Bleaching pressurized groundwood pulps in the grinder pit with hydrosulfite

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Pulp brightness increased significantly after grinder bleaching with hydrosulfite.

Pilot-plant studies have established that the strength of super-pressurized groundwood (PGW-S) pulp is 10–30% greater than conventional pressurized groundwood (PGW) pulp and exceeds the strength of atmospheric groundwood (GW) pulp by an even greater amount (*1, 2*). The PGW and PGW-S processes are carried out at higher temperatures and pressures than GW pulp, as seen in **Table I**. These severe conditions facilitate the grinding process and preserve fiber length, but they also have a negative impact on the brightness of the unbleached pulp, as seen in **Table II**.

Efforts to increase the brightness of PGW and PGW-S pulps to the level of GW pulps—but without sacrificing strength—have focused on the possibility of prebleaching during the grinding stage using an inexpensive bleaching agent such as sodium hydrosulfite. Pilot-plant and mill-scale bleaching trials were conducted to explore the maximum brightness gain achievable using such a grinder-bleaching process. The studies highlighted the potential for achieving higher brightness by adding sodium hydrosulfite during the grinding process and then brightening the pulp in a conventional tower-bleaching stage.

In this paper, the grinder-bleaching sequence is defined as a two-stage addition of sodium hydrosulfite, as seen in **Fig. 1**. According to this definition, the addition of sodium hydrosulfite, sodium hydroxide, and a chelating agent into the grinding process is followed by a conventional tower-bleaching stage using sodium hydrosulfite.

The superior bleaching performance available with the two-stage addition of sodium hydrosulfite can help maintain target finished brightness during seasonal periods of poor wood quality.

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Grinder-bleaching sequence

First stage—bleaching in the grinder pit

The first stage in Fig. 1 is a flow diagram of the single-pocket pilot grinder used in the initial phase of our study. This grinder has a nominal production capacity of 300 kg/h (100 mL CSF), and the consistency of the pulp in the grinder pit is normally 1-2%. For PGW-S trials, the shower-water was heated to temperatures as high as 140°C. Pressure in the grinder was induced by compressed air up to a maximum 450 kPa. Several different combinations of temperature and pressure were investigated.

After grinding, the pulp is fed from the grinder pit through a shredder to a blow cyclone, where the steam is separated from the PGW or PGW-S pulps. After the blow cyclone, the pulp goes to a pressurized disc filter, which closes the hot loop of pressurized grinding by recirculating the filtrate to the grinder showers.

In grinder bleaching, the brightening chemicals are fed to the suction side of the shower-water pump, which circulates the filtrate back to the grinder showers. Bleaching is performed at low consistency (*3*). In this report, the prefix "C" is used to indicate chemical addition to the shower-water system, e.g., CPGW-S.

Second stage—conventional tower bleaching

Figure 2 is a flow diagram for a conventional low-to-medium-consistency sodium hydrosulfite brightening process. The brightening agent is typically added as a solution at the inlet of some type of mixing device. Generally, this would be a standard centrifugal pump, a static mixing device, or a high-shear pump/mixer. The pulp and sodium hydrosulfite mixture is then fed to an upflow bleaching tower to provide sufficient reaction time and to prevent contact of the mixture with air.

Experimental

Wood species

The wood species used in the trials was fresh Norway spruce (*Picea abies*) debarked at Tampella's Anjala mill in Anjalankoski, Finland. Seasonal fluctuation in wood quality was apparent during the trials, with the initial brightness of the PGW pulp varying as much as 4-5 ISO points between trials.

Pilot-plant trials

Chemical addition. A mixture of sodium hydrosulfite and sodium hydroxide (caustic) was fed into the shower-water system during the pilot trials. The hydrosulfite solution was generated at the mill from Borol® (Morton International, Inc.) solution and delivered to the pilot plant, where it was mixed with caustic and water before application in the grinding process. Caustic was added to counteract the effect of wood acids released during grinding and formed as by-products of the bleaching reaction. Without caustic, these acids caused the pH of pulp in the grinder pit to fall below 5. Optimum pH for pulp in conventional hydrosulfite bleaching is between 5 and 6. To maintain optimum pH for pulp in the grinding pit, shower water had to be maintained at about pH 6–7 and bleaching liquor at about pH 11–12.

