Extended delignification, an alternative to conventional kraft pulping

Fernando E. Mera

Northwest regional manager, Beloit Corp., Pulping Systems Division, 6005 N.E. 82nd Avenue, Portland, Ore. 97220

Jeffrey L. Chamberlin

Senior research engineer, Beloit Corp., Pittsfield R&D Center, 448 Hubbard Avenue, Pittsfield, Mass. 01201

ABSTRACT *Mill and pilot plant data for market-grade bleached pulp were evaluated. The pulp quality was equivalent to or better than that of bleached pulps obtained by conventional kraft pulping and bleaching techniques. However, operating parameters favored extended cooking in the rapid displacement heating process. These parameters were lower active alkali consumption, lower bleaching chemical demand, and lower bleach plant effluent liability.*

KEYWORDS
Bleaching
Delignification
Kraft pulping
Pulping

Conventional kraft pulping to bleachable kappa number ranges of 28–32 for softwoods and 18–22 for hardwoods has been common in the industry for many years. As an alternative to kraft pulping to conventional ranges, the further reduction of the kappa number in the digester, better known as "extended delignification," has been successfully demonstrated in the mill.

Based on data from pilot plant trials and commercial operation, a quantitative and qualitative comparison of extended pulping with conventional kraft pulping was undertaken. Our rapid displacement heating process (RDH) was used in this study. Commercial experience with the RDH pulping system has already been reported (*1, 2*). The process features have been described (*3*), and the impact on the mill energy balance has been evaluated by others (*4, 5*).

In our study, softwood chips from Latin America and the Pacific Northwest were cooked to low kappa numbers (in the 18–20 range) and bleached to 90% ISO brightness using a short bleaching sequence of (D+C)(E+O) DED. Pulps and liquors were tested by TAPPI and CPPA methods. The pilot plant trials were performed at the Econotech facilities in Vancouver, and the commercial data were obtained from the Joutseno Oy Pulp Mill in Finland.

Pilot plant trials on RDH pulping

The simulation of the RDH pulping system was carried out using Joutseno Mill process parameters. The pilot plant procedure is as follows:

1. The digester was preheated and charged with chips.
2. The digester was charged with warm liquor in excess of the digester volume to ensure a hydraulically filled digester.
3. Warm liquor was displaced with hot black liquor at 167°C. White liquor was added with the the hot black liquor at a rate equal to that of the mill. Pressure was kept at 95 psig.
4. The digester was brought up to the pulping temperature by circulating the liquor through an indirect heat exchanger.
5. The "H" factor was monitored from the time white liquor was added to the digester.
6. When the desired "H" factor was reached, displacement with 80°C filtrate was carried out. Concentration of the various liquors was monitored throughout the cook.

Bleaching was performed to obtain market-grade pulps of high brightness. Conventional five-stage (D+C)(E+O)(D_1 E_2D_2) and three-stage (D+C)(E+O)[DED] sequences with and without oxygen were evaluated. The reported bleaching parameters were not optimized for chemical usage.

Shown in **Table I** are data for the mixture of *Pinus elliottii* and *Pinus taeda*. RDH cooks required less active alkali to obtain an equivalent kappa number. Low kappa numbers were obtained by increasing active alkali charge and "H" factor. Tear and tensile strength data for the mixture are shown in **Fig. 1**. The RDH, extended, short-sequence pulps with high ClO_2 substitution are stronger than the pulps of the conventional five-stage sequence.

Chips from the lodgepole pine and spruce mixture were cooked to three different kappa numbers. This trial was carried out to evaluate RDH pulping parameters, bleachability, and

I. Conventional kraft vs. RDH parameters

Parameter	*Conventional kraft*	*Conventional RDH*	*Extended RDH*
Active alkali, % on o.d. wood	17	16	17.0
Liquor/wood ratio	3.5	5.0	5.0
H factor	1400	1400	2000
Max. temp., °C	173	173	173
Kappa no.	33	30	20
Yield, %	47	47	45
Viscosity, cm^3/kg	1160	1120	985
Brightness, ISO %	91	...	91

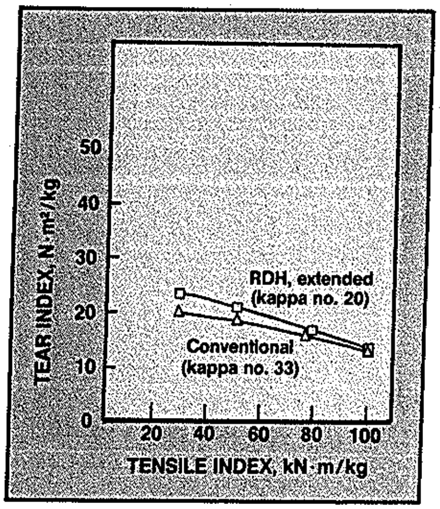
Mixture of *Pinus elliottii* and *Pinus taeda*.

