

Processing of Nonwood Fibers In Modern Pulp Mills

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ABSTRACT

Most nonwood pulp and paper processes have been derived from existing wood based technologies, not without their share of successes and failures. Nonwood fibers are very diverse and their properties vary so much, that adapting existing wood pulp processes and equipment is not always possible.

A number of project related research programs were carried out to assess the effect of different cooking processes and subsequent ECF and TCF bleaching sequences on straw and bagasse pulp, two major raw materials used in nonwood fiber pulp & paper production.

Keywords: Straw

Bagasse

Soda process

Kraft process

Anthraquinone

ECF bleaching

TCF bleaching

INTRODUCTION

During recent years there has been increased pressure from the environmental protection groups and government to reduce the emissions in the pulping industry and also to decrease the virgin wood fiber consumption in paper production.

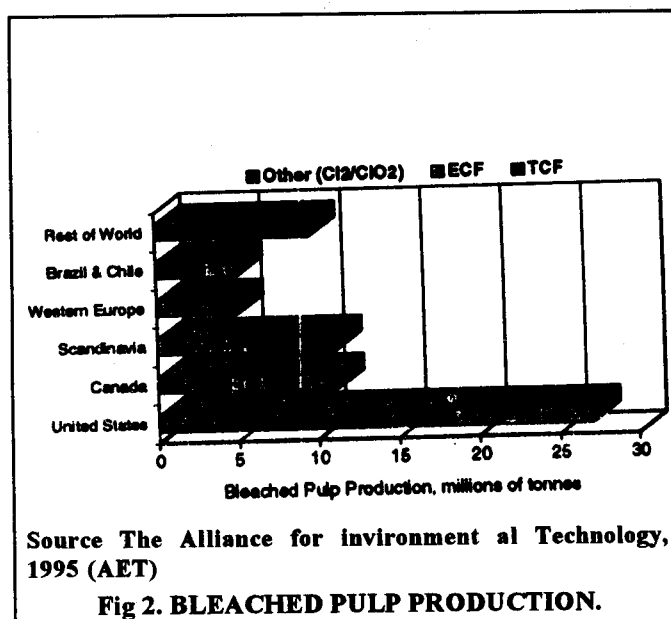
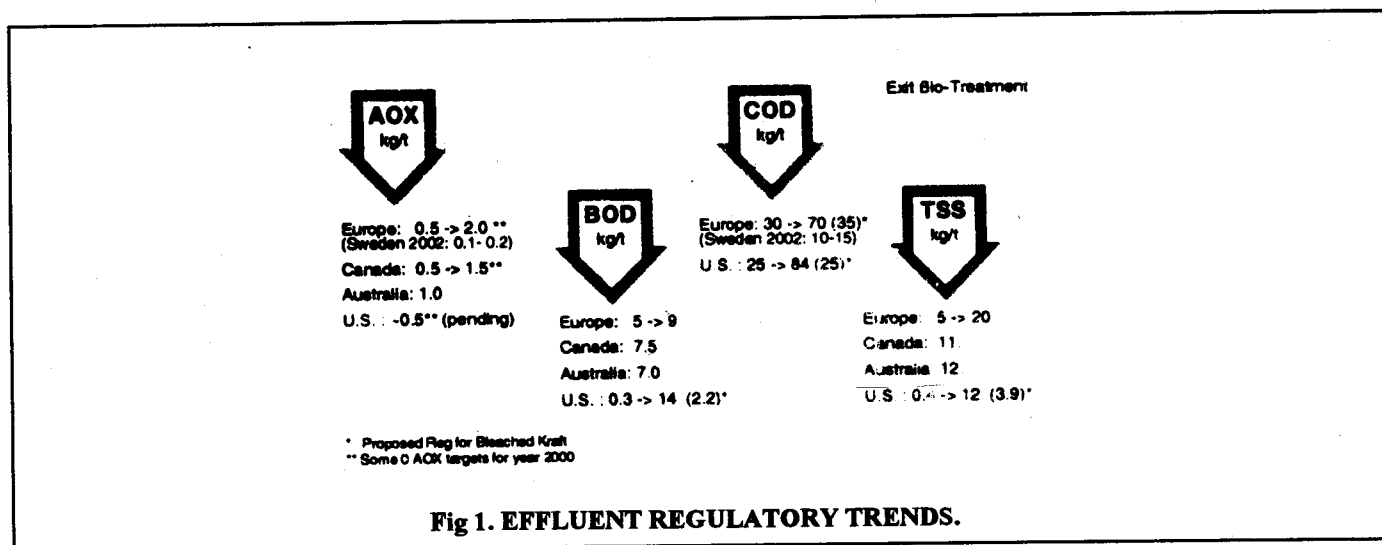
These concerns from society and new regulations are forcing the industry to reduce its environmental impact as shown in Figure 1. This has led to considerable improvements in the way chemical pulp is produced.

