

One- and two-stage APTMP™ — A route to high-brightness pulp

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IT IS WELL KNOWN FROM THE LITERATURE that the impregnation of alkaline peroxide into wood chips prior to refining processes can improve important quality characteristics such as brightness and certain strength values. Andritz Sprout-Bauer has reported on its APTMP™ process in several earlier papers (1, 2) and has installed a 450-metric tons/day facility in eastern Canada. This pulp has been used as the major furnish in value-added coated mechanical printing paper for a year. Market acceptance reportedly has been very good.

Likewise, since 1988, Millar Western Pulp Ltd. has used a patented Scott Paper alkaline peroxide high-yield pulping process (3) to produce market pulp of good strength and brightness. In this process, several stages of chemical impregnation precede atmospheric or slightly pressurized refining, and depending on chemical addition levels, brightness after subsequent tower bleaching with peroxide of up to 81% ISO for softwood and 87% ISO for hardwood species (e.g., spruce/pine or trembling aspen) can be achieved. This pulp has found acceptance not only in hygienic paper grades but also in communications paper grades that can use high-yield pulp.

Recently, Andritz Sprout-Bauer has evaluated alkaline peroxide pretreatment technology as a means to upgrade the quality of thermomechanical pulp (TMP) used captively in manufacturing newsprint and other mechanical printing paper grades (4). This paper studies alka-

line peroxide thermomechanical pulp (APTMP™) technology on a different wood species mix and investigates important operating criteria, such as the need for stabilizing peroxide after effective impregnation of chemicals and removal of species harmful to peroxide prior to refiner bleaching.

By understanding more about alkaline peroxide treatments prior to pressurized refining, it may be possible to reduce the cost of capital required to retrofit existing mills that require higher brightness and improved strength to produce specialty paper grades.

DISCUSSION

Several pressurized refining series using either one- or two-stage alkaline peroxide chip impregnation treatments were evaluated at Andritz Sprout-Bauer's pilot facilities located in Springfield, OH. A hemlock/true fir furnish indigenous to the northwest North American coastal region was supplied by Smurfit Newsprint Corp., located in Newberg, OR. A Model 560GS Impressafiner having a 4:1 compression ratio was used for all impregnation treatments during the trials. Chips were presteamed for 20–25 min prior to first-stage impregnation and for an additional 10 min prior to second-stage impregnation. APTMP™ pulps were produced after impregnation by refining in a primary Model 418 pressurized double disc refiner followed by secondary processing in a Model 401 atmospheric double disc refiner. Comparison of pulp properties after refining was made by producing baseline

Pilot studies on low-level chemical APTMP processes that utilized either one or two stages of impregnation prior to primary refining of hemlock/true fir chips from the Smurfit Newsprint, Newberg, OR, mill are reported. Results of this work indicate that two-stage impregnation is more efficient in terms of brightness gains attainable at a given chemical charge. Up to 14 points ISO were gained using less than 2.0% H₂O₂ with two stages.

With two-stage impregnation, tear index improved by 28%. One-stage impregnation did not improve tear. Large reductions in shive content, 61% and 83%, could be realized by one- or two-stage APTMP treatment, respectively. Other strength properties and specific energy requirements were minimally affected. This may have been due to the relatively low alkali charges used to ensure adequate brightening.

Application:

Western hemlock chips were impregnated with an alkaline peroxide solution in a one- or two-stage APTMP™ process developed by Andritz Sprout-Bauer. The effect on optical and physical properties of this pulp in a pilot plant study is reported.

TMP under operating conditions as close to equivalent as possible during the refining stages.

Impregnation stages and effect on optical properties and residual chemicals

Table I summarizes nine series of chip impregnation steps followed by two-stage refining that were evaluated during this study, indicating chemical addition charges as applicable.

Series B and D are TMP controls that were produced under identical chip presteaming and refining conditions. Chemical addition was either made in one stage (Series A, C, and

G) or split between two impregnation stages (Series E, F, H, and I). Caustic-to-peroxide ratios used during the study were about 1:1 ($\pm 20\%$) in total except for Series G, which was a repeat of Series C at a lower caustic-to-peroxide ratio to optimize brightness gain.