The grinder-bleaching stage was optimized to establish the maximum achievable brightness gains by varying the hydrosulfite addition rate between approximately 4–12 kg/metric ton o.d. pulp. Hydrosulfite addition rates were estimated based on generation concentration and dilution factors. The hydrosulfite content of the shower water before injection into the grinder was too low to be detected by titration.

The residual hydrosulfite content of the pit pulp was impossible to measure by analytical procedures. Instead, a reversion study was performed on a sample of grinder-bleached pit pulp by heating it in an oven for one hour. Pulp brightness increased slightly, indicating that the pulp may have contained some residual hydrosulfite.

The grinder-bleaching pH was tracked by measuring the pH of the shower-water and the pit pulp during grinding. No clear optimum pH was noticed during the pilot-scale trials.

Samples of pit pulp were gathered two hours after starting the grinder-bleaching process, when the process was running at a steady-state condition. Pulp properties were measured at the pilot plant, and samples of pit pulp were sent to Morton International's R&D laboratory for laboratory post-bleaching studies. Environmental load was measured using shower-water samples collected from the hot loop of the pilot grinder.

Post-bleaching studies. Pit pulp for laboratory post-bleaching studies was collected from the pressurized disc filter and stored in heavy-gauge plastic bags. Brightness of the pit pulp was determined immediately after grinding.

Post-grinder bleaching was performed using the equivalent of 7 g on o.d. pulp in polyethylene bags. The pulp was diluted with hot (65°C) deionized water to 3% consistency, sealed, and mixed to disperse the fiber. The

I. Grinding process conditions

Process	*Shower-water temp., °C*	*Pressure, kPa*
Atmospheric groundwood (GW)	75	0
Pressurized groundwood (PGW)	105	250
Super-pressurized groundwood (PGW-S)	140	450

II. Properties of PGW pulps at 100 mL CSF

	PGW	*PGW-S*	*PGW-S*
Grinder pressure, kPa	*250*	*430*	*430*
Shower-water temp., °C	*95*	*95*	*120*
Long fibers (+28 mesh), %	30.7	35.0	37.3
Fines (-200 mesh), %	28.0	26.6	25.9
Density, kg/m³	414	407	415
Porosity, s	52	57	69
Tensile index, N•m/g	36.5	37.4	41.5
Tear index, mN•m²g	5.39	6.04	6.29
Light scatt. coeff., m²/kg	66.2	65.5	62.1
Brightness, % ISO	63.7	62.8	59.4