In pulping, the efforts are concentrated on modified cooking processes and extended delignification.

In bleaching, ECF technology has become the standard choice to bleach plant sequence design, and capacity has grown at an average rate of 5 million tons/year in the past 5 years. The use of chlorine gas and hypochlorite has been all but abandoned for wood pulp bleaching in favour of the use of chlorine dioxide. The chart in Figure-2 illustrates the production of bleached pulp around the world in 1995.

TCF technology has been commercialized over the last several years primarily for sulphite pulps and primarily in German speaking countries.

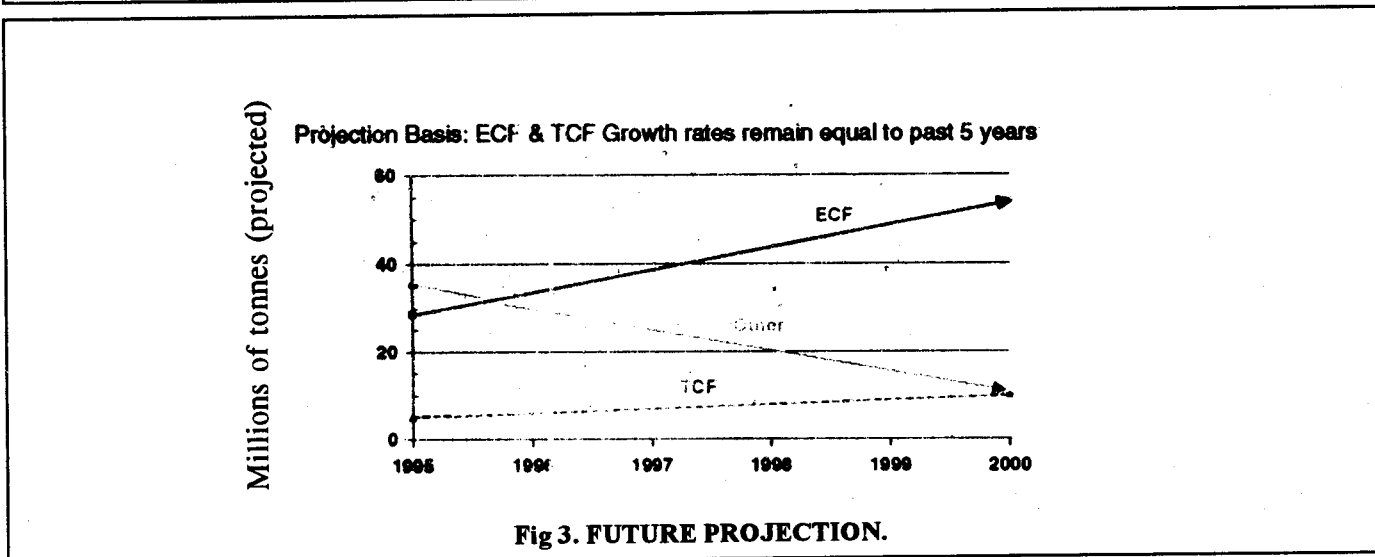
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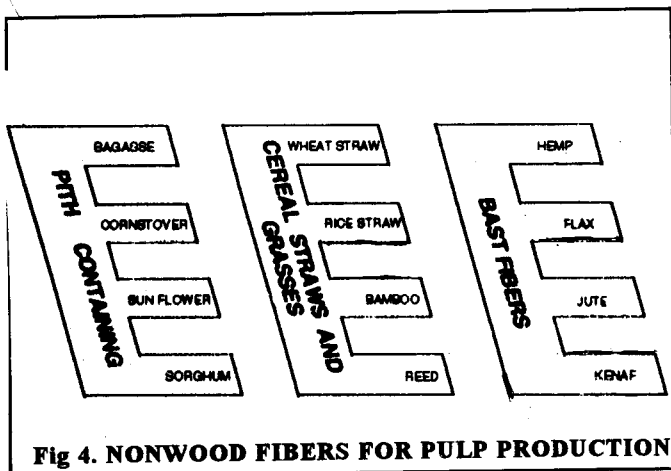


This development was driven in Europe in response to demand, in the United States by stronger standards by the government protection agency (EPA) and in South America and The Pacific Rim by the demands in the export markets. Future projections for ECF & TCF growth rates are given in Figure 3. All these data are valid for wood chemical pulps, but we assume that a similar trend can be expected for nonwood fibers.