II. RDH process parameters

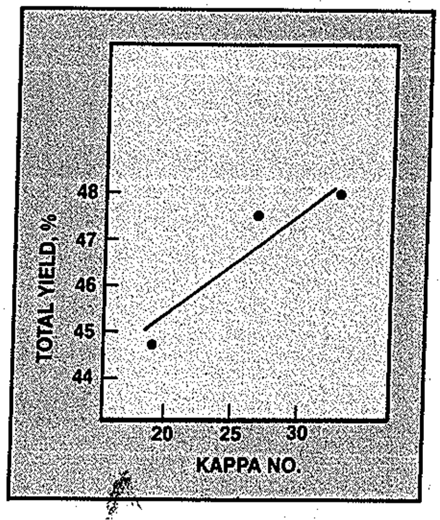
	Conventional	*Intermediate*	*Extended*
Active alkali, % on o.d. wood	15.0	15.5	16.75
Sulfidity, %	30	30	30
Liquor/wood ratio	6	6	6
H factor	1400	1400	2000
Yield, %	48.0	47.5	45.0
Kappa number	33.5	26.7	18.9
Viscosity, cp	41.4	38.2	26.2
Residual active alkali, g/L	14.3	16.4	15.7
Carbohydrates analysis, %			
Mannan	5.1	5.0	5.2
Xylan	8.6	7.9	8.5
Glucan	76.9	77.0	77.7

Northwest softwood: lodgepole pine and spruce

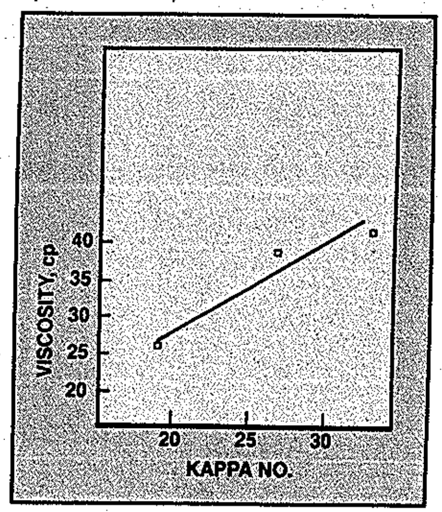
1. Tear strength and tensile strength data for the mixture of *Pinus elliottii* and *Pinus taeda*



2. Kappa number and total yield for unbleached RDH pulps (lodgepole pine and spruce mixture)



3. Viscosity vs. kappa number for unbleached RDH pulps (lodgepole pine and spruce mixture)



physical properties. The pulping parameters are shown in **Table II**. To drop the kappa number from 33.5 to 18.9, the active alkali charge was increased by 1.75% on o.d. wood, and the "H" factor was increased from 1400 to 2000. The carbohydrate analysis indicated that the glucan fraction increased as the kappa number decreased. Total yield and viscosity vs. kappa number are shown in **Figs. 2 and 3**. Yield and viscosity decreased as a function of the drop in kappa number.

The tear and tensile strengths for the unbleached pulps are shown in **Fig. 4**. The RDH pulp with a kappa number of 18.9 is stronger than the RDH pulps with kappa numbers of 26.7 and 33.5. An explanation for this phenomenon is not yet available, but it may be related to the increase in the glucan fraction over the mannan and xylan fractions as the kappa number drops.

RDH-enhanced selectivity and strength properties may be related to a higher concentration of hydrogen sulfide ions at the beginning of the cook prior to adding fresh white liquor. The wood chips are exposed to hydrogen sulfide ions in the RDH process during the warm liquor fill. Vikstrom (*6*) indicates a sulfide ion deficiency at the beginning of conventional kraft pulping when the reaction rate is changing from the initial to the bulk phase.

Bleaching data from a sequence without an oxygen stage are shown in **Table III**. Effluent color decreased as a function of delignification. The viscosity of the bleached pulp is shown in **Fig. 5**. The viscosity of pulp produced by extended delignification is less affected during bleaching (Table III). As **Fig. 6** shows, total active chlorine demand for equivalent brightness was reduced from 11.7% (kappa no. 33.5) to 7.5% (kappa no. 18.9). NaOH was also reduced from 4.3% to 2.7%.