A stabilizing agent (sodium silicate or Dow Chemical's XUS-11082) was used in all series except Series I and was added with the other chemicals in either the first (if one-stage) or second (if two-stage) impregnation steps. Diethylenetriamine pentaacetate (DTPA), a chelating agent effective in removing metal ions such as iron and manganese (which decompose hydrogen peroxide), was added at a constant rate of 0.8% on oven-dry (o.d.) pulp in the first impregnation stage of each APTMP™ series.

The final brightness after secondary refining and residual hydrogen peroxide after pressurized refining for each APTMP™ series are illustrated in Figs. 1 and 2, respectively.

One-stage impregnation

The brightness gain observed from a one-stage APTMP™ treatment using a peroxide application of 1.0% on o.d. pulp (Series A) was only about 5 points. Residual peroxide after primary refining was less than 0.02% on pulp. This suggests that resin acids and metals are reacting with the peroxide and decomposing it before it has a chance to brighten the fiber. Series C and G investigated higher chemical application rates, with peroxide addition increased to 2.3% on o.d. pulp during each series. In Series C, the pulp had yellowed due to alkali darkening. Residual peroxide after primary refining was not detectable, and brightness after secondary refining was actually lower than in Series A.

Series G was therefore done using a lower alkali-to-peroxide ratio (0.7:1.0 instead of 1:1), and brightness off the secondary refiner

IMPREGNATION			
Series	Stages	% H ₂ O ₂	% NaOH
A	1	1.0	1.1
B	1	0	0
C	1	2.3	2.3
D	2	0	0
E	2	0.3+2.9	1.1+1.9
F	2	0.3+1.5	1.6+0.5
G	1	2.3	1.6
H	2	0.2+1.4	1.0+0.5
I	2	0.2+1.4	1.0+0.5

I. Chip impregnation steps

increased to 57.8% ISO. Although it is believed that a lower alkali ratio brought about higher brightness, not all of this gain, however, can be attributed to this variable. Series G chips were retained after impregnation for a longer period (1.25 vs. 0.33 hours) prior to primary refining due to equipment changes (rotary valve to plug screw). Visual brightening of the chips was observed prior to refining, indicating that this prerefining retention time was useful. The low residual peroxide after primary refining for Series G (0.02% on pulp) again suggests that extractives and metals were consuming peroxide.

Two-stage impregnation

Splitting the chemical charge between two stages of impregnation in an APTMP™ process increases the removal of extractives and other unwanted substances in the wood chips prior to refining. Series F, I, H, and E were investigated to determine the effect of two-stage impregnation on hemlock/true fir chips. In all of these tests, our objective was to add most of the alkali into the first impregnation stage and most of the peroxide into the second impregnation stage. This practice is based on developmental experience gained by the Andritz Sprout-Bauer organization. Specific caustic and peroxide addition levels are indicated in Table I.

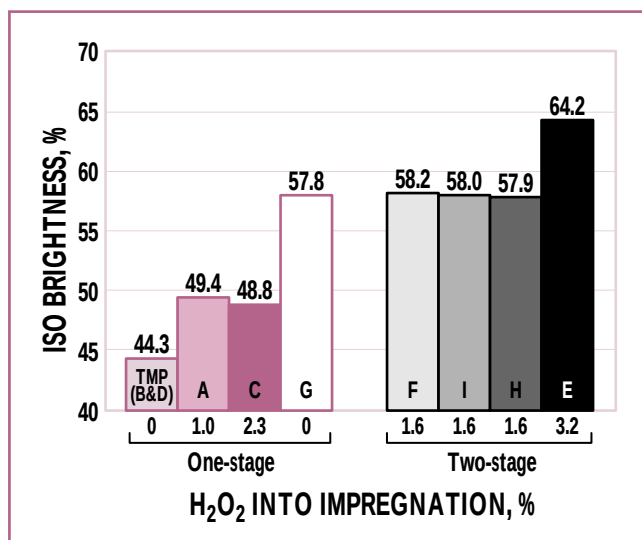
Figure 1 indicates that the average brightness gain achieved in Series F, I, and H, in which the H₂O₂

application was 1.6–1.8% on o.d. pulp, was approximately 14 points compared to baseline TMP brightness. The difference in these tests was the degree and type of stabilization, which is discussed in the next section. One additional two-stage impregnation treatment (Series E) was done to evaluate the potential for achieving even higher brightness gain. A total of 3.2% hydrogen peroxide was used to increase pulp brightness by 20 points compared to the baseline TMP. A higher level of caustic soda (3.0% on o.d. pulp in total) vs. the other two-stage treatments was also used in Series E.

