Manufacture and quality characteristics of high yield pulps from south American wood species (the)

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RESUMO:

THE MANUFACTURE AND QUALITY CHARACTERISTICS OF HIGH YIELD PULPS FROM SOUTH AMERICAN WOOD SPECIES

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INTRODUCTION

The area of the pulp quality spectrum between high yield mechanical pulps and low yield chemical pulp has been the target for significant research and development effort during recent years. This comment is applicable not only to pulp and paper producers but also to equipment suppliers. Their combined efforts have resulted in the development of a range of high yield chemimechanical pulps (CMP), capable of penetrating that section of the market which has traditionally been considered to be the strict domain of low yield chemical pulps. Concurrently, efficient and reliable equipment suitable for the continuous manufacture of such pulps has been developed. As indicated in Appendices 1 and 2, Sunds Defibrator alone has installed, or is in the process of installing, some 30 high yield pulping systems. While some of these are existing refiner mechanical pulp (RMP) or thermomechanical pulp (TMP) mills which have subsequently been converted in chemithermomechanical pulp (CTMP) mills, others are new mills which have been designed specifically for the production of CTMP or CMP.

CHEMICAL TREATMENT

The properties of mechanical pulps can be strongly modified by sulphonation, by oxidation or by alkali extraction. The chemicals are normally applied to the wood prior to refining, but can also be added directly into the refiner, between the refining stages, or as a post treatment either on the final pulp or on a selected fraction of the pulp such as the screen rejects. The flexibility of the long fibre fractions of pulps treated in this manner improves and the pulps consequently exhibit improved sheet consolidation and bonding properties. Chemical treatment of chips prior to refining in most cases gives a more selective fibre separation, leading to a higher long fibre content, and dramatically lower shive content compared to conventional mechanical pulping.

Treatment of chips with reducing or oxidizing agents, such as sodium sulphite or hydrogen peroxide, results in higher brightness and bleachability improvements of the final pulp. The addition of chelating agents, especially in the presence of reducing agents, deactivates heavy metals that otherwise interfere in subsequent bleaching. Addition of alkali, alkaline sulphite or surface active agents to

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the chips or pulp, permits the removal of pulp extractives, thus rendering the pulps more suitable for use in absorbent grades of paper such as tissue and fluff.

OUTLINE OF CTMP AND CMP PROCESSES

At the present time a number of different processes or variants of processes have already been developed covering a wide range of raw materials and product qualities. In general, a relatively sharp borderline exists between the two pulp types - chemithermomechanical pulp (CTMP) and chemimechanical pulp (CMP). CTMP represents a spectrum of pulp qualities that still exhibits physical property profiles and property interrelationships which are characteristic of mechanical pulps. Such pulps are normally produced under conditions indicated in Figure 1 involving relatively low chemical charges in connection with

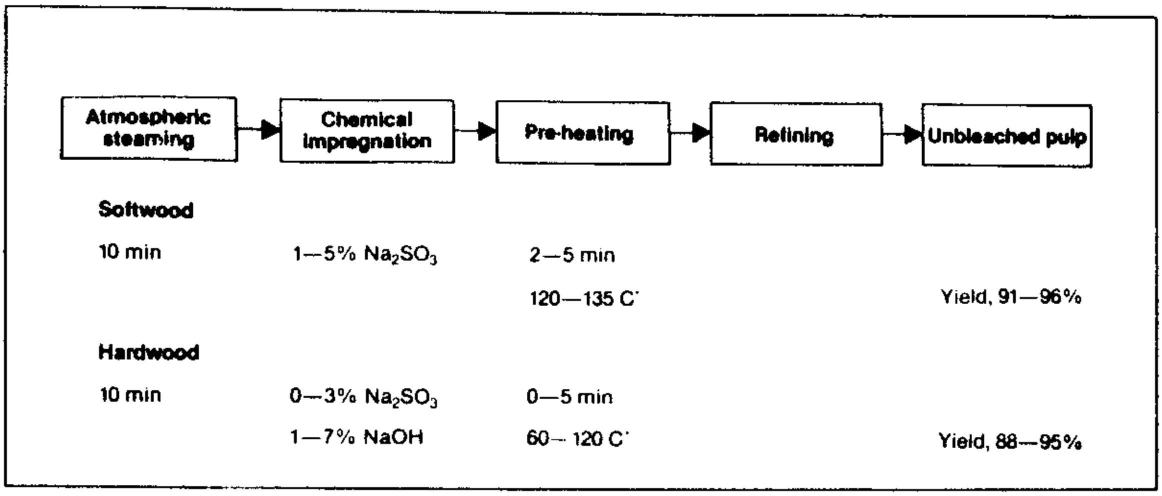

Figure 1: Typical Conditions for CTMP Manufacture

moderate preheater treatment temperatures and retention times. These pulps are used today to replace or supplement conventional mechanical pulps in newsprint and magazine printing grades. At higher freeness levels, CTMP from softwoods is also finding increased use as a bleached pulp in the production of tissue, fluff and paperboard.

CMP is produced by a more severe pretreatment of the chips as indicated in Figure 2. Such pulps exhibit a further improvement in consolidation and bonding properties but are characterized by lower levels of light scattering coefficient and low brightness. Consequently they cannot be used as the major furnish component of printing papers. These pulps, which are produced at relatively high yield levels (88-90%) compared to chemical pulps (44-45%), are however sufficiently strong to be used as complete or partial replacement pulps for the chemical reinforcing pulp component of newsprint and associated furnishes. They will also be used in other products in the future.