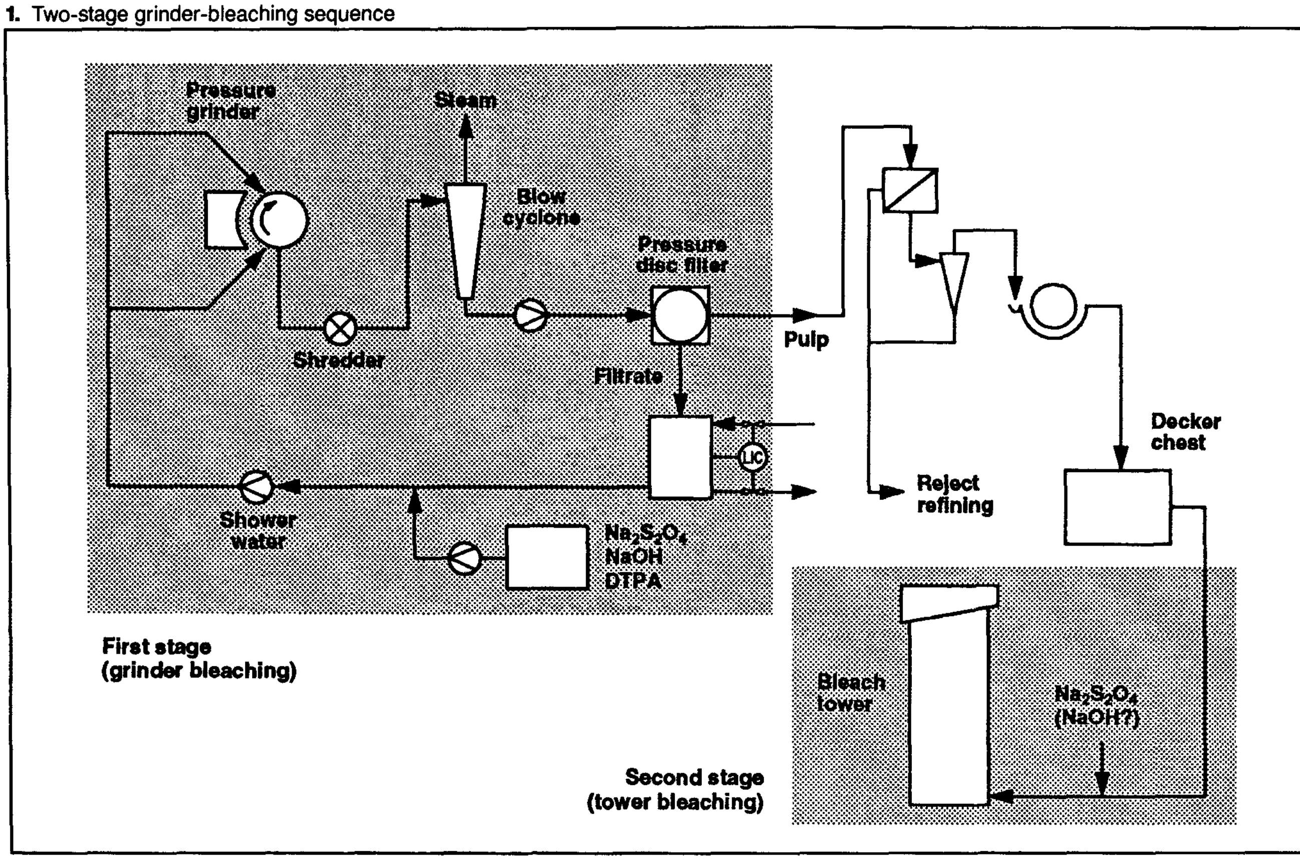
III. Pilot grinding conditions

	GW (70°C)	*PGW-S (105°C)*	*PGW-S (140°C)*
Grinder pressure, kPa	0	450	450
Shower-water temp., °C	70	105	140
Shower-water flow, L/s	4.5	4.5	4.5
Pit-pulp consistency, %	1-2	1-2	1-2

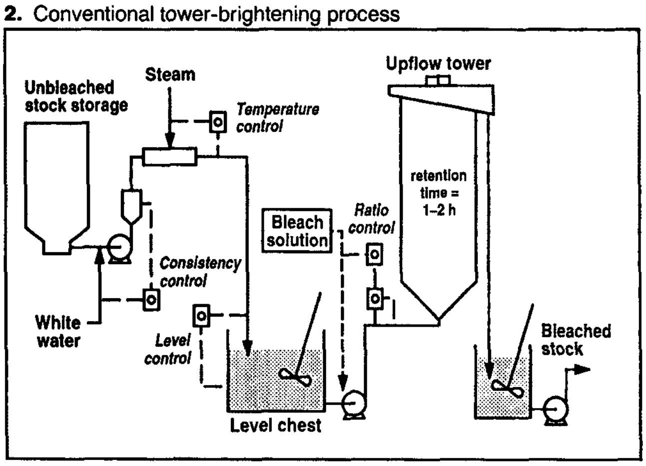
IV. Brightness gain and pH of CPGW-S pulps after grinder bleaching at various charges of sodium hydrosulfite (pilot results)

$Na_2S_2O_4$ charge in grinder, kg/ton o.d. pulp	*pH*	*Brightness gain, ISO points*
4.0	5.5	2.2
5.5	5.4	4.5
5.7	5.2	3.3
6.1	5.1	5.0
8.0	5.7	6.6
12.0	5.4	4.9