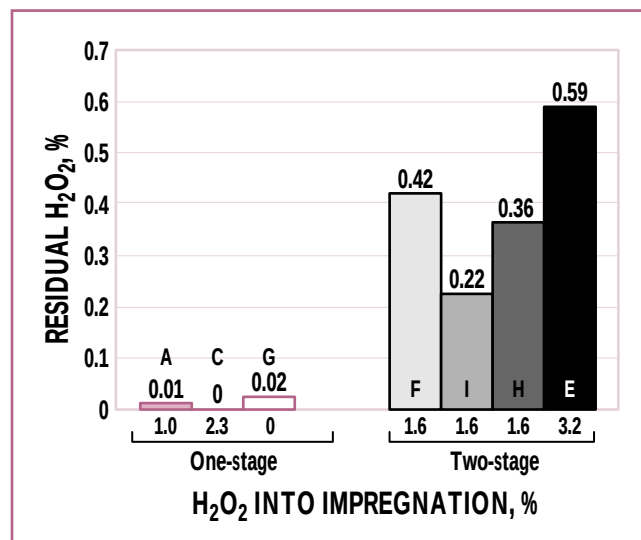
Residual peroxide levels after primary refining are shown in Fig. 2. It is obvious that two-stage impregnation allows substantial peroxide residuals to be carried through secondary refining, creating a longer potential opportunity for pulp brightening. This is advantageous not only in terms of potentially lower required peroxide charge into the APTMP™ process, but it is also preferred in terms of control, since the presence of alkali without peroxide during refining creates the opportunity for darkening and loss of brightness control capability.

Stabilization chemistry and its effect on brightness gain

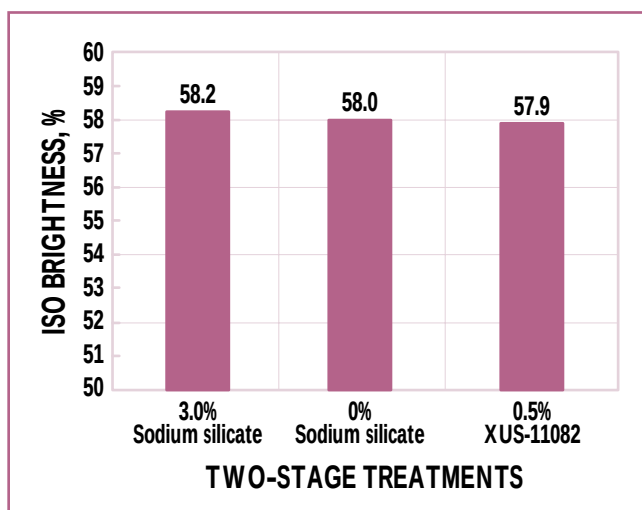
It is well known that sodium silicate is useful during hydrogen peroxide brightening processes that are practiced on a variety of mechanical and high-yield pulps (5, 6). Its roles



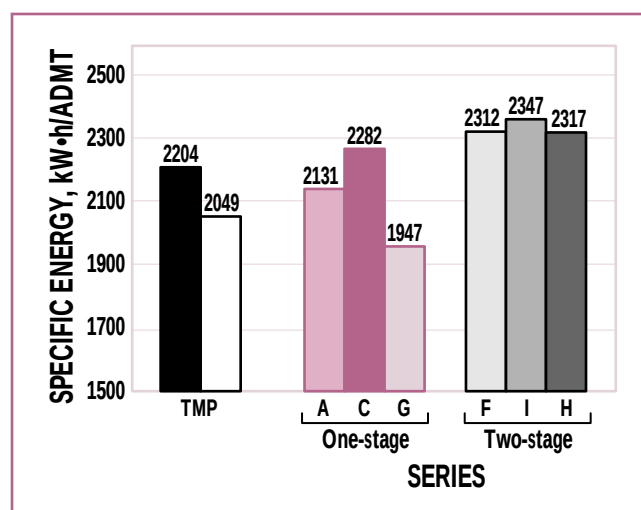
1. Secondary refiner brightness



2. Residual peroxide after primary refiner



3. Effect of stabilizers on brightness



4. Effect on specific energy

include stabilization of peroxide, buffering of pH in the range most efficient for peroxide brightening, and alkalinity source.

