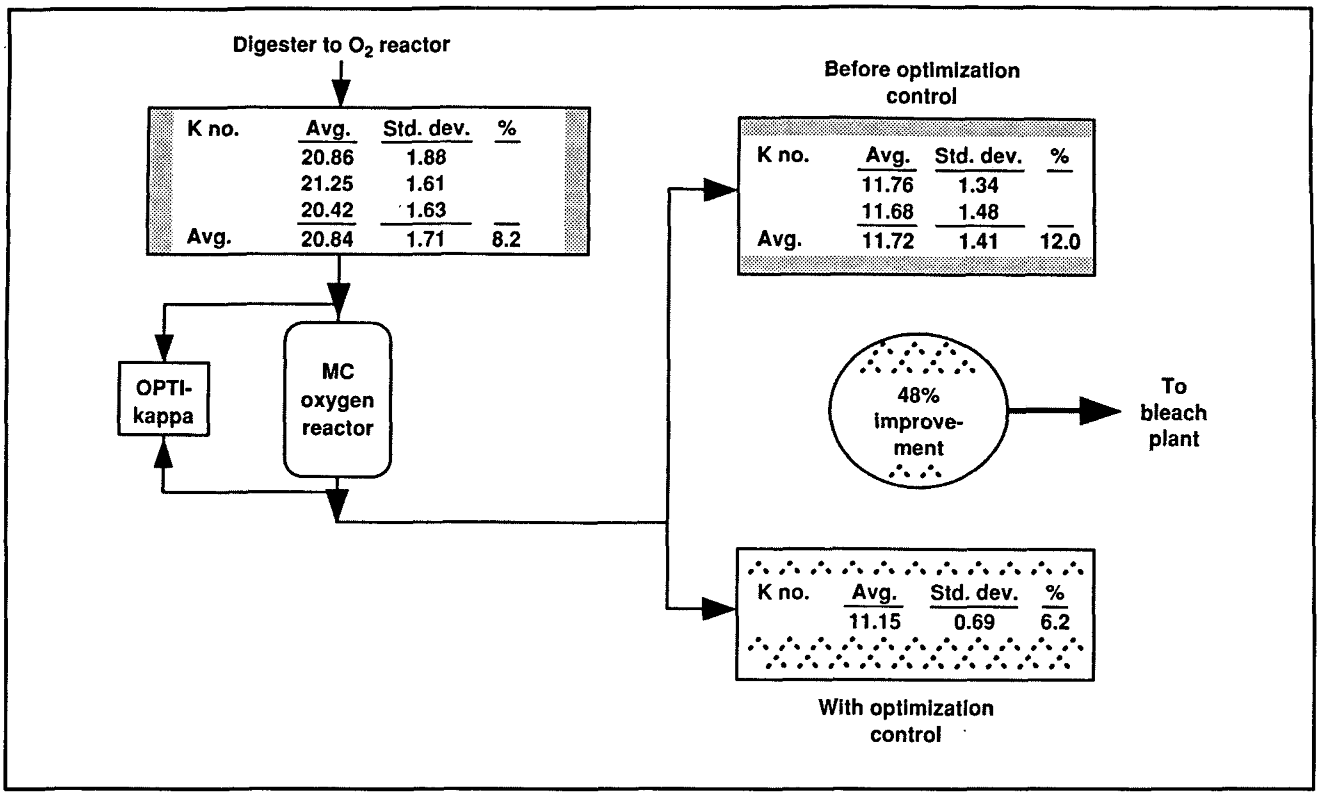
In swing lines, the ability to know when the pulp is fully at the new species is beneficial. An in-line measurement indicating the precise interface between the two species helps ensure that first-quality pulp is always available for critical grades without running longer than necessary to the twilight tower. For blend operations the signal can indicate changes in the blend as they occur so appropriate compensation may be initiated.