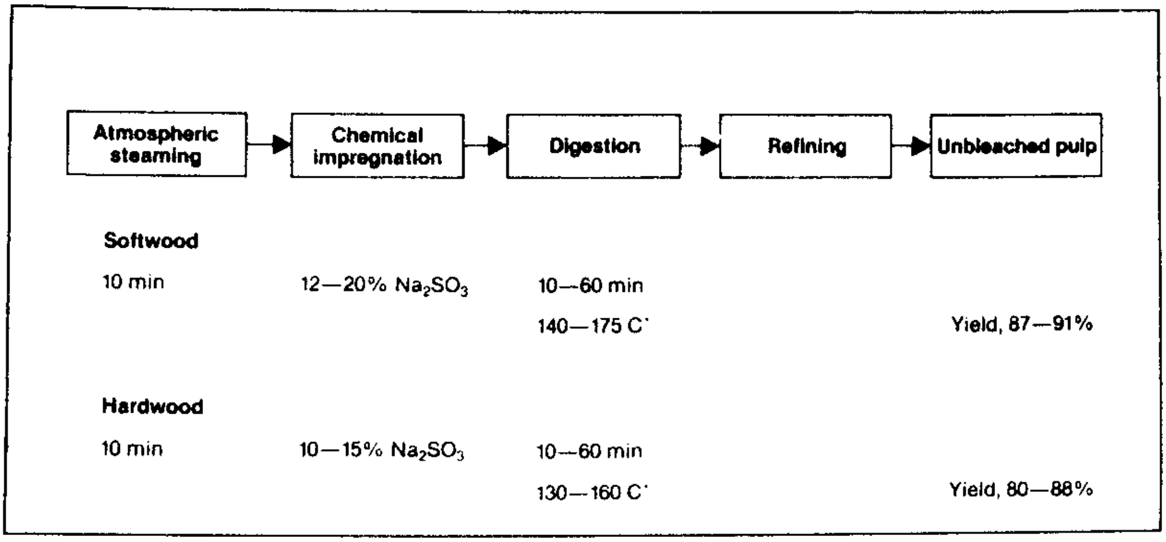

Figure 2: Typical Conditions for CMP Manufacture

PILOT PLANT EXPERIENCES WITH HIGH YIELD PULPING OF SOUTH AMERICAN WOOD SPECIES

Softwoods

Pulp quality data for TMP produced from Radiata pine (Pinus radiata) from Chile, Loblolly pine (Pinus taeda) from Brazil and Slash pine (Pinus elliottii) from Argentina are given in Table 1. For comparison, this table also contains data for Black spruce (Picea mariana) from Eastern Canada. These data indicate clearly that the faster growing South American pines require a significantly higher level of specific energy to achieve a given level of drainage than the slower growing Canadian sprice. It is further evident from the data that at a given level of drainage, the density and bonding properties of TMP from South American Loblolly and Slash pine are generally lower than those obtained from spruce while Radiata pine exhibits comparable properties. These observations are in line with information on the TMP quality characteristics of Radiata pine from Australia and New Zealand and of Loblolly and Slash pine from the Southern United States.

The chemical pretreatments outlined earlier for the manufacture of CTMP and CMP can be applied to improve pulp quality. Pilot plant quality data for TMP, CTMP and CMP from Loblolly pine from Brazil are shown in Table II.

The CTMP referred to in Table II was produced by impregnating Loblolly pine chips with 4.2% sodium sulphite prior to preheating (4 minutes) and two-stage refining. Relative to TMP, it is evident that the CTMP requires higher specific energy to attain a given level of drainage. At equal drainage level however, the CTMP exhibits lower shive content and improved density and bonding properties. The sodium sulphite pretreatment of the chips also resulted in a 3-4 point improvement in brightness. The strength improvements relate directly to the reduction in scattering coefficient, this deficiency explaining the somewhat lower opacity of the CTMP relative to the TMP.

A typical CTMP plant showing atmospheric steaming followed by chemical impregnation and two stage refining under pressure is shown in Figure 3.