In these studies, sodium silicate was added to the first (if one-stage) or second (if two-stage) impregnation stage of all APTMP™ treatments except Series H and I. Addition level was maintained at a constant 3.0% (as-is basis) on o.d. pulp. In Series H, 0.5% XUS-11082 replaced the sodium silicate as suggested (7). In Series I, neither sodium silicate nor XUS-11082 was used as an additional stabilizing agent. A comparison of two-stage treatment brightness val-

ues after secondary refining is illustrated in Fig. 3.

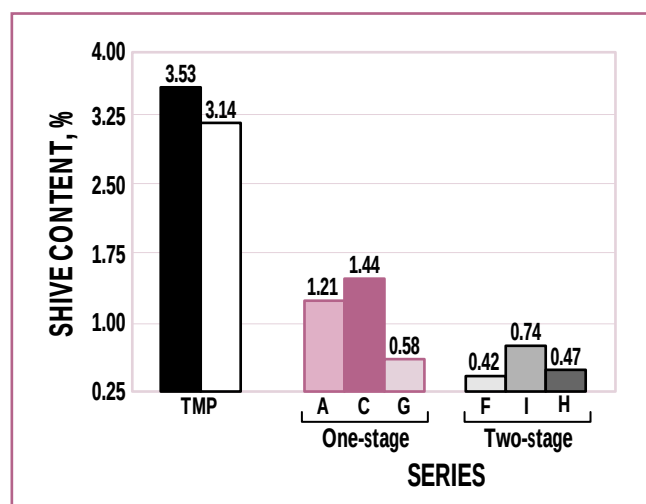
These data indicate that additional stabilization chemicals are not necessary to achieve efficient brightening, provided that a good pretreatment (e.g., DTPA) and impregnation process is undertaken on chips prior to refining. Note that the DTPA addition level has not been optimized in these studies and could likely be reduced to lower chemical costs.

Impact on energy and pulp quality

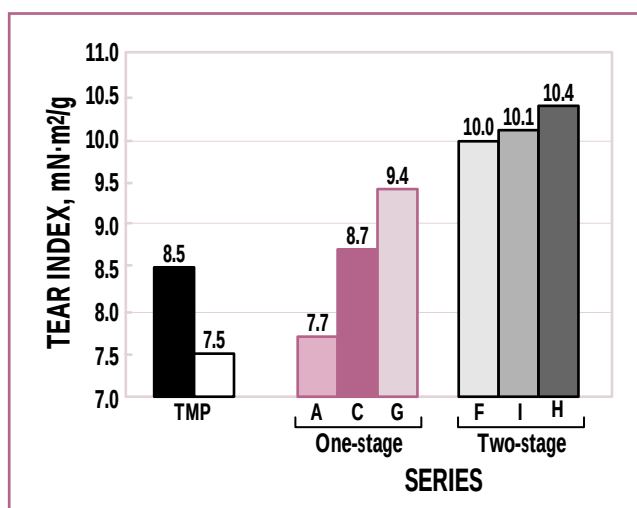
In addition to brightness, improvements in pulp quality and reduced specific energy costs during refining

were desired in these studies. Prior work (4) showed APTMP™ fiber to be stronger than the comparative TMP, have better bonding characteristics, and cleaner in terms of shives and dirt. Realizing some of these benefits would make the capital required to install impregnation equipment at a mill such as Smurfit-Newberg, OR, more readily available.

The results of this work showed that some of the desired pulp quality benefits could be realized. Comparisons between TMP and various APTMP™ series are made at 100 mL CSF unless stated otherwise.



5. Effect on shive content



6. Effect on tear index

Specific energy requirements. The APTMP™ process did not demonstrate a statistically measurable reduction in specific energy on the hemlock/true fir furnish evaluated in this study. With actual energy requirements illustrated in Fig. 4, APTMP™ pulps ranged from 10% higher (Series I) to 8.4% lower (Series G) than the average TMP (Series B and D). Previously published work on 50% hemlock/50% lodgepole pine demonstrated a 300-kW/h/o.d. metric ton savings (4). The use of lodgepole pine and higher alkali residuals may have been responsible for the energy savings.