Bleaching data from a sequence with an oxygen stage are shown in **Table IV**. The major appeal of this sequence is the reduction in color from the effluent. However, viscosity and strength properties decreased

III. RDH bleaching without an oxygen stage

	Conventional RDH	Intermediate RDH	Extended RDH
Initial kappa no.	33.5	26.7	18.9
Initial viscosity, cp	41	39	26
Total active Cl_2, %	11.7	9.8	7.5
Total NaOH, %	4.3	3.4	2.7
Elrepho brightness, %	91.7	91.9	91.0
Viscosity, cp	32.0	26.4	21.0
Effluent			
(D+C) color, mg/L	1710	1440	1242
(E+O) color, mg/L	8456	7000	5826

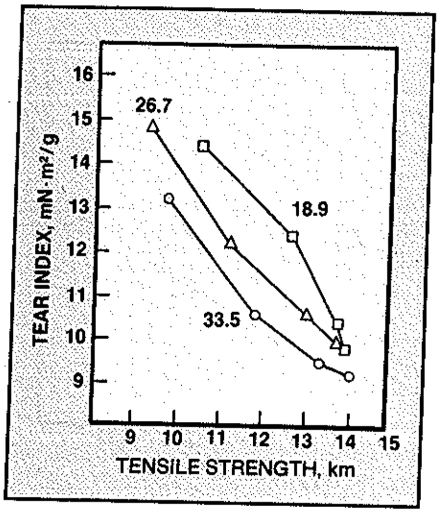
Lodgepole pine and spruce mixture.

IV. RDH bleaching with an oxygen stage

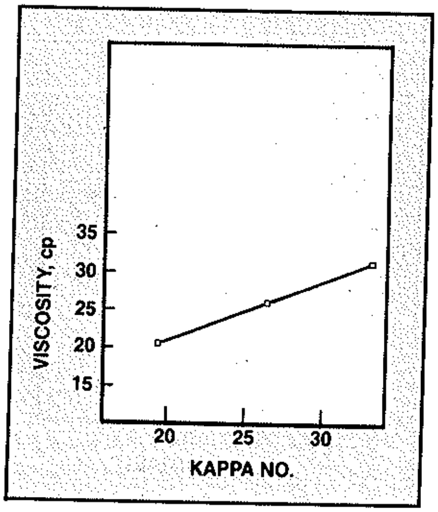
Initial kappa no.	33.5	26.7
Initial viscosity	41	39
O_2 stage		
NaOH, %	2.1	1.8
$MgSo_2$, %	0.1	0.1
Retention, min	60	60
Temperature, °C	100	100
Consistency, %	11	11
Kappa no.	15.1	13.1
Viscosity, cp	22.3	20.1
O_2 charge, psig	80	80
(D+C) (E+O) DED		
Total active Cl_2, %	6.5	5.8
Total NaOH, %	2.3	2.0
Brightness, %	91.3	91.2
Viscosity, cp	18.5	17.3
Effluent		
(D+C) color, mg/L	595	491
(E+O) color, mg/L	3580	2827

Lodgepole pine and spruce mixture

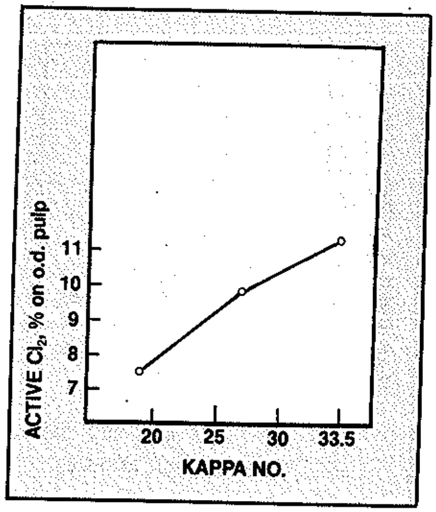
4. Tear and tensile strength for unbleached RDH pulps (lodgepole pine and spruce mixture)



5. Viscosity of RDH pulps bleached to 90%+ brightness



6. Total active chlorine for RDH pulps bleached to 90%+ brightness



when the oxygen stage was introduced. As **Figs. 7 and 8** show, the tear and tensile strengths at equivalent brightness were better for the RDH, extended-delignification pulp bleached without an oxygen stage.

Mill data on RDH pulping

Strength properties for unbleached RDH pulps produced at the Joutseno Mill in Finland are shown in **Table V** and tensile strength are shown in **Fig. 9**. In **Fig. 10**, viscosity and tear strength at constant tensile strength are plotted against kappa number. The effluent is characterized in **Table VI**.