TCF is likely to be a strong contender after the year 2000, as total mill closure or TEF becomes realistic design goal. This means mills of the future will need to process all wastes internally without any leaving the plant.

BELOIT has the know-how and experience to





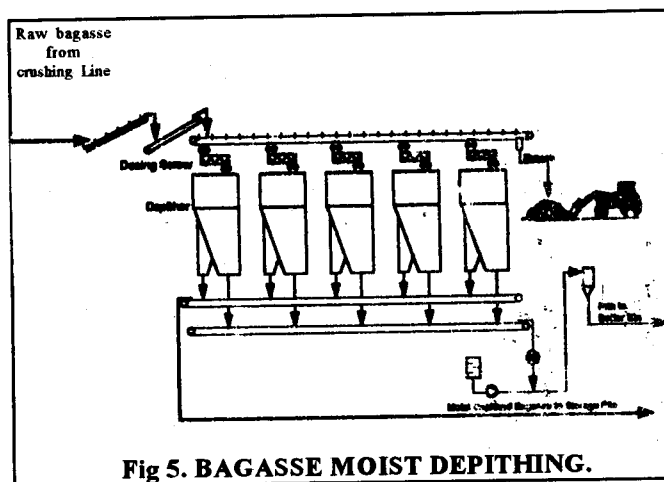
apply this knowledge for process technology and equipment design for nonwood fibers.

We have concentrated our development in improving the pulping process and bleaching conditions for a better pulp quality and more environmentally friendly technology.

This paper presents the initial results in the development of ECF/TCF bleaching sequences for straw and bagasse pulps.

RAW MATERIAL PREPARATION

The pulping process starts with the appropriate selection of the raw material preparation system. Most nonwood fibers used for pulp production are agricultural residues and contain considerable amounts of impurities, which have to be removed



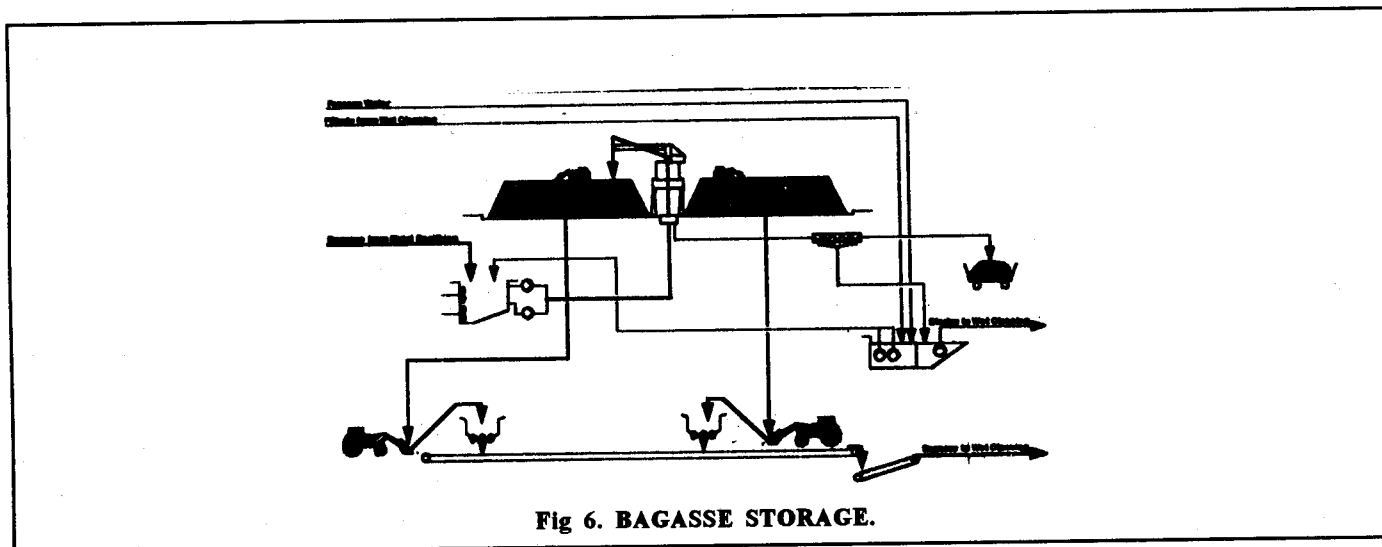
prior to processing in the fiber line.