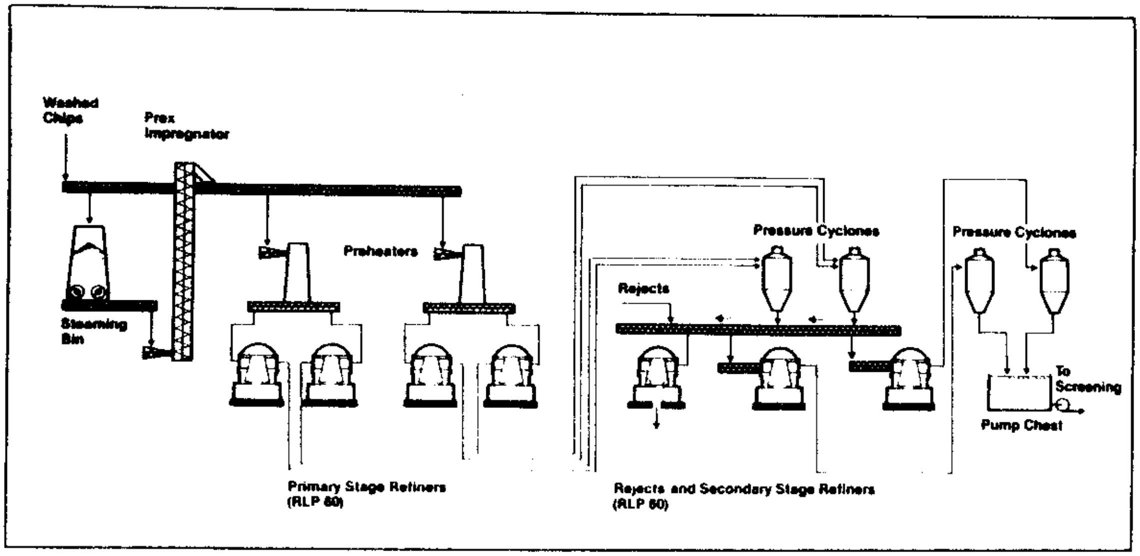

Figure 3: Two stage CTMP Plant for Softwoods

The CMP referred to in Table II was produced by impregnating the Loblolly pine chips with 16% sodium sulphite (pH 9.5) and digesting the chips in the vapour phase at 160°C for 30 minutes prior to two stage refining. Relative to the milder CTMP treatment, the more severe conditions used for CMP resulted in further improvements in density and strength properties even at the higher freeness levels at which such pulp is normally used. The relatively severe treatment conditions clearly had an adverse effect on brightness and from the point of view of scattering coefficient and opacity, the CMP exhibits physical properties which are more closely identified with true chemical pulp as anticipated.

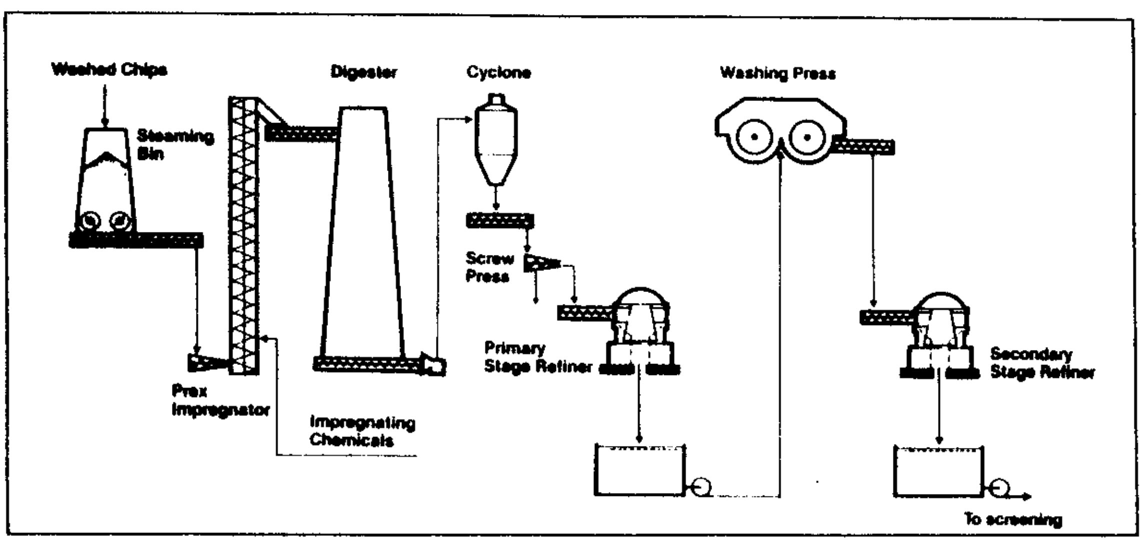

Figure 4: Two stage CMP Plant

A typical commercial CMP plant showing impregnation, digestion and two stages of refining with interstage washing for residual liquor removal is shown in Figure 4.

Hardwoods

In general, hardwoods are unsuitable for mechanical pulp production due to the morphology and physical properties of the raw material. With the exception of some low density species, for example poplars, that yield mechanical pulps suitable for certain applications, a chemical treatment of the short and thick-walled hardwood fibres is required to obtain a pulp with useful properties. CTMP from hardwoods is produced commercially by a pretreatment of the chips with alkali prior to refining. Addition of sulphite to the impregnation liquor is often included, as this in many cases will protect the wood against the darkening effect of the alkali, and result in a useful unbleached product.

Hardwood CTMP can be produced in a process such as that indicated in Figure 5. After atmospheric steaming the chips are impregnated with