Shive content. The most improved benefit in terms of pulp quality parameters on this hemlock/true fir furnish was a reduction in shive content. This benefit was observed for both one- and two-stage impregnation processes, as seen in Fig. 5. Pulmac shive reduction on a 0.10-mm screen was decreased on average from 3.3% for TMP to 1.3% and 0.55% for one- and two-stage treatments, respectively. Series G, which was repeated using a lower alkali-to-peroxide ratio and extended impregnation time before primary refining, had a shive content of 0.58%. This is typical of other two-stage impregnation treatments and much lower than the other one-stage treatments.

Tear index. Tear strength showed improvement after an APTMP™ treatment compared to baseline TMP data. This only resulted after two-stage impregnation and from Series G (one-stage with extended hold time before primary refining). Expected improvement, as indicated in Fig. 6, would be about 28%.

Other pulp properties. APTMP™ treatment, due to its alkaline pH conditions, lowers printing opacity by 2–5%. Two-stage impregnation, probably due to more efficient penetration of alkali into the fiber, lowers opacity more than one-stage treatment. No adverse effects of the scattering coefficient were observed following an APTMP™ treatment. Opacity and scattering coefficient values for each refining stage, as well as pH conditions, are presented in Table II.

The APTMP™ pulps demonstrated a lower bulk than the TMP control at a similar freeness. Other physical properties, such as tensile, tensile energy absorption (TEA), and burst, were marginally affected by the APTMP™ treatments done in this study. Additional strength property data are shown in Table III.

The alkali residual and final pH of the APTMP™ pulps were lower than

previous studies on West Coast softwoods (hemlock/lodgepole pine) (4). This suggests that the chips used in this study consumed a higher proportion of sodium hydroxide. A higher sodium hydroxide charge would elevate the residual pH at the secondary refiner (8.0–8.5), with expected improvements in overall bonding strength and energy reduction. APTMP™ Series E had the highest application of sodium hydroxide (3.0% NaOH) to the fiber. These results are not presented in Table III as this pulp was not refined below 178 mL CSF. When compared to the TMP control at a similar freeness, the 3.0% NaOH APTMP™ had a higher burst index (+27%), tensile index (+15%), percent stretch (+12%), and TEA (+27%), suggesting improved strength at a higher final pH and residual alkali. Additional studies are required to quantify bonding strength improvement at slightly elevated sodium hydroxide levels.

Low-capital approaches to two-stage APTMP™

Two-stage impregnation has been shown to have benefits over one-stage impregnation in this study both in terms of lower operating costs (lower peroxide charge to reach equivalent brightness) and

Series	A	B	C	D	E	F	G	H	I
Imp. stages	One	One	One	Two	Two	Two	One	Two	Two
% H ₂ O ₂ application	1.0	None	2.3	None	0.3/2.9	0.3/1.5	2.3	0.2/1.4	0.2/1.4
% NaOH application	1.1	None	2.3	None	1.1/1.9	1.6/0.5	1.6	1.0/0.5	1.0/0.6
% stabilizer	3.0 Sili.	None	3.0 Sili.	None	3.0 Sili.	3.0 Sili.	3.0 Sili.	0.5 XUS	None
DTPA, %	0.8	None	0.8	None	0.8	0.8	0.8	0.8	0.8
% residual H ₂ O ₂	0.01	N/A	0	N/A	0.59	0.42	0.02	0.36	0.22
% residual alkali	0	N/A	0.03	N/A	0.10	0.10	0	0	0.03
1st stage pH	11.2	N/A	11.5	N/A	12.1	12.8	11.1	12.7	12.6
2nd stage pH	N/A	N/A	N/A	N/A	11.1	10.2	N/A	10.8	10.9
Final pH	6.2	N/A	7.6	N/A	7.7	7.4	6.2	6.7	6.9
% ISO brightness	49.4	43.6	48.8	45.3	64.2	58.2	57.8	57.9	58.0
% printing opacity*	96.5	98.6	96.8	98.8	N/A	94.4	95.6	95.3	95.2
Scattering coefficient*	54.3	53.0	55.5	53.1	N/A	55.9	57.9	57.1	57.1
*Interpolated for comparison at 100 mL CSF									

II. Effect on optical properties

pulp quality parameters (lower shives and higher tear). However, more equipment is required, resulting in higher capital costs.