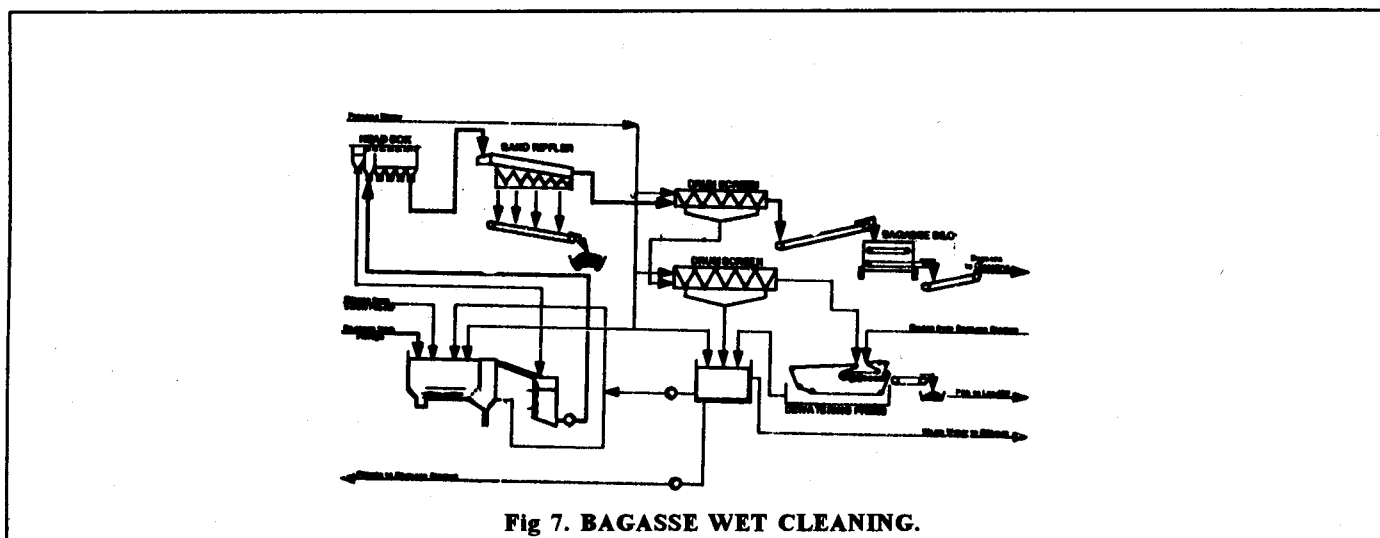
As listed in **Figure 4**, we can generally distinguish between 3 different categories:

1. Pith containing fibers such as bagasse, Sorghum, corn stalks, etc.
2. Cereal straws and grasses such as wheat straw, rice straw, esparto, sabai, kahi, reed and bamboo.
3. Other non-wood fibers for speciality grades such as flax, hemp, jute, abaca and linters.

Each of the above groups has to be prepared differently for successful pulp and paper production.

Figures 5-7 are simplified flowsheets for a typical bagasse preparation system comprising





depithing, storage and wet cleaning. Bagasse fibers are non-uniform and contain a lot of parenchyma cells. They do not contribute towards mechanical strength and are responsible for excessive equipment-wear, poor drainage, low capacity, higher chemical consumption and poor bleachability. New depithing methods and storage systems have been developed to obtain a well depithed, more reactive and uniform bagasse fiber.

For straw, the dry cleaning method, as shown in Figure 8, which comprises chopping, dedusting and the separation of grain, nodes, sand and grit, is sufficient. In the case of rice straw, which contains a lot of sand and silica, an additional wet cleaning process in a pulper, as illustrated in Figure 9, is applied.

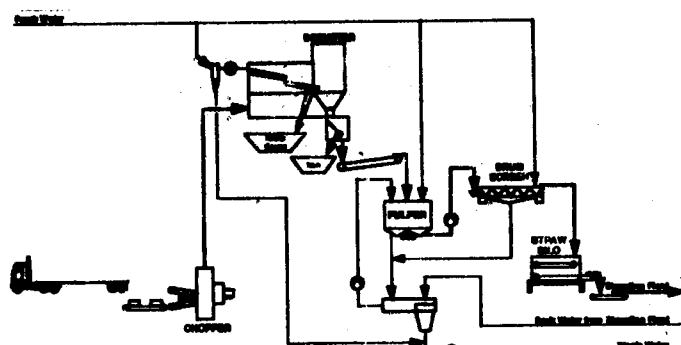
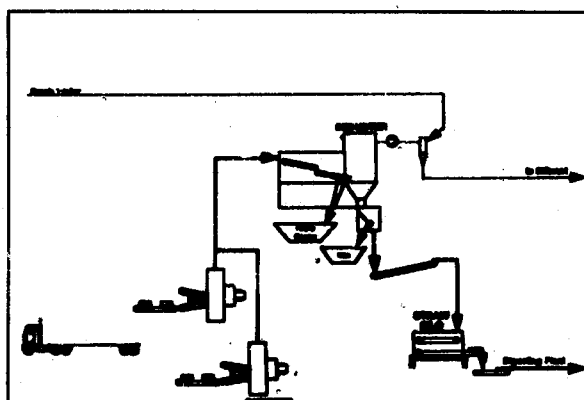
Raw materials with characteristics as per Table-1 have been used for the laboratory tests.