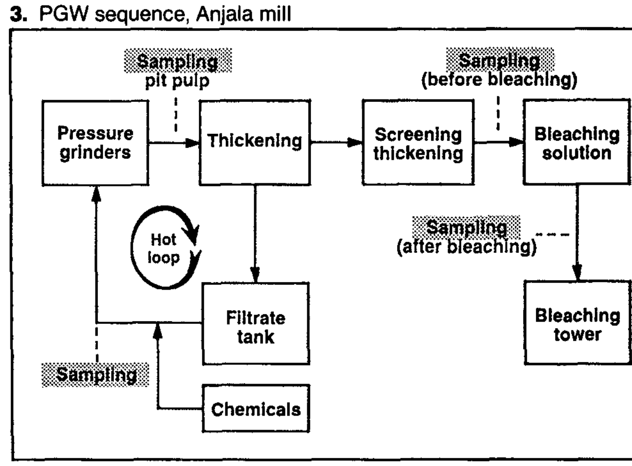
1. Two-stage grinder-bleaching sequence



2. Conventional tower-brightening process



3. PGW sequence, Anjala mill



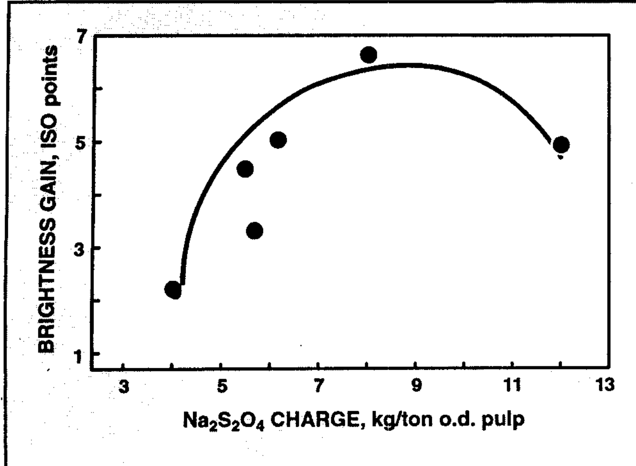
required amount of hydrosulfite was added under nitrogen purge, the bag was sealed, thoroughly mixed, and placed in a constant-temperature bath at 60°C for one hour. At the end of the bleaching period, each bag was removed from the constant-temperature bath, mixed, opened, and measured for pH. The pulp was then diluted to 1% consistency with deionized water and the slurry adjusted to pH 4.5 prior to handsheet formation. Duplicate handsheets (each 3.5 g) were made and air dried overnight at 50% RH. Brightness was measured using an Elrepho spectrophotometer. The reported ISO brightness is an average of five readings for each handsheet.

Mill trials

The hydrosulfite grinder-bleaching technique that was developed in the pilot plant was applied to a commercial pulp and paper mill equipped with Tampella pressure grinders. Hydrosulfite, caustic, and DTPA (diethylenetriamine pentaacetic acid) were fed into the shower-water system of the PGW grinders. Shower-water temperature was 97°C, and grinder pressure was 250 kPa. **Figure 3** is a flow diagram of the mill production line.

Flow rates for hydrosulfite and DTPA were monitored during grinding. Shower water and unthickened pit pulp were sampled at the locations shown in Fig. 3. The pH at both locations was monitored, and the caustic flow rate

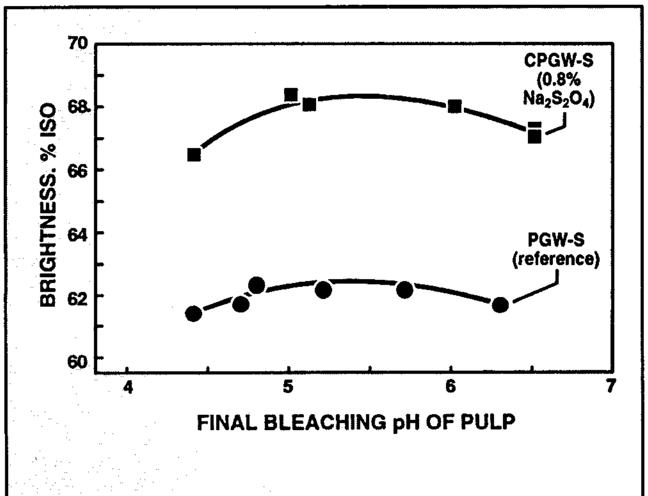
4. Brightness gain as a function of hydrosulfite charge in the shower water (pilot results)