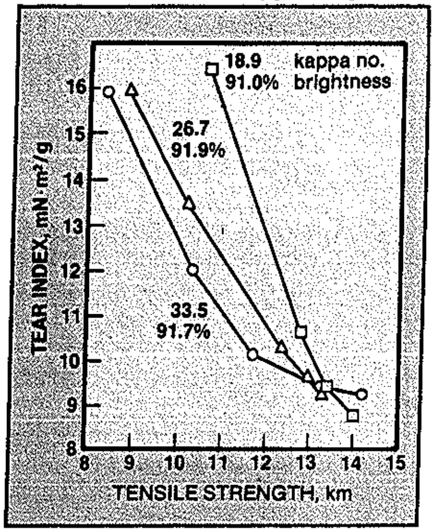
Unbleached RDH pulps tested under mill parameters are equivalent in strength properties over a wide range of kappa numbers, as Fig. 9 shows. However, in the pilot plant trials, unbleached RDH pulps produced by extended delignification are stronger than unbleached RDH pulps cooked to conventional kappa numbers, as Fig. 4 shows. This strength difference is maintained after bleaching (Fig. 7). Bleached RDH pulps produced by extended delignification are stronger than conventional bleached kraft pulps, as Fig. 1 shows. Jokela also found that bleached RDH pulp produced by extended delignification was stronger than conventional bleached kraft pulp (*7*).

Black liquor viscosity

The molecular weight of the lignin fraction influences black liquor viscosity. One way to decrease viscosity of strong black liquors is to expose the weak black liquor to high temperatures for a few hours. Soderhjelm (*8*) compared the viscosity of the liquor entering the RDH hot black liquor accumulator with the viscosity leaving the accumulator. The temperature in the accumulator was 150°C. The viscosity decreased from 355 mPa·s to 150 mPa·s at 70% solids contents.

The evaluation of the pilot plant black liquor (**Fig. 11**) was in agreement with mill data. The residual active alkali (13 g/L) in the hot black

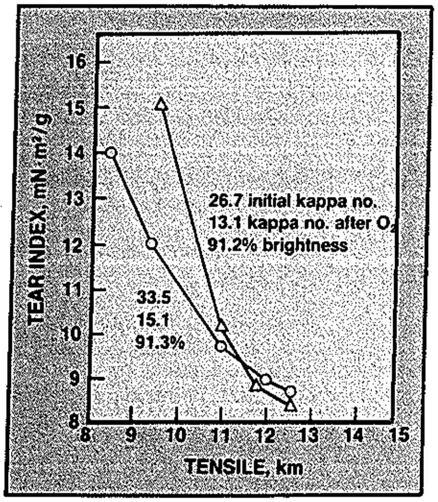
7. Tear and tensile strength for RDH pulps bleached without an oxygen stage



V. Strength properties for unbleached RDH pulps at the Joutseno mill

Kappa	*Viscosity, dm³/kg*	*Schopper-Riegler, °*	*Tensile, N·m/g*	*Burst, kPa·m²/g*	*Tear, mN·m²/g*	*Beating, min*
16.9	944	20	80.0	5.95	15.9	19
		30	99.5	7.35	12.9	39
		50	108.5	8.25	12.1	66
17.5	880	20	79.5	5.80	15.1	16
		30	97.5	7.10	12.7	31
		50	106.5	7.95	11.6	48
20.9	971	20	86.0	6.50	14.2	17
		30	113.0	8.15	12.2	45
		50	116.0	8.70	11.0	50
24.3	1017	20	93.0	6.70	14.1	20
		30	108.0	8.15	12.0	45
		50	113.5	8.70	10.8	65
29.5	1100	20	92.5	6.30	15.0	20
		30	109.0	7.70	12.8	44
		50	112.0	8.35	11.3	68

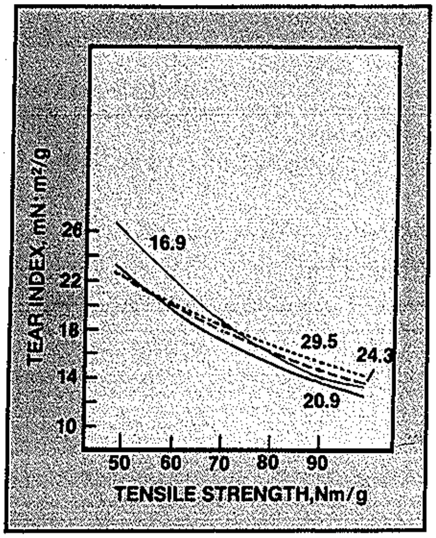
8. Tear and tensile strength for RDH pulps bleached with an oxygen stage