PULPING

Of the various cooking technologies still used for nonwood fibers, soda and kraft are the dominant processes for bleachable grade pulp. For high yield pulp CMP/CTMP, NSSC and sulphur-free process are used.

The most widely used system for the cooking of nonwood fiber is the PANDIA® continuous digester, as shown in Figure 10. The primary advantages of this equipment are enhanced yield and uniform pulp quality reduced steam and chemical consumption, amenability to process automation and reduction in manpower and space.

72 such systems for all kind of nonwood fibers have been implemented with a total installed capacity of 2.5 million tons.



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TABLE-1	
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PROXIMATE ANALYSIS OF NONWOOD FIBERS

	Dep.Bagasse Thailand	WheatStraw England	Rice Straw Kasachstan
1%NaOH soluble, %	32.0	52.5	44.3
AB Soluble, %	2.2	4.8	5.9
H ₂ O Soluble(cold), %	1.8	18.8	11.0
H ₂ O Soluble(hot), %	2.3	21.7	16.1
Klasonn lignin, %	21.2	16.3	12.5
Pentosans, %	28.1	26.8	26.5
Holo-Cellulose, %	73.6	69.0	65.0
Ash, %	1.06	9.1	14.9
-SiO ₂ , %	1.0	4.3	8.6

TABLE-2	
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Pandia Lab Digester Cooking Results for Rice Straw

Cooking process		Soda	Soda/AQ	Kraft
Pulping conditions				
chemicals charge,	% Na ₂ O/o.d.	12.5	12.5	11.6
Sulphidity,	%	-	-	25
AQ,	%	-	0.1	-
Cooking Temp,	°C	170	170	170
Cooking time,	min	10	10	10
Yield unscreened,	%	44.3	44.6	46.0
Rejects,	%	0.9	0.7	0.3
Yield screened,	%	43.4	43.9	45.7
Kappa No. screened		11.9	13.1	12.8
Initial freeness,	°SR	38	38	38
Viscosity,	cm ³ /g	906	814	908

PANDIA® COOKING RESULTS

A series of soda, soda-AQ and kraft cooks were conducted to determine the optimum cooking parameters. From the preliminary cooks optimized conditions were selected, as shown in Table 2-4.

The result in Table 2-4 confirm the experience that with the addition of AQ less chemical charge is required for the same Kappa number. The results are an improved yield and viscosity. Kraft process without AQ provides similar results.

BROWN STOCK WASHING

An essential part of pulp processing is the thorough washing of the unbleached pulp. Washing

TABLE-3	
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Pandia Lab Digester Cooking Results for Wheat Straw

Cooking process		Soda	Soda/AQ	Kraft
Pulping conditions				
chemicals charge,	% Na ₂ O/o.d.	12.5	10.9	12.5
Sulphidity,	%	-	-	20
AQ,	%	-	0.1	-
Cooking Temp,	°C	170	170	170
Cooking time,	min	20	20	20
Yield unscreened,	%	42.8	46.2	48.0
Rejects,	%	0.3	0.2	0.6
Yield screened,	%	42.5	46.4	47.4
Kappa No. screened		14.0	10.7	16.8
Initial freeness,	°SR	32	34	32
Viscosity,	cm ³ /g	859	969	1034

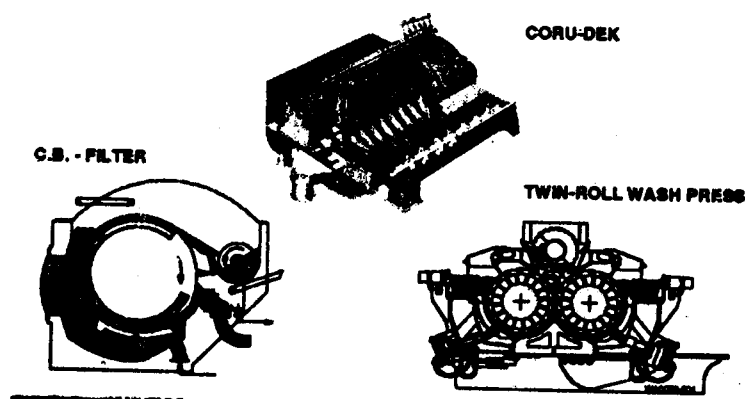


Fig 11. BELOIT WASHING EQUIPMENT OVERVIEW.