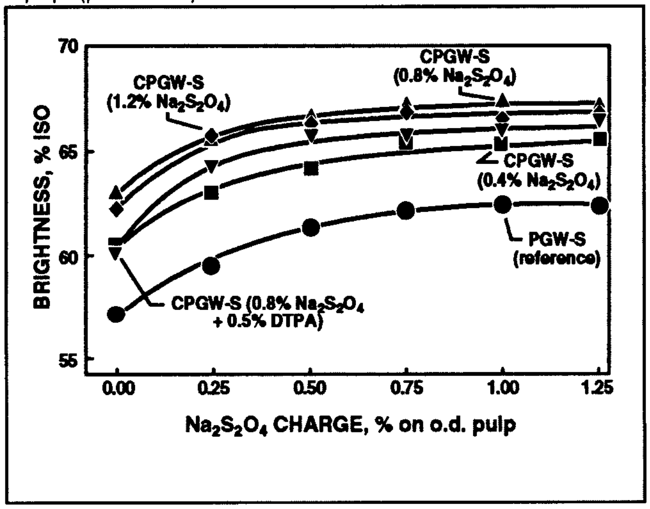
V. Effect of sodium hydrosulfite charge on post-grinder brightness for two CPGW-S pulps at different shower-water temperatures (pilot results)

	GW (70°C)	*CPGW-S (105°C)*	*CPGW-S (140°C)*
Reference brightness, % ISO	64.1	62.8	58.2
$Na_2S_2O_4$ charge to grinder, % on o.d. pulp	...	0.87	0.63
Brightness after grinder bleaching, % ISO	...	67.1	63.9

5. Brightness as a function of final bleaching pH for reference PGW-S and CPGW-S (pilot results)



6. Brightness gain as a function of hydrosulfite charge in second (conventional) bleaching stage for reference PGW-S and four CPGW-S pulps (pilot results)



was varied to maintain pH 5-6 for the pit pulp and pH 6-7 for the shower water.

Hydrosulfite flow rate was varied between 7-20 kg/metric ton o.d. pulp to determine the optimum dosage. The brightness of the pit pulp as well as of the final tower-bleached pulp was measured during the trial.

Results and discussion

Pilot-plant trials

Initial brightness after grinder bleaching. The grinding conditions of the pilot-plant trials are listed in **Table III.** To establish the maximum pit-pulp brightness that can be achieved with grinder-bleaching technology, the dosage of hydrosulfite to the shower water was varied between 4-12 kg/ton. The pH of the pulp at the end of the bleaching stage is an important factor in determining the optimum chemical addition rate. **Table IV** shows that the pit-pulp samples had similar bleached pHs, indicating that bleached-pulp pH did not influence the brightness response.

Figure 4 shows that the optimum hydrosulfite dosage in the pilot-plant trials was 8 kg/ton (0.8%). Increasing the dosage to 12 kg/ton decreased the maximum brightness gain achievable. Hydrosulfite addition of 6-8 kg/ton to the shower-water system of the CPGW-S grinding process provided a brightness gain of 5-7 points. The pit-pulp pH was 5-6, and the caustic dosage was 2-4 kg/ton.

Additional pilot-plant trials were conducted over a period of six months to confirm the validity of these promising results. The initial brightness of atmospheric GW pulp was easily reached in all the additional trials. One of the CPGW-S trials was carried out at the same high pressure (450 kPa) but at a lower shower-water temperature (105°C). **Table V** shows that the brightness of this CPGW-S pulp increased from 62.8% ISO to 67.1% ISO with a hydrosulfite dosage of 9 kg/ton. In contrast, the brightness of the GW pulp was only 64.1% ISO.

Complexing agent (DTPA) was added in one of the trials, but it had no clear effect on the grinder-bleaching results in the short pilot trials.

VI. Effect of laboratory post-bleaching (0.8% $Na_2S_2O_4$) on final pulp brightness (pilot results)

	PGW-S (reference)	*CPGW-S*	*CPGW-S*	*CPGW-S*	*CPGW-S*
$Na_2S_2O_4$ charge to grinder, %	...	*0.4*	*0.8*	*1.2*	*0.8*
DTPA charge to grinder, %	...	...	...	...	*0.5*
Brightness gain in post-bleaching, ISO points	5.2	4.8	4.3	4.2	5.8
Total brightness gain, ISO points	5.2	7.0	10.9	9.1	10.9

VII. Effect of laboratory post-bleaching (0.8% $Na_2S_2O_4$) on final pulp properties (pilot results)

	PGW-S (reference)	*CPGW-S*	*CPGW-S*	*CPGW-S*	*CPGW-S*
$Na_2S_2O_4$ charge to grinder, %	...	*0.4*	*0.8*	*1.2*	*0.8*
DTPA charge to grinder, %	...	...	...	...	*0.5*
Freeness, mL CSF	101	106	104	123	112
Density, kg/m^3	428	423	428	417	417
Porosity, s	56	47	49	33	38
Tensile index, N•m/g	40.7	41.4	41.3	38.2	35.7
Tear index, nN •m^2/g	6.22	5.88	5.94	5.89	6.00
Tensile energy absorption, J/m^2	38.0	34.5	38.0	34.4	29.3
Light scatt. coeff., m^2/kg	61.5	59.0	56.9	57.4	57.2
Opacity, %	96.7	94.8	93.7	94.3	93.9