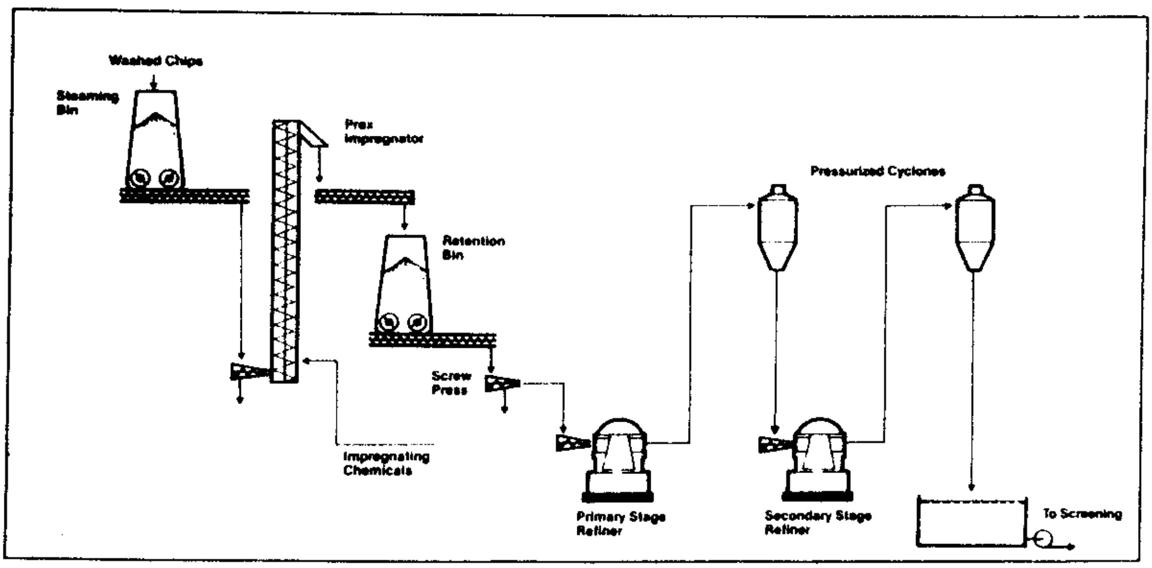

Figure 5: Two-stage CTMP Plant for Hardwoods

the alkaline impregnation liquor in a PREX impregnator. The impregnated chips are discharged to a reaction bin with a retention time of 15-30 minutes and subsequently refined without preheating in a single or two-stage process, depending on the freeness level required in the pulp.

Pulp properties of CTMP from some different hardwood species are given in Table III together with comparative data for softwood TMP and SGW. As is evident from this table, the alkaline treatment results in yield losses which are dependent on alkali charge as well as on the raw material used. An increased alkali charge will lead to improved sheet consolidation. This will appear as increased density, with corresponding improvements in the density dependent properties, such as tensile index, burst index and surface smoothness. Figure 6 shows that an increased alkali charge results in higher tensile strengths, but also

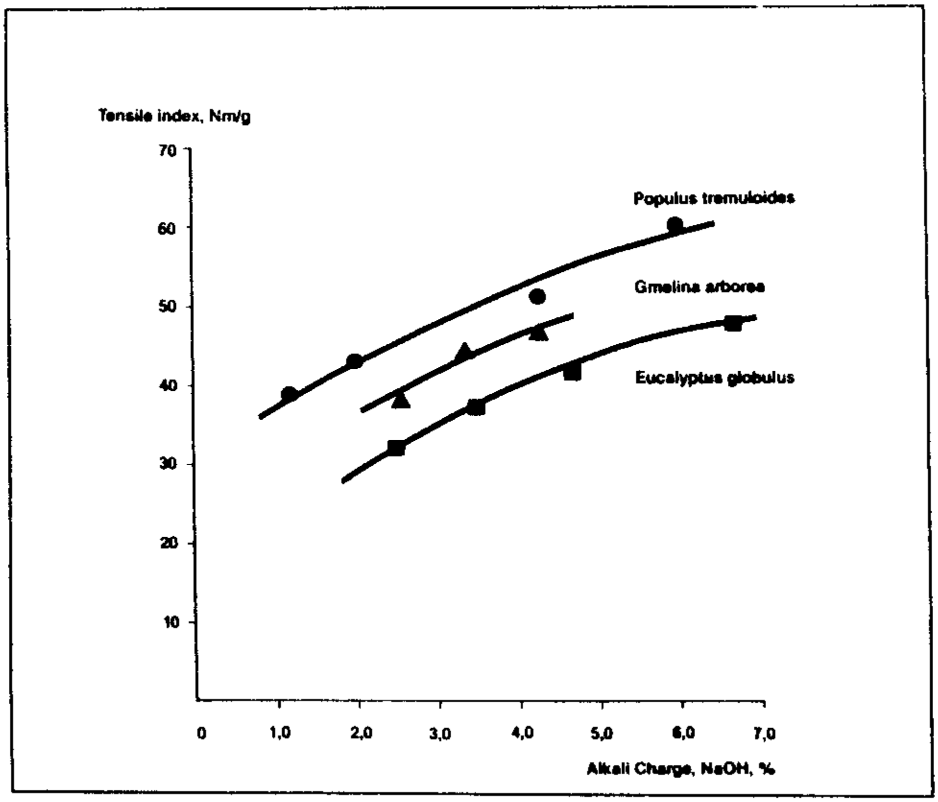

Figure 6: Effect of Alkali Charge on Tensile Index of CTMP from Various Hardwoods (100 ml CSF. Tappi Testing)

that the relationship between alkali charge and tensile index differs for different wood species. A consequence of this is that in order to maintain the CTMP from hardwood mixtures at an even quality level, it is of utmost importance to control the composition of the raw material blend. Strength properties such as wet web strength and tear index which are to a large extent dependent on fibre length, are generally low for hardwood CTMP and normally on the same level as those for softwood SGW, or approximately half the values associated with good quality spruce TMP.

As the density and bonding properties of CTMP improve with increasing alkali charge, the scattering coefficient and opacity of the pulp will decrease. In addition, high alkali charge will also affect the brightness and the bleachability of the pulp in a detrimental manner. This dilemma concerning the relationship between strength and optical properties must be addressed with caution in the manufacture of successful printing paper from hardwood CTMP in that the optical properties of the furnish must not be compromised for the sake of additional strength.

As in the case of softwoods, the production of high yield pulps with superior drainage and strength properties to those exhibited by CTMP demands more severe treatment conditions than those generally employed in the CTMP process. A system suitable for production of this type of pulp has already been shown in Figure 4. The process stages include chip washing, atmospheric steaming and chemical impregnation prior to digestion and refining. Residual chemicals present in the chips after digestion are removed in a PREX unit prior to the primary refining stage and a washing stage is incorporated into the system between the primary and secondary stages of refining.

Pulp property profiles for CMP produced from various hardwood species are given in Table IV. Physical properties are clearly yield related, the yield being dependent on the combined effects of chemical application level, digestion temperature and retention time in the digester. Lower yield pulps will exhibit improved density and bonding properties but at the expense of reduced brightness and lower light scattering coefficient and opacity.