TABLE-4

Pandia Lab Digester Cooking Results for Bagasse				
Cooking process		Soda	Soda/AQ	Kraft
Pulping conditions				
chemicals charge,	% Na ₂ O/o.d.	12.5	11.6	11.6
Sulphidity,	%	-	-	20
AQ,	%	-	0.1	-
Cooking Temp,	°C	170	170	170
Cooking time,	min	16	16	16
Yield unscreened,	%	54.3	55.1	56.8
Rejects,	%	0.5	0.5	0.3
Yield screened,	%	53.8	54.6	56.5
Kappa No. screened		15.0	12	14.5
Initial freeness,	°SR	19	18	19
Viscosity,	cm ³ /g	795	920	1064

is defined as the removal of the maximum amount of dissolved organic and soluble inorganic material in the post cooking pulp mass with the minimum amount of wash water. An excess of dissolved solids after the washing plant creates problems in the bleach plant, paper mill and effluent plant.

In order to reduce the bleaching chemical consumption and preserve pulp strength, the carry-over from brown stock washing to oxygen delignification has to be limited to 150 kg COD/BDMT. Good washing is a must to avoid excessive active chlorine consumption in the first bleaching stage and to lower the final effluent discharge from the bleaching plant. Typically 10-15 kg COD/BDMT

are to be obtained in modern plants.

Depending on the application, one or a combination of the following washing equipment as shown in Figure 11 can be used:

1. **CORU-DEK Vacuum Washer** for replacement or new installations.
2. **Compaction Baffle Filter** is a pressurized drum filter that achieves high capacity and low level installation.
3. **Twin Roll Wash Press** for high discharge consistencies.

The selected washing equipment mainly depends on the specific mill requirements such as capacity, washing efficiency, available space etc.

A comparison of the design data of all 3 machines is given in Figure 12.

SCREENING

Conventional pressure screening and cleaning as used for wood pulps is also effective for nonwood fiber pulps. A typical screening concept is given in Figure 13.

The latest development is the HI-Q Fine Screen which provides efficient and economical shive and dirt removal from the pulp stream. The innovative Stingray™ Rotor makes it possible to operate and accept consistencies of 4%, while using 0.15 and

PARAMETER	UNIT	CORU-DEK VACUUM FILTER	C.B. FILTER	TWIN ROLL WASH PRESS
Inlet Consistency	% B.D.	1.0-1.5	3.5-5.0	3.5-5.0
Disch. Consistency	% B.D.	11-15	13-17	30-50*
Loading	MODTPD/Sq.m.	4**	15**	12-15**
Height	M (above ground)	12.0	5	5
Face Wire odourless		Yes	No	No
Air-tight hood		No	Yes	Yes
Space requirement		Considerable	Minimal	Minimal

* depending on operating conditions and freeness

** Bagasse chemical pulp

Fig. 12. BELOIT WASHING EQUIPMENT COMPARISON.

0.2 mm slotted screen plates resulting in extremely high screening efficiency of at least 93% for bleachable grade pulp.

This new design, shown in Figure 14, is also available as a retrofit for existing conventional screens, taking advantage of the ability to improve efficiency, raise unit capacities and reduce reject rates.

BLEACHING

In the past, environmental concerns were not a critical factor and mills were designed very open, consuming large quantities of water and cheap bleaching chemicals such as chlorine and hypochlorite.

Most nonwood fibers have the advantage of low lignin content and therefore a great potential

for non-chlorine bleaching sequences.

However, many existing nonwood fiber mills are still using chlorine gas and hypochlorite as bleaching agents. Some of these mills, as well as new installations, are investigating ECF and TCF sequences for environmental reasons.

There are some nonwood fiber mills which have an O₂-delegnification, fewer are operating on ECF and, to our knowledge, none is running on TCF

Various ECF and TCF sequences have been evaluated and compared as illustrated in Tables 6-8. Bleaching conditions for all stages are summarized in Table 5.

When using D-EO-D instead of C-E-H sequence, the final brightness is increased by 3-5%