Installation experience

Sweden

In Sweden, the pressure to reduce the chlorinated compounds in effluent from the pulp and paper industry has been increasing for the last decade. The current AOX limit of 2 kg/a.d. metric ton will be cut in half by 1995 and in half again before the end of the decade. These

5. Improvements in medium-consistency oxygen reactor control using an on-line kappa analyzer



regulations have led the Swedish industry to invest heavily in process changes such as oxygen and extended delignification and in controls to minimize effluents. Today, over 85% of the bleached pulp fiber lines in Sweden utilize an on-line kappa sensor to optimize fiber-line delignification and chemical addition. One Swedish operation produces fully bleached pulp with a dual-vessel Kamyr digester, oxygen reactor, and a DE(O)DD bleach plant, swinging from hardwood to softwood every four to seven days. On-line measurements of kappa, dissolved lignin, and fiber size are taken from sample points around the reactor, in the bleach plant, and at the CEK position. By extending delignification using the oxygen reactor and optimizing control, an AOX as low as 0.2 kg/a.d. metric ton is achieved.

Oxygen delignification

The desired control for a medium-consistency oxygen reactor is to minimize variations out of the reactor without detrimental impact on pulp strength. The variations in the incoming pulp lignin content must be addressed to provide a stable kappa number from the reactor, which will lead to chemical savings and yield improvements in the bleaching operation that follows. By modeling the reactor operation and sensing both the incoming and outgoing kappa, the control system can compensate for incoming kappa variations that would normally cause viscosity problems or lead to excessive use of chemicals.

Figure 5 shows the results of oxygen reactor control with and without the benefit of on-line kappa measurement. Using typical control without the on-line kappa information, the percent variation of laboratory kappa numbers actually increased through the reactor. Using a proprietary control algorithm incorporating the on-line kappa measurements, a 48% reduction in the outgoing laboratory kappa number variation was documented. This substantial reduction in variation produced a chemical savings in the bleaching operations that followed of over US$ 2.15 per ton.

Conventional bleaching

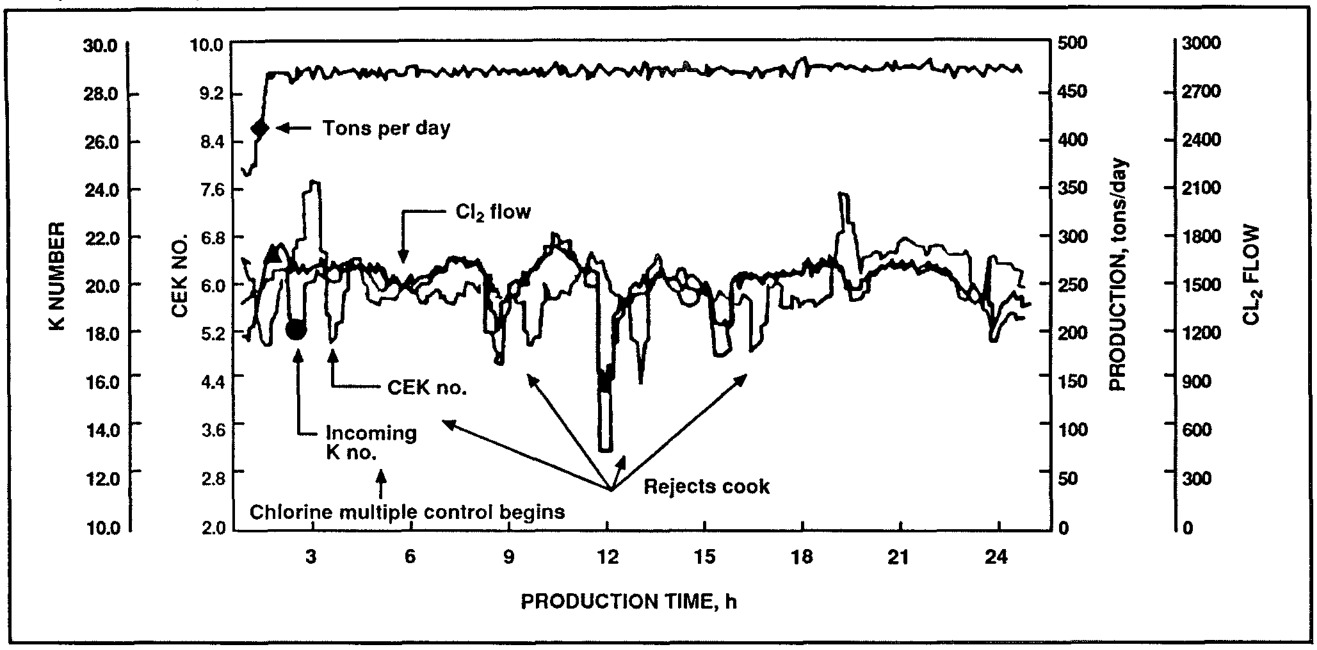
For conventional bleaching operations, two sample points normally are used: one before the C/D chemical addition; and another either before or after the E-stage washer to provide a CEK number.