Although the relative effects of process conditions on the quality characteristics of pulps from South American hardwoods have not been evaluated in detail, considerable work has been done on other hardwood species. The effect of cooking temperature at constant chemical application level and digestion time on yield, specific energy to a given level of freeness of 350 ml and physical properties at this freeness level for CMP from North American Aspen (Populus tremuloides) is summarized in Table V. At digestion temperatures exceeding 145-150°C, brightness levels decrease below 50% and such pulps demand high peroxide application levels for brightening to useful brightness levels. Aspen CMP at a starting brightness of 50% can be bleached to a brightness level in excess of 75% using 3-4% peroxide. While this level is high, the peroxide consumption and thus the overall economics of the bleaching process can be improved significantly by effective washing prior to bleaching and by the use of a high efficiency bleaching process permitting the recycling of residual peroxide.

END USES OF HIGH YIELD PULPS

The main shortcomings of conventional TMP is related to its relatively high proportion of stiff and inflexible long fibres. This material limits the density that can be achieved and consequently affects the bonding properties adversely. The advantages exhibited by CTMP relative to TMP in this regard are well documented, CTMP exhibiting lower shive levels, improved density and significantly higher bonding properties. In addition, impregnation with low levels of sodium sulphite results in a brightness gain of 3-5 points. CTMP technology, in conjunction with new but established bleaching technology, permits high brightness levels to be attained at reasonable bleaching chemical costs. The resulting bleached CTMP has shown potential for use in a wider spectrum of products than that available to TMP.

NEWSPRINT AND ASSOCIATED GRADES

Traditionally, newsprint has been produced from a furnish consisting of a 1:3 mixture of chemical reinforcing pulp and stone groundwood. The improved strength properties of TMP permitted a reduction in the chemical reinforcing pulp requirement and in a small number of installations, due either to the availability of good quality wood or to specific marketing conditions, TMP was able to totally eliminate the requirement for chemical reinforcing pulp. In most cases however, the use of TMP has not permitted the complete removal of chemical pulp from the furnish. This is particularly true in those locations where the softwoods available for mechanical pulp are fast growth and consequently coarse fibred species.

More recently, CTMP has been used in newsprint and associated grades, where it has proved itself capable of eliminating the chemical reinforcing pulp component of the furnish without sacrificing sheet quality characteristics. The potential of CTMP for value added grades such as offset newsprint, roto news, magazine grades and telephone directory paper is now well recognized. The pulp has also been used in the manufacture of computer print-out paper and its use as a major furnish component of LWC base paper is clearly within reach.

The significantly improved bonding characteristics of CMP relative to CTMP are a direct result of the lower scattering coefficient and opacity of this type of pulp. These shortcomings eliminate the use of CMP as the major furnish component of printing papers. CMP is, however, sufficiently strong to be used as a partial or complete replacement pulp for the chemical reinforcing pulp component of newsprint and associated furnishes.

PAPERBOARD GRADES

Multiply board has traditionally been made using bleached and unbleached kraft pulp in the top and back layers respectively, with a lower cost material in the intermediate layers. Earlier, high freeness stone groundwood was used for this purpose but TMP and CTMP are now used in the central layers to impart the required degree of flexural rigidity to the product.

To date, experience with CTMP in board is limited but it has been shown that conversion from TMP to CTMP at constant density results in improved drainage, reduced shive content, improved strength and rigidity and better runnability in converting operations. The improvement in drainage implies a 10-15% reduction in refining energy compared to TMP. Furthermore, problems associated with taste/odour when using straight mechanical pulp were eliminated by the use of CTMP. CTMP is thus a desirable furnish component for liquid packaging board, a material for which conventional mechanical pulps proved unsuccessful.

TISSUE AND FLUFF GRADES

Pulp for use in fluff and tissue grades must exhibit good water absorption properties, not only in terms of maximum water holding capacity but also in terms of initial rate of penetration. This implies that such pulps must have a low residual resin content, and this is compatible with good peroxide bleaching response. In addition to these requirements, fluff pulp must possess good dry network strength. Thus while a combination of hardwood and softwood CTMP can be used in the manufacture of tissue, generally only softwood CTMP is used for fluff grades.

The impregnation of softwood chips with sodium sulphite prior to preheating and refining results in pulps which, after washing, exhibit a low extractives content. If chelating agents are introduced into the chips during the impregnation phase, heavy metal ions present in the wood are deactivated. The combination of these two aspects results in pulps which are significantly easier to bleach than corresponding TMP and higher brightness levels in the range 75-80% ISO brightness are attainable. At high freeness levels in the range 250-600 ml CSF, bleached CMTP, with its relatively high long fibre content, its low shive content and its very low level of residual extractives, exhibits good water penetration and water absorption capacity, making the pulp suitable for use in absorbent grades of paper such as tissue and fluff products. Such tissue is already being produced in Brazil using CTMP from Cunninghamia pine and at least one tissue grade consists of 100% CTMP. Recent trials have shown that CTMP from Loblolly pine (Pinus taeda) and Slash pine (Pinus elliottii) are also suitable materials in this regard.

For certain tissue applications in North America, where a combination of good absorbency and high strength is demanded, CTMP has been quoted as being at the lower limit with regard to strength properties. In such cases, CMP has been identified as a favourable substitute provided that high brightness can be achieved.

FINE PAPER GRADES

In general, the use of CTMP in fine paper grades has progressed less rapidly than the application of the pulp in other paper grades discussed above. Recent trials carried out in a fine paper mill in Scandinavia are indicative, however, of the level of interest in reducing overall furnish costs by moving towards the use of high yield pulps.