One way that capital can be minimized is to use existing equipment. For instance, some impregnation could be accomplished by utilizing an unused atmospheric refiner in series with an Impressafiner. Further work to optimize these cost-saving ideas would be required in the pilot plant.

Economic payback from converting TMP line(s) to APTMP™ can be further improved due to the process's ability to coimpregnate hemlock/true fir with lower-quality woods. Future APTMP™ studies are

planned to evaluate the addition of Douglas-fir and cottonwood.

SUMMARY

Alkaline peroxide treatment of thermomechanical pulp may offer an economical option to upgrade the quality of newsprint or mechanical printing paper grades. Mills considering upgrading a portion or all of their production to value-added grades (improved news, lightweight coated, and supercalendered) can benefit most from an APTMP™ conversion. In addition to chemical pulp reduction, the addition of lower-quality softwoods and hardwoods further reduces production costs. Results from this study showed that:

- APTMP™ technology can be used to improve the brightness of TMP from dark coastal species such as hemlock/true fir. Less than 2.0% hydrogen peroxide is required to increase brightness by 14 points ISO.
- Two-stage APTMP™ is superior in terms of efficiency of chemical requirements than one-stage treatment. Peroxide application on o.d. pulp is reduced from 2.4% to 1.6% by an additional impregnation stage before refining.
- Both one- and two-stage APTMP™ treatments have a significant effect on the reduction of shive content compared to baseline TMP. Pulmac shive content was

Series	A	B	C	D	E	F	G	H	I
Imp. stages	One	One	One	Two	Two	Two	One	Two	Two
% H ₂ O ₂ application	1.0	None	2.3	None	0.3/2.9	0.3/1.5	2.3	0.2/1.4	0.2/1.4
% NaOH application	1.1	None	2.3	None	1.1/1.9	1.6/0.5	1.6	1.0/0.5	1.0/0.6
% stabilizer	3.0 Sili.	None	3.0 Sili.	None	3.0 Sili.	3.0 Sili.	3.0 Sili.	0.5 XUS	None
DTPA	0.8	None	0.8	None	0.8	0.8	0.8	0.8	0.8
CSF*	100	100	100	100	N/A	100	100	100	100
kW·h/ODMT	2131	2049	2262	2204	N/A	2312	1947	2317	2327
kW·h/ODMT (Prim. Ref.)	1325	1369	1255	1178	N/A	918	946	982	877
Bulk	2.6	2.92	2.53	2.79	N/A	2.62	2.63	2.66	2.63
Burst index	1.9	1.6	2.4	2.7	N/A	2.7	2.3	2.8	2.9
Tear index	7.7	7.5	8.7	8.5	N/A	10	9.4	10.4	10.1
Tensile index	36.5	34.8	41.4	40.4	N/A	47.1	43.7	45.2	40.8
T.E.A.	23.5	23.2	32.4	34.3	N/A	39.1	30.4	35	31.4
% Shives	1.21	3.14	1.44	3.53	N/A	0.42	0.58	0.47	0.74

*Interpolated for comparison at 100 CSF

III. Effect on specific energy and physical properties

KEYWORDS

Alkali treatment, brightness, chemical treatment, impregnation, mechanical pulping, multistage process, optical properties, oxides, peroxides, processes, refiner mechanical pulping, single stage process, softwoods, thermomechanical pulping, tsuga, two stage process.

found to decrease by 61% and 83% after one- and two-stage impregnation, respectively.

- Two-stage impregnation improved the tear strength index by an average of 28% (from 8.0 to 10.2 mN·m²/g) compared to baseline TMP pulp. One-stage impregnation did not demonstrate improved tear. Improved tear offers savings in terms of reduced purchased chemical fiber requirements for runnability. TJ

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The authors would like to express their gratitude to the management of FMC Corp. and Smurfit Newsprint Corp., who have allowed this paper to be published. Also, thanks are given to the many trained personnel at the Andritz Sprout-Bauer facility in Springfield, OH. Finally, gratitude is expressed to Hector Audette of Dow Chemical Canada for his assistance in investigating the XUS-11082 stabilizer.

Received for review Sept. 26, 1995.

Accepted Feb. 22, 1996.

Presented at the TAPPI 1993 Pulping Conference.

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