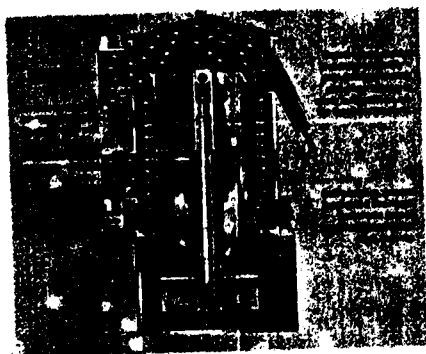


Fig13.SCREENING AND CLEANING PROCESS OVERVIEW

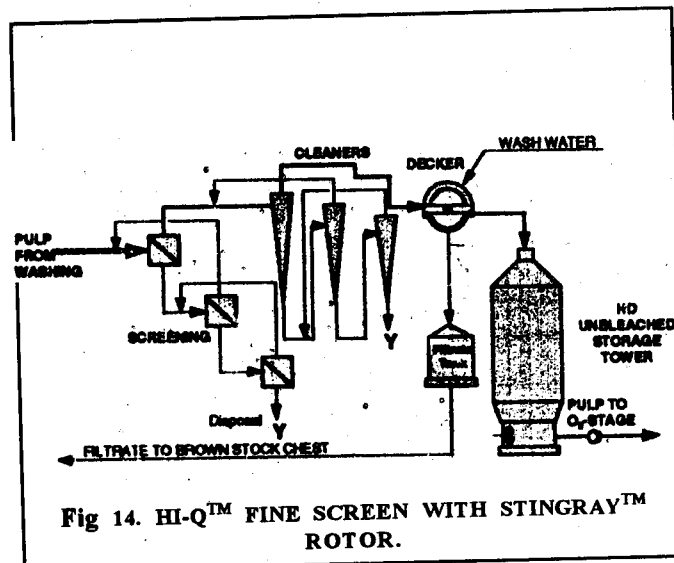


Fig 14. HI-Q™ FINE SCREEN WITH STINGRAY™ ROTOR.

TABLE-5										
GENERAL BLEACHING CONDITIONS										
Stage	Q	A	D ₀	E ₀	E _{OP}	P _{HT}	Z	E	D _N	D
Consistency %	10	10	10	10	10	10	10	10	10	10
Temperature °C	90	65	65	75	75	105-98	40	60	75	75
Time min	60	30	60	15+60	15+60	15+1804	90	240	240	
End pH	6.0	2.5	3.0	10.5	10.5	10-10.5	2.5	11	3.5	3.5
Pressure kPa		-	-	150	150	500-0	-	-	-	-
EDTA %	0.5	-	-	-	-	-	-	-	-	-
Epson salt %	-	-	-	-	-	0.5	-	-	-	-

TABLE-6					
BLEACHING SEQUENCES FOR NONWOOD FIBER PULPS					
Sequence	C-E-H	D ₀ -E-D ₁	O-D ₀ -EO-D ₁	O-A-P-P	O-A-Z-P
Kappa brown stock	12-15	12-15	12-15	12-15	12-15
Brightness (% ISO)	80-83	84-86	84-88	75-82	84-86
Bleaching chemicals					
Chlorine (kg/BDMT)	40-60	-	-	-	-
Chlorinedioxide as ClO ₂ (kg/BDMT)	-	20-25	15-20	-	-
Caustic soda (kg/BDMT)	30	18	12(+15)*	15-20(+15)*	8-10(+15)*
Sulfuric acid (kg/BDMT)	-	5	17	15-20	15-20
Chelant (EDTA) (kg/BDMT)	-	-	-	3-6	3-6
Oxygen (kg/BDMT)	-	-	15-20	15	15
Ozone (kg/BDMT)	-	-	-	20-30	10-20

*NaOH used in Oxygen Delignification is recycled with black liquor.

TABLE-7					
BLEACHING SEQUENCES FOR NONWOOD FIBER PULPS					
Sequence	C-E-H	D ₀ -E-D ₁	O-D ₀ -EO-D ₁	O-A-P-P	O-A-Z-P
Kappa brown stock	12-15	12-15	12-15	12-15	12-15
Brightness (% ISO)	80-83	84-86	84-87	75-82	80-86
Wast water (m ³ /BDMT)	20	20	20	15-20	15-20
COD (kg/BDMT)	70	60	40	40*	40*
AOX (kg/BDMT)	4	1	0.5	0	0

*Can be reduced by recycling the filtrate.

ISO. At the same time the AOX load is reduced from 4 to 1Kg/BDMT. With a preceeding O₂-stage the Cl₂ consumption in Do-stage is 20-30% lower, the AOX is further reduced to 0.5 kg/BDMT and the COD load decreased from 60 to 40 kg/BDMT.

In the case of TCF bleaching, the AOX is almost completely eliminated. If part of the bleach-

ing filtrate is used in O₂-stage and brown stock washing the COD load is only 10kg/BDMT.

Brightness levels in the 84-87% ISO range have been reached with ClO₂ or ozone stages.

Although there are significant operating costs with the production of TCF pulps, this can be

TABLE-8					
BLEACHING SEQUENCES FOR NONWOOD FIBER PULPS					
Sequence	C-E-H	D ₀ -E-D ₁	O-D ₀ -EO-D ₁	O-A-P-P	O-A-Z-P
Kappa brown stock	12-15	12-15	12-15	12-15	12-15
Brightness (% ISO)	80-83	84-86	84-87	75-82	80-86
Chemical costs (USD/BDMT) (Chinese price basis)	16	32	20	52	42
Relative investment costs (european basis) (%)	100	130	170	140	160

compensated with a lower investment and operating costs in effluent treatment.