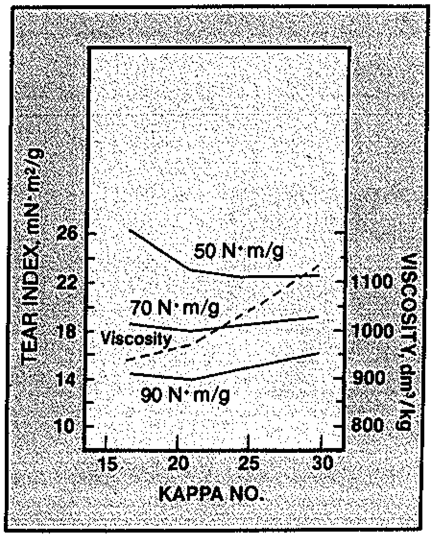
VI. Characterization of the effluents for RDH extended vs. conventional kraft pulping

Process	*Kappa no. to bleach plant*	*Total active Cl_2, % on o.d. pulp*	*ISO brightness, %*	*COD, kg/ton*	*BOD, kg/ton*
Conventional kraft					
Without oxygen stage	34	11.7	89	78	14
With oxygen stage	23	7.5	90	57	11
RDH extended					
Without oxygen stage	23	7.5	88	50	10
With oxygen stage	15	5.3	88	40	8.5

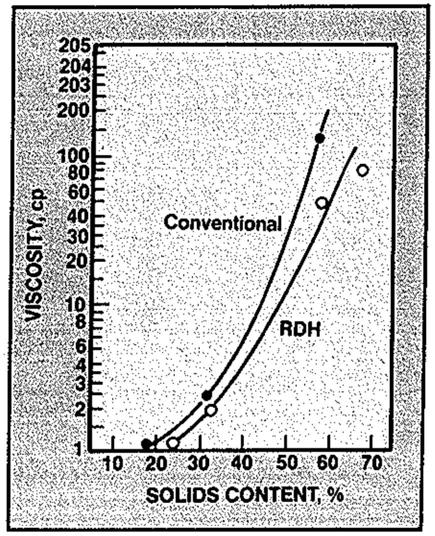
9. Tear and tensile strength for unbleached RDH pulps at the Joutseno Mill (with curves designated by kappa no.)



10. Tear and viscosity vs. kappa no. for unbleached RDH pulps at the Joutseno Mill (with curves designated by tensile strength)



11. Black liquor viscosities of RDH vs. conventional kraft pulping



liquor accumulator could be promoting the breakdown of lignin compounds of high molecular weight.

The possibility of firing RDH black liquors at higher solids contents in the recovery boiler is appealing.

Conclusions

RDH pulping by extended delignification produces bleached, market-grade pulps with strength properties equal to or better than conventional kraft pulps. Therefore, pulping to the lowest practical kappa number is advisable.

RDH pulping requires less active alkali charge than conventional pulping for the same degree of delignification. Advantages of RDH pulping by extended delignification in the bleach plant are: (a) less consumption of active chlorine and NaOH for the same brightness and (b) lower COD and BOD discharge loads.

The viscosity of pulps produced by extended delignification is affected less during bleaching than that of conventional pulps. Finally, the black liquor viscosity of RDH pulps is lower than that of conventional pulps.

Literature cited

1. Kaiser, M. and Pitre, R., 1986 Pulping Conference Proceedings, TAPPI PRESS, Atlanta, p. 627.
2. Sainiemi, J. and Hiljanen, S., 1986 Pulping Conference Proceedings, TAPPI PRESS, Atlanta, p. 643.
3. Swift, L. K. and Norman, R. E., The World Paper Week, New Available Techniques and Current Trends, SPCI, Stockholm.
4. Sebbas, E. and Mannisto, H., Energy Management Conference Proceedings, CPPA, Montreal, p. 39.
5. Swift, L. K. and Dayton, J. S., Energy Management Conference Proceedings, CPPA, Montreal, p. 31.
6. Vikstrom, B., STFI-Kontakt, June Report, p. 4, 1986.
7. Jokela, V., M.S. thesis, Helsinki University of Technology, Helsinki, Finland, 1986.
8. Soderhjelm, L., Paperi Puu 68(9):651 (1986).

Received for review July 15, 1987.

Accepted Aug. 21, 1987.

Presented at the 1987 Pulping Conference Proceedings.