With the initial sample point, the fiber size measurement is used to detect species or blend changes, and the dissolved lignin measurement is used to compensate for any change in the washer carry-over. The C/D-stage chemicals are applied based on the kappa measurement to achieve the desired chlorine multiple and percent substitution. Changes in the CEK number are measured (lignin going into the first brightening stage) and are fed forward to control the chemical application in the following stage. Some mills use an alternate control strategy where the C/D-stage chemicals are applied to achieve a constant CEK test. In these operations, the CEK sample results provide a feedback signal to bias the C/D-stage control. Chemical savings in excess of 10% and reduced environmental impact from bleach plant effluent have been documented on conventional bleach lines (*6*).

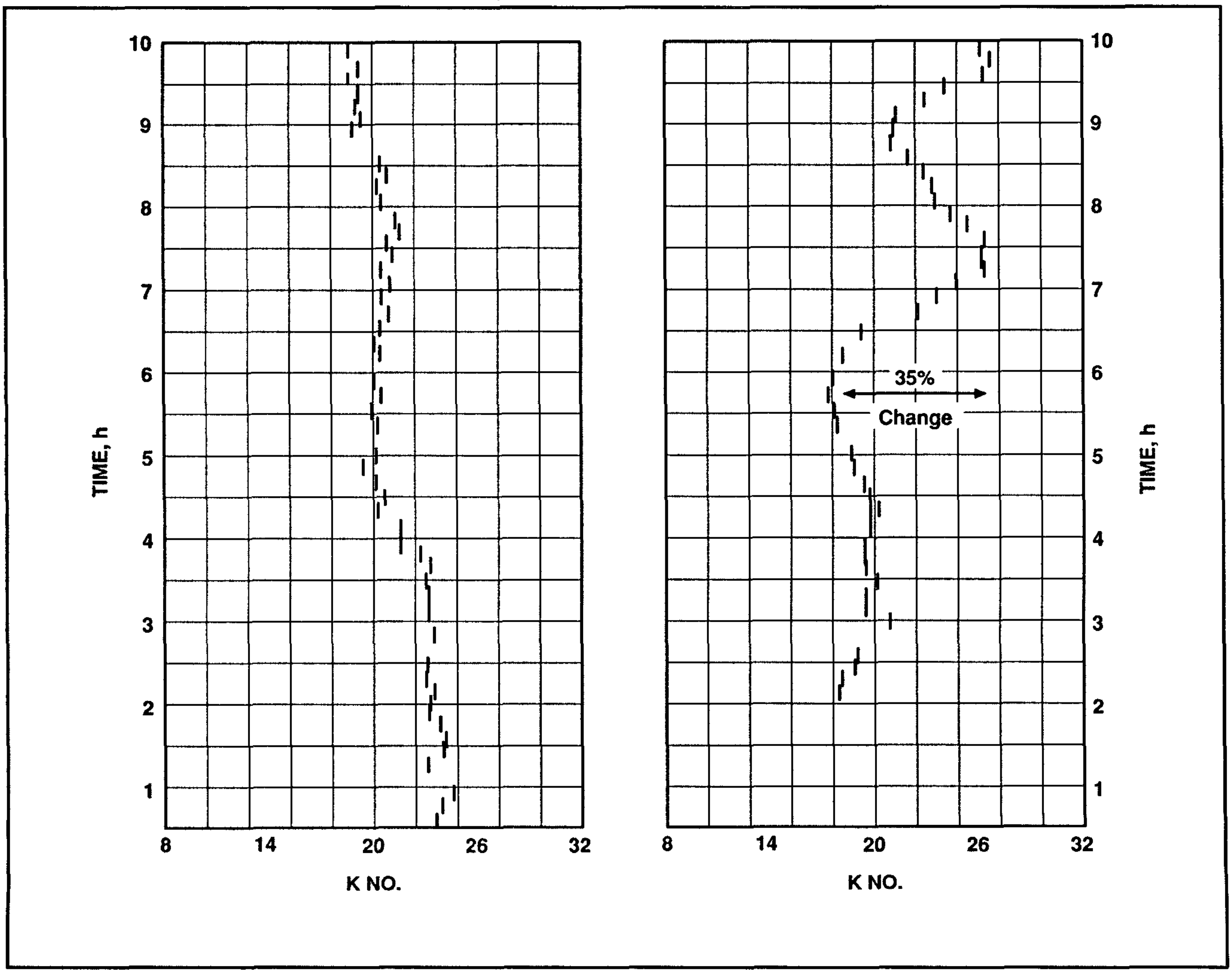
Digester control

As an example of the ability of the OPTI-Kappa to be used for digester control and evaluation, **Fig. 6** shows the trends from a conventional bleaching line that is fed by 12 batch digesters. Shortly after seeing the kappa trends, the

6. Improved bleach plant visibility on the impact of rejects cooks in a batch operation



7. Kappa number trends from the blow line of a Kamyr digester producing bleachable-grade pulp during normal and upset conditions



operators and pulp mill management better understood the operation. Randomly, about four times a day, one of the digesters is used to recook rejects, which are sent to the bleach plant as normal pulp. These blows show up as soft cooks at both the incoming and CEK location.

Prior to this measurement, there was no means of responding to the rapid change, and most of the time it was not noticed. With control in use, the variations at the CEK location are reduced, and a chemical savings of approximately 2% is achieved. Other methods of reducing the disruption from the rejects cooks are now under consideration by the mill.