With no attempt to optimize CTMP quality or to determine at which level of drainage such pulp should be used, a fine paper quality was produced using a 1:1 fibre furnish of bleached CTMP and bleached birch kraft pulp. In addition, 20% calcium carbonate was used as a filler and the paper was surface sized with 3% conventional starch.

The bleached CTMP was produced by impregnating chips with 2.5% sodium sulphite and 0.1% DTPA prior to preheating and refining. After peroxide bleaching and flash-drying, the CTMP had a freeness level of 200 ml CSF, a very low shive content and a long fibre fraction of 42-44%. This pulp exhibited a density of 350 kg/m^3, a tensile index of 44 Nm/g and a brightness of 77-78% ISO.

The trial paper had a basis weight of 80 g/m^2 and was manufactured to standard specifications for copy paper, book print and offset grades. Despite some deficiencies in physical properties, the trial paper compared quite well to the comparison standard grade and responded well in offset printing trials, where linting was described as normal and pressroom runnability was judged to be acceptable. Considering that no attempt was made to specify or optimize the quality of the CTMP prior to the papermachine trial, the result was clearly extremely positive. Further work will clarify the potential of CTMP for use in fine paper grades.

HEAT RECOVERY ASPECTS

In the mid 70's, the high energy cost associated with TMP manufacture impeded the growth rate of TMP tonnage in North America. Since that time, the rapid development and application of suitable heat recovery technology in conjunction with modified refiner design to permit operation at higher casing pressures has significantly changed this situation. Pressurized cyclones are now used extensively in both single and two-stage TMP and CTMP plants. These units separate fibre and contaminated steam and thus deliver a flow of contaminated but fibre-free steam to the heat recovery unit at a pressure just below that prevailing in the refiner casing. Refiners are currently operating at casing pressures in the range 150-450 kPa (gauge pressure). Excess steam is also available from the preheater in the pressure range 100-150 kPa. In modern TMP/CTMP systems, some 65% of the electrical energy supplied to the refiner motors can be recovered in the form of high pressure steam. The pressure of the contaminated steam delivered to the clean steam generating unit will clearly determine whether a thermocompression stage is required to meet the downstream requirements of the system.

A schematic diagram of a Rosenblad heat recovery unit currently operating on a two-line, single stage TMP installation is shown in Figure 7.

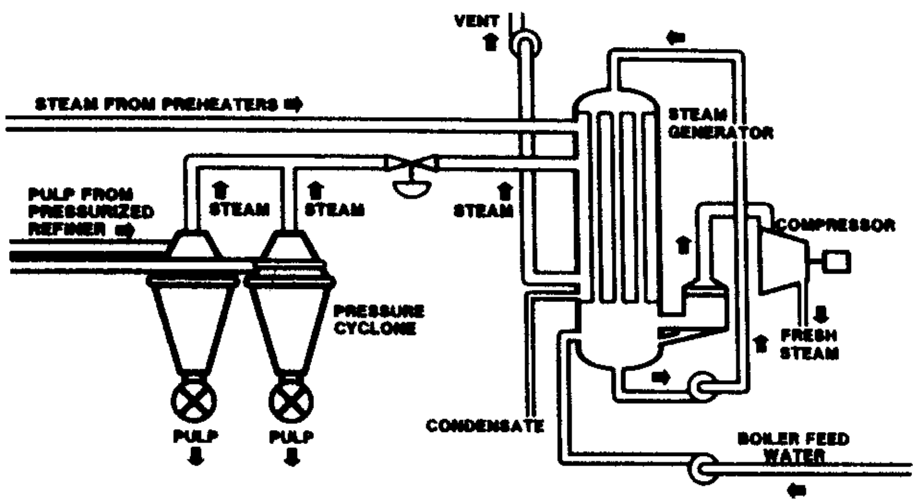

Figure 7: Holmen Rosenblad Heat Recovery System

High pressure contaminated steam from the two cyclones is fed into the shell side of a steam generator consisting of a lamellae type, falling-film heat exchanger. Boiler feed water is fed in the form of a spray to the inside of the unit. The boiler feed water is thus evaporated and the clean steam generated in this manner is fed through a demister and subsequently into the low-pressure steam net where it can, for example, be used in the papermachine drying operation. Although Figure 7 shows a thermocompressor after the steam generator, this is clearly only necessary if the outlet pressure needs to be raised to meet the requirements of the low-pressure steam net.

ENVIRONMENTAL ASPECTS

Effluent from all mills contains both inorganic and organic material, the latter deriving from the wood and consisting mainly of lignins, carbohydrates and breakdown products from these materials. In the manufacture of mechanical pulp, problems associated with mill effluent are largely related to the discharge of toxic substances generally in the form of resin acids, suspended solids and biochemical oxygen demand (BOD), the latter representing a measurement of the amount of biologically decomposable material present in the effluent.

In the case of conventional TMP manufacture, the pulp yield is in the range 94-96%, the pulping process removing organic substance corresponding to about 15-25 kg BOD per tonne. Such effluent is readily amenable to biological treatment and the impact of the process on the environment can thus be reduced to a very low level. In the manufacture of CTMP and CMP, the BOD level is yield related and thus dependent on the severity of the chemical treatment. Chemithermomechanical pulp, produced by the impregnation of chips with relatively low levels of sodium sulphite (2-4%) prior to preheating and refining would exhibit BOD levels in the range 30-45 kg BOD per tonne. Chemimechanical pulp produced by impregnation of the chips with high levels of sodium sulphite (14-17%) prior to higher temperature digestion and subsequent refining would exhibit BOD loading levels up to 55-65 kg BOD per tonne. Even in this case, adequate BOD reduction for discharge to the receiving water can be achieved by biological treatment in an aerated lagoon. Recently published information, however, suggests that a better approach involving a combination of anaerobic and aerobic treatment may be more efficient, this two-stage process having an overall BOD reduction in the range 95-98%.