The key to successful TCF bleaching is metal management, especially when peroxide is used to brighten (Figure 15).

Depending on the raw material preparation and the pulping process, the unbleached bagasse pulp usually contains substantial amounts of metals:

Fe 200-550 mg/kg

Mn 10-50 mg/kg

Mg 250-450 mg/kg

When a final brightening target is in the mid to low 80's, a Mn-level below 5 ppm should be satisfactory. But when the final brightness of 85-88% ISO is the target, Mn-removal will be key and, if possible, should be below 1 ppm. Also, for pulp viscosity protection it is important to add magnesium to the pulp. Iron is also detrimental to peroxide and generally it can be removed to about

20 ppm with a standard acid or chelation stage (see Figure 16, removal stage option and targets).

BLEACH PLANT FLEXIBILITY

From the economical and environmental point of view, an ECF sequence O-D₀-EO-D₁ as shown in Figure 17 is recommended.

With minor modifications and minimal capital expense, this ECF sequence can be converted to O-Q or A-EOP-P or P_{HT} sequence, as illustrated in Figure 18.

With the ECF sequence 84-87% ISO can be reached. After conversion to Q-EOP-P sequence 82-85% ISO should be obtainable. When using P_{HT} in the final bleaching stage, as opposed to P, a brightness of 85% ISO or higher should be achievable.

CONCLUSION

1. Efficient raw material preparation and cleaning is a key to produce good pulp quality and to minimize the operating problems in the pulp mill.

The Key to Successful TCF Bleaching

Fig. 15. METALS MANAGEMENT.

Peroxide Brightening Stage

- Removal Targets:
 - ▲ Manganese (Mn) <5ppm (brightening)
 - ▲ Mg/Mn Ratio >30
 - ▲ Iron (Fe) <20ppm
- Removal Stage Options:
 - ▲ D₀ (pH 2-2.5)
 - ▲ A (Acidification pH 2-2.5)
 - ▲ Q (Chelation pH 5-7)
 - ▲ Z (Ozone pH 2.5-3)

Fig. 16. METALS REMOVAL.

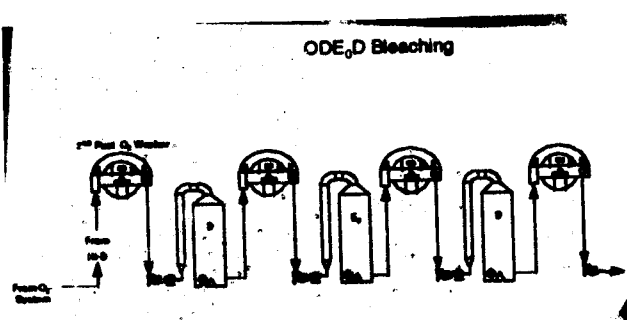


Fig. 17. TYPICAL ECF BLEACH PLANT.

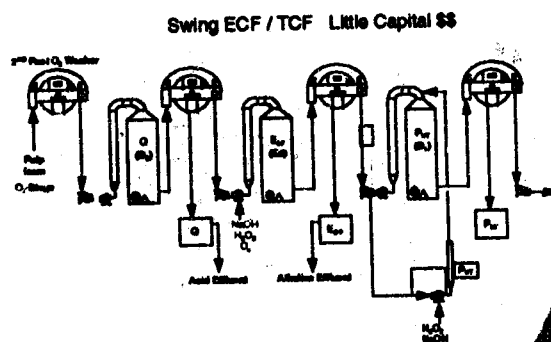


Fig. 18. Bleach Plant Flexibility-ECF/TCF Swing.

2. The PANDIA® tube digester system is the epitome of economic investment for pulp mills using nonwood fibers. For the production of bleachable grade pulp from nonwood fibers, the soda process is preferred for environmental reasons. The addition of AQ improves the digester yield and viscosity. The kraft process results in superior pulp quality.
3. The washing system has to be designed to reduce the carry over to the bleach plant to below 15 kg COD/BDMT.
4. To meet the environmental standards, new bleach plant installations have to be designed for ECF and/or TCF sequences.
5. The possibility to swing from ECF to TCF should be foreseen in the bleach plant design. This requires only minimal additional capital investment but increases the operating costs resulting in a minor environmental impact.
6. TCF bleaching sequences have the future potential towards a TEF fiberline with the benefits listed in Figure 19.

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