Final brightness after conventional bleaching. To establish the maximum brightness gains achievable with sodium hydrosulfite, process variables for post-bleaching were optimized in the laboratory on the PGW-S reference pulp and on the grinder-bleached CPGW-S pulps.

Pulp pH and the chemical addition rate for the post-bleaching stage were varied to determine their effect on brightness. The pH optimization studies were conducted on a PGW-S reference pulp and on a grinder-bleached pulp treated with hydrosulfite at the rate of 8 kg/ton. **Figure 5** shows that the optimum pH range for the maximum brightness gain for both pulps was between 5.0 and 6.0. The optimum hydrosulfite treatment rate was determined by varying the chemical charge between zero and 1.5% hydrosulfite. **Figure 6** shows that the maximum brightness gains were achieved at a dosage of 0.75–1.0% $Na_2S_2O_4$. Dosages above 1.0% did not increase brightness.

Based on these results, physical and optical properties were determined on a series of grinder-bleached pulp samples after treatment with 0.8% hydrosulfite in the post-bleaching stage. The brightness gains achieved at the post-bleaching stage as well as the total brightness gains obtained with the grinder-bleaching sequence are compiled in **Table VI**. These results indicate that an overall brightness gain approaching 11.0 points could be achieved with a total hydrosulfite charge of 1.6%. Under optimum brightening conditions, conventional tower bleaching of the PGW-S pulp would provide a brightness gain of only 6.0 points with 0.8% hydrosulfite. The reference pulp (PGW-S) was also bleached in two conventional stages, with hydrosulfite addition rates of 0.8% in each stage. Total brightness gain of the twice-bleached PGW-S reference pulp was only 6.5 points. The grinder-bleaching sequence (CPGW-S), on the other hand, showed the potential to nearly double the brightness gain over standard tower bleaching with a 0.8% increase in hydrosulfite addition rate.

Pulp and paper properties. The mechanical and optical properties of the post-bleached samples are listed in **Table VII**. Density and porosity of all the pulps increased slightly during hydrosulfite post-bleaching. The strength properties of the reference pulp increased by 18%, while the strength was about the same for the other pulps, except CPGW-S pulp with 0.8% hydrosulfite and 0.5% DTPA, which had an average of 10% lower strength properties after post-bleaching than before. The scattering coefficient and opacity of the pulps did not change during post-bleaching.

Table VIII shows the properties of the PGW-S reference pulp and CPGW-S grinder-bleached pulps before final bleaching. With the exception of the optical properties, there were no significant differences between the grinder-bleached pit pulps and the reference pit pulp. The increased brightness of the CPGW-S pulps resulted in lower opacity and light-scattering coefficient. The strength properties of the CPGW-S pulps showed a slight improvement.

The pilot-scale trials showed that specific energy consumption was slightly lower for the grinder-bleached pulps. Results are presented in **Table IX.**

Environmental load. The environmental load of the hydrosulfite grinder-bleaching process was studied in pilot-scale trials. The seven-day biochemical oxygen demand (BOD_7) of the shower-water samples was measured in the grinder-bleaching stage and in the reference grinding. The effect of hydrosulfite grinder bleaching on the BOD_7 load of the PGW and PGW-S processes was increased by about 3 kg/a.d. metric ton, as seen in **Table X.**

Thiosulfate levels. Thiosulfate level was measured in the shower-water samples collected during the grinder-bleaching pilot trials. The results showed no detectable levels of thiosulfate (<1 ppm) in the hot loop of the pilot grinder, possibly because of the short grinding time in the pilot-scale trials.