An on-line kappa sample point is installed downstream from continuous digesters on more than 25 fiber lines. These fiber lines produce hardwood and softwood pulps, primarily bleachable grades, although some applications are on linerboard. Some of the installations sample the pulp from the Kamyr blowline (typically from the sample pot), but others sample farther downstream after the screen room. In either case, the nearly continuous display of the kappa trend has been useful in understanding digester operation and improving control (**Fig.** 7).

Using the on-line measurement for feedback control has improved the kappa control of Kamyr digester optimization control packages by approximately 20% (*7*). The higher frequency of the kappa data and the greater consistency and reliability of the information has made on-line measurement a desirable tool for improved control and evaluation of the Kamyr process.

Conclusions

On-line kappa analyzers providing measurements of kappa, dissolved lignin, and fiber size can dramatically improve the management of the pulp fiber line. The on-line kappa measurement is important for optimizing chemical use, for managing delignification in the oxygen reactor, and to provide feedback to the pulping operation. Sensing the dissolved lignin for control of washing and to compensate for changes in the washer carry-over to oxygen reactors and the initial bleaching stage has additional potential. Kappa sample points along the fiber line are useful in the optimization of the yield, costs, environmental impact, and quality of the operation.□

Literature cited

1. Kubulnieks, E., Lundqvist, S-O., and Petersson, T., Tappi J. 70(11): 38(1987).
2. Bowen, J. and Hsu, J.C.L., Tappi J. 73(9): 205(1990).
3. Miller, W. J., Shackford, L. D., Jiang, H., and Genco, J., Tappi J. 74(2): 117(1991).
4. Jameel, H., Extended Delignification Technology, presented at Workshop on Emerging Pulping and Chlorine-free Bleaching Technologies, Raleigh, NC, March 1991.
5. Hansson, A. and Kubulnieks, E., The STFI OPTI-Kappa: a new tool for On-line Measurement of Dissolved Lignin, STFI Report, Dec. 4, 1990.
6. Soderberg, J., Almberg, M., Kubulnieks, E., Lundqvist, S-O., *et al.*, Tappi J. 71(11): 145(1988).
7. Horner, M. G. and Rasmusson, L., 24th EuCePa Conference Proceedings, Pulp Technology, EuCePa, Helsinki, 1990, p. 242.

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