CONCLUDING REMARKS

The chemical impregnation of chips in conjunction with conventional or modified TMP technology results in a wide range of high yield pulps exhibiting improved consolidation and bonding characteristics compared to conventional refiner mechanical pulps. As a consequence, these pulps are suitable for a much broader spectrum of end uses than that available to conventional mechanical pulps. The detrimental aspects of these chemically modified mechanical pulps relate to somewhat increased manufacturing costs associated with chemical application level, to reduced opacity and to increased environmental impact related to decreased yield levels.

Chemithermomechanical pulp from both softwoods and hardwoods has already experienced commercial exposure in a wide variety of end products ranging from printing grades to absorbent grades and certain types of board. Production capacity of pulps of the CTMP type will continue to grow with increased feedback from the initial installations and the growth rate itself will accelerate as the relatively new pulping and bleaching technologies become established.

The use of softwood chemimechanical pulp as a partial replacement for the chemical reinforcing pulp in newsprint is already well established. Furthermore, the capabilities of the process for optimizing the strength properties of high yield pulps from hardwoods is well understood. While the increased environmental impact associated with the manufacture of CMP currently represents a detrimental factor restricting the more rapid growth of the process, both unbleached and bleached CMP may well present strong competition for chemical pulps in the manufacture of printing and other grades in the future.

Table I Quality Characteristics of TMP from South American Pine Species

Wood Species		Black Spruce *Picea mariana*			Radiata Pine *Pinus radiata*			Loblolly Pine *Pinus taeda*			Slash Pine *Pinus elliottii*		
Country of Origin		Canada			Chile			Brazil			Argentina		
Specific Energy	kWh/t	2010	2145	2430	2220	2360	2550	2400	2545	2640	2515	2668	2925
Freeness	ml. CSF	140	120	81	120	100	80	170	120	80	130	107	89
Shive Content	%	0.53	0.46	0.30	0.50	0.45	0.40	0.67	0.41	0.30	0.39	0.32	0.24
Density	kg/m^3	350	365	400	340	355	375	295	320	345	300	310	325
Burst Index	$kPa.m^2/g$	2.10	2.25	2.50	1.90	2.15	2.30	1.25	1.45	1.50	1.15	1.28	1.50
Tensile Index	Nm/g	36.0	37.5	44.0	38.0	42.0	43.5	23.0	26.0	29.5	24.0	27.0	32.0
Tear Index	$mN.m^2/g$	10.4	10.9	10.9	9.8	9.5	9.2	8.9	8.2	8.1	7.0	7.4	8.0
Brightness	%	56.9	57.1	57.1	52.0	51.5	51.0	55.6	56.4	56.2	58.0	58.5	58.0
Opacity	%	93.0	93.5	94.0	92.0	92.5	93.0	90.5	91.5	92.5	89.5	89.5	90.5
Scattering Coefficient	m^2/kg	55.0	56.0	57.2	52.5	54.0	55.0	54.0	57.0	57.0	52.5	53.0	55.4

Table II Quality Characteristics of TMP, CTMP and CMP from Brazilian Loblolly Pine (*Pinus taeda*)

Pulp type		TMP			CTMP			CMP			SBK
Sodium Sulphite Application	%		0			4.2			16.0		-
Preheater/Digester Temperature	°C		130			125			165		-
Preheater/Digester Time	min		1.5			2.5			30.0		-
Specific Energy	kWh/t	2400	2545	2640	2450	2900	3600	1330	1430	1500	-
Freeness	ml. CSF	170	120	80	170	120	80	500	350	250	585
Shive Content	%	0.67	0.41	0.30	0.11	0.05	0.04	0.20	0.17	0.18	-
Long Fibre Content	%	-	-	-	28.7	25.1	22.1	58.9	54.3	51.1	-
Fines Content	%	-	-	-	26.5	30.3	33.4	9.1	16.5	19.0	-
Density	kg/m^3	295	320	345	304	337	365	385	430	480	549
Burst Index	$kPa.m^2/g$	1.25	1.45	1.50	1.38	1.62	1.93	2.84	3.20	3.60	3.40
Tensile Index	Nm/g	23.0	26.0	29.5	26.2	30.0	38.0	39.6	49.0	54.0	45.3
Tear Index	$mN.m^2/g$	8.9	8.2	8.1	7.4	7.8	7.9	8.6	8.3	8.4	18.4
Brightness	%	55.6	56.4	56.2	59.0	59.0	58.0	45.1	44.6	44.5	-
Opacity	%	90.5	91.5	92.5	88.7	89.2	90.5	87.2	85.1	85.0	85.0
Scattering Coefficient	m^2/kg	54.0	57.0	57.0	49.9	52.4	54.1	33.5	30.5	29.5	29.0

Table III Physical Properties of Bleached CTMP from Hardwoods

(120 ml CSF, Bench Bleaching on Pilot Plant Pulps, Tappi Testing Procedures)