VIII. Properties of PGW-S reference pulp and CPGW-S grinder-bleached pulps before final bleaching (pilot results)

	PGW-S (reference)	*CPGW-S (0.8% $Na_2S_2O_4$)*
Freeness, mL CSF	120	120
Density, kg/m³	408	408
Porosity, s	56	62
Tensile index, N•m/g	38.6	41.5
Tear index, mN•m²/g	5.69	5.89
Brightness, % ISO	56.9	63.5
Light scatt. coeff., m²/kg	59.0	57.2
Opacity, %	97.4	94.4

IX. Specific energy consumption for PGW-S reference pulp and CPGW-S pulps ground to 120 mL CSF (pilot results)

	PGW-S (reference)	*CPGW-S (0.8% $Na_2S_2O_4$)*
SEC, kW•h/ton (90% pulp)	940	868

X. BOD_7 loads in PGW effluent (pilot results)

	BOD_7, kg/ton a.d. pulp
PGW	6.6
CPGW	9.5
PGW-S	9.6
CPGW-S	12.1

Mill trials

The good results obtained on the pilot scale led to several mill-scale trials at the Anjala paper mill.

Initial brightness after grinder bleaching. Approximately 4-6 points of brightness gain were achieved in all three grinder-bleaching trials using a hydrosulfite dosage of about 6-10 kg/ton. The average DTPA charge was 4 kg/ton, and the caustic addition rate was 4 kg/ton.

Figure 7 shows brightness results that were obtained for pit pulp when the hydrosulfite addition in the grinder-bleaching stage was varied from 7 kg/ton to 15 kg/ton. The results show that the maximum brightness gain was achieved at a dosage of approximately 10-12 kg/ton. The higher treat rates did not increase pulp brightness significantly.

The target pH level of the pit pulp in grinder bleaching was between 5 and 6, and the flow rate of caustic to the grinder shower water was varied to reach the target pH. The pit-pulp pH was then plotted as a function of brightness, but no clear optimum pH for grinder bleaching was found, even on the mill scale. However, the highest brightness values were achieved at pH 5.0-5.6.

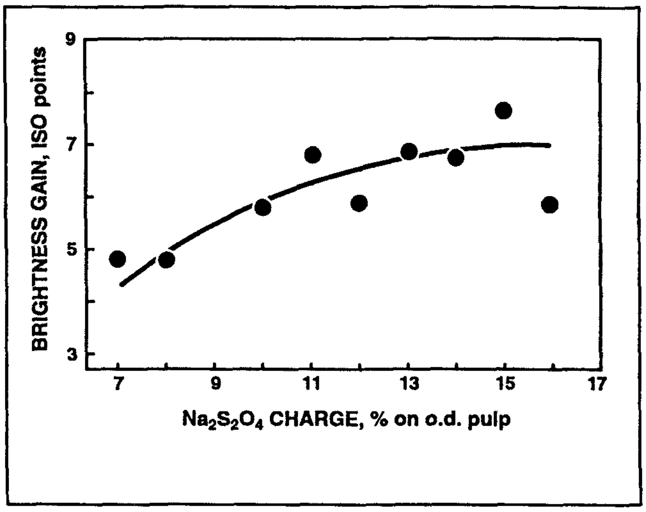
Final brightness after tower bleaching. Sodium hydrosulfite, in combination with sodium hydroxide and DTPA, was injected into the shower-water system of the PGW grinder. This initial addition of sodium hydrosulfite was followed by a second addition of sodium hydrosulfite and sodium hydroxide at the typical injection point. At this mill, the brightening agent is added at the inlet of a medium-consistency pump and then fed to an upflow bleaching tower. The grinder-bleaching sequence as operated at this facility was consistent with the experimental method used in the pilot-plant trials.

XI. Properties of PGW reference pulp and CPGW grinder-bleached pulps (mill results)

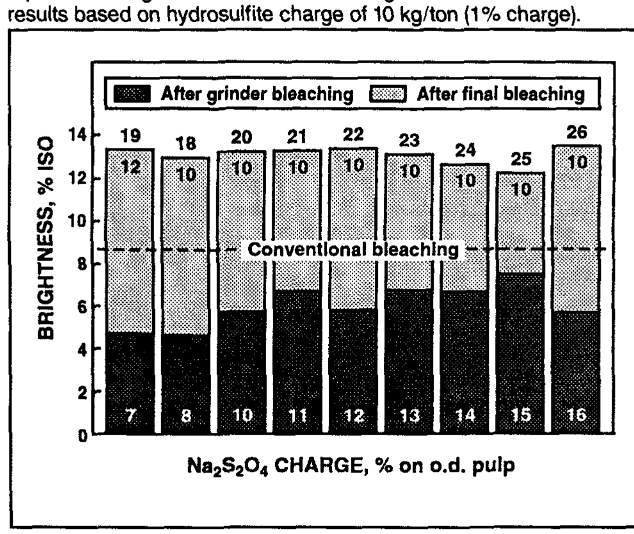
	PGW	*CPGW*
Freeness, mL CSF	180	180
Density, kg/m³	366	371
Porosity, s	13	11
Tensile index, N•m/g	26.9	25.4
Tear index, mN•m²/g	4.90	4.25
Brightness, % ISO	64.7	69.8
Light scatt. coeff., m²/kg	63.6	64.9
Opacity, %	95.2	93.8

Approximately 7-8.9 points of brightness gain were obtained in the post-bleaching stage for pulps initially bleached in the grinder pit at hydrosulfite dosages of 8-12 kg/ton as seen in **Fig. 8.** Bleaching pH was maintained

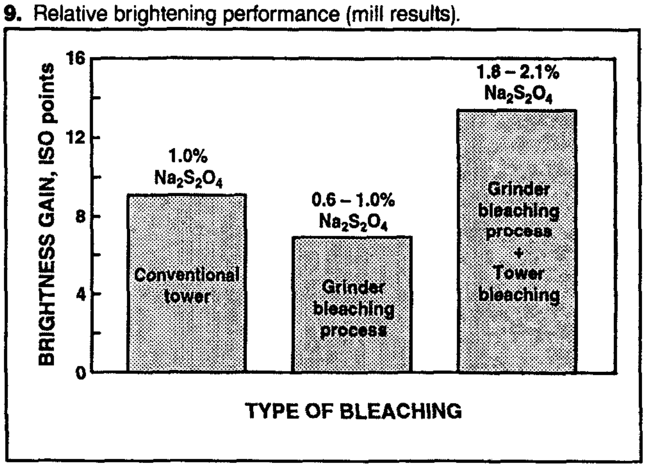
7. Brightness gain as a function of hydrosulfite charge in the shower water (mill results)



8. Brightness gain as a function of hydrosulfite charge (mill results). Numbers atop bars represent total charge; numbers within bars represent charges in first and second stages. Conventional bleaching results based on hydrosulfite charge of 10 kg/ton (1% charge).



9. Relative brightening performance (mill results).



at 5.0-6.0 to ensure optimum brightening conditions.

After the injection of hydrosulfite into the shower-water system, a brightness gain of 4-6 points was developed by the inlet of the first thickening stage. The brightness remained essentially constant through thickening, screening and cleaning. The post-bleaching hydrosulfite stage provided an additional brightness gain of approximately 7 points.

The mill trials have established that overall brightness gains of 13+ points can be achieved at total sodium hydrosulfite application rates of 18-20 kg/ton, as seen in Fig. 8. By comparison, typical tower bleaching provides only 8-9 points of brightness gain at 10 kg hydrosulfite/ton, as seen in **Fig. 9**. This suggests that a potential gain of five additional brightness points is possible over standard tower bleaching. Comparison of mill results with the pilot-plant trials shows comparable brightness gains.

Pulp and paper properties. It is difficult to compare the strength properties of the grinder-bleached pulp with those of the reference pulp, since they were ground with different types of grinder stones. **Table XI** shows that the strength characteristics of the grinder-bleached pit pulp were slightly lower, although variation in the properties was quite high.

Conclusion

The initial brightness of pressurized groundwood (PGW) can be increased up to 5 ISO points by adding sodium hydrosulfite to the grinder shower water at a rate of 8-10 kg/o.d. metric ton of pulp. Maximum initial brightness for PGW and PGW-S (super pressurized) pulps can be obtained at shower-water temperatures less than 100°C. Mill experience indicates that addition of a grinder-bleaching sequence can increase final brightness by 12-14 points. In contrast, the brightness of conventional PGW pulps increases only 8-9 points after tower bleaching with hydrosulfite.

Grinder bleaching with hydrosulfite had no negative effect on the grinder operation or the properties of the pit pulp. However, addition of a grinder-bleaching stage increased the seven-day BOD load by about 3 kg/a.d. metric ton. Thiosulfate in the shower water used in grinder bleaching was negligible to nondetectable.□

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