Raw Material		Trembling Aspen (Populus tremuloides)		Beech (Fagus silvatica)	Gmelina (Gmelina arborea)		Eucalyptus (Eucalyptus globulus)		Scandinavian Spruce (Picea abies)	
Pulp type		CTMP		CTMP	CTMP		CTMP		SGW	TMP
Impregnation										
NaOH	%	1.0	1.0	3.1	2.7	2.7	5.4	4.5	-	-
Na2SO3	%	3.0	3.0	3.6	0	0	0	0	-	-
Bleaching										
H2O2	%	1.0	3.0	3.2	1.0	1.5	4.0	4.0	-	-
NaOH	%	0.8	1.8	2.0	1.5	2.0	1.8	2.5	-	-
Yield										
Unbleached	%	92.6	92.6	91.5	87.3	87.3	90.7	91.4	97.0	96.0
Bleached	%	91.3	90.3	89.0	85.2	85.0	89.2	88.9	-	-
Physical Properties										
Density	kg/m^3	430	435	380	365	375	480	400	400	375
Tensile Index	Nm/g	39.0	40.5	25.5	27.5	29.0	45.5	40.5	31.0	41.0
Tear Index	$mN.m^2/g$	6.3	6.3	4.3	4.2	4.3	5.2	4.9	4.2	9.5
Brightness	%	73.0	78.0	78.0	71.0	74.5	75.5	78.5	60.0	58.5

Table IV — Pulp Quality Characteristics of Unbleached CMP from Hardwoods

(350 ml CSF, Pilot Plant Pulps, Tappi Testing Procedures)

Raw Material		Trembling Aspen (Populus tremuloides)	Red Alder (Alnus Rubra)	Birch (Betula verrucosa)	Eucalyptus (Eucalyptus globulus)
Sodium sulphite	%	20.0	15.0	15.0	15.0
Digestion Time	min	30	40	15	20
Digestion temperature	^{o}C	150	160	150	160
Yield	%	86.2	83.0	87.7	85.4
Density	kg/m^3	520	560	400	440
Tensile Index	Nm/g	51.0	65.0	36.0	40.0
Tear Index	$mN.m^2/g$	6.7	5.0	5.8	3.9
Light Scattering Coefficient	m^2/kg	33.5	30.0	38.0	36.0
Brightness	%	50.0	45.0	62.0	63.0

Table V Physical Properties of North American Aspen CMP* at 350 ml CSF (Tappi Testing)

Cooking temperature	°C	130	140	150	160
Cooking time	min	30	30	30	30
Approximate yield	%	88.0	87.5	86.5	83.5
Specific energy consumption	kWh/t	1800	940	850	730
Density	kg/m^3	450	525	575	625
Burst Index	$kPa.m^2/g$	1.65	2.75	3.10	3.60
Breaking Length	m	4000	5000	5500	6500
Tear Index	$mN.m^2/g$	5.5	6.5	6.6	6.9
Opacity	%	89.0	86.5	84.0	81.0
Unbleached Brightness	%	52.0	51.0	49.8	46.4

* All pulps impregnated with 160-200 kg/t sodium sulphite (pH 10.5)

Appendix 1 — CTMP Plants Based on Sunds Defibrator Equipment

Mill	Location	Daily Capacity ADMT	Raw Material	End Use
Rockhammar	Sweden	150	Spruce	Market Pulp - Multigrade
Skoghall	Sweden	400	Spruce	Fluff/Paperboard
Matfors	Sweden	150	Spruce	Magazine
Fors	Sweden	260	Spruce	Paperboard
Ostrand	Sweden	240	Spruce	Market Pulp - Fluff/Tissue
Quesnel River	Canada	530	Spruce/Pine	Market Pulp - Multigrade
Bathurst	Canada	480	Spruce/Balsam	Market Pulp - Newsprint
Winstone	New Zealand	400	Mixed Pines	Market Pulp - Multigrade
Melhoramentos	Brazil	75	Tropical Pines	Tissue
Folla	Norway	240	Spruce	Market Pulp - Tissue
Taio	Japan	300	Mixed Softwoods	Newsprint
Mo-Do Iggesund	Sweden	200	Spruce	Tissue/Paperboard
Serlachius	Finland	200	Spruce	Tissue

Appendix 2

CMP Plants Based on Sunds Defibrator Equipment

Mill	Location	Daily Capacity AMDT	Raw Material	End Use
CIP	Canada	450	Spruce	Newsprint
Fort William	Canada	135	Spruce	Newsprint
NBIP	Canada	488	Spruce	Newsprint
Georgia Pacific, Bellingham	USA	80	Red Alder	Tissue
Georgia Pacific, Lyons Falls	USA	125	Mixed Hardwoods	Printing Papers
Georgia Pacific, Plattsburg	USA	125	Mixed Hardwoods	Tissue
Daishowa, Yoshinaga	Japan	150	Mixed Hardwoods	Newsprint
Jujo, Kushiro	Japan	200	Mixed Hardwoods	Newsprint
Oji, Tomakomai	Japan	350	Mixed Hardwoods	Newsprint
APPM, Wesley Vale	Australia	70	Eucalyptus	Printing Grades
ANM, Boyer	Australia	150	Eucalyptus	Newsprint
Calabra	Italy	150	Mixed Hardwoods	Market Pulp
Torviscosa	Italy	120	Mixed Hardwoods	Market Pulp
Nigerian Newsprint	Nigeria	300	Gmelina arborea	Newsprint
Hindustan Paper	India	235	Eucalyptus	Newsprint
Massuh	Argentina	120	Mixed Hardwoods	Printing Grades
Junkers	Denmark	250	Birch	Market Pulp
Treschow-Fritzoe	Norway	80	Birch	Market Pulp