Multi-Stage Bleaching of Bamboo Kraft Pulps—A Comparative Study

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SUMMARY

Unbleached bamboo kraft pulp at two different levels of permanganate number, viz., 15 & 24, was bleached to 81±1 PV brightness in CEHH, CHEH, CEHP, CEHD, HCEH and CEDP sequences. In each bleaching sequence, losses in pulp yield, bleaching chemicals consumption, final pulp brightness, post colour number, strength, viscosity, etc. were determined.

The research findings from the present study are that brightness stability is better and the pollution load is significantly lower in case of the lesser K No. pulp, in all the bleaching sequences studied.

A brief discussion of the mill bleached pulps and mill trials in bleaching at Central Pulp Mills is also included in the paper.

INTRODUCTION

The main objective of the investigation is to study in depth, the various four stage bleaching sequences to obtain a final bleached pulp of 81±1 PV brightness having better brightness stability with a post colour number of around 4.0, as against the normal value of 7.0 for a bleached bamboo kraft pulp of 80 PV brightness (in CEHH sequence).

Since most of the paper mills in India cook bamboo to a permanganate number between 15 & 24, these two levels of delignification are chosen for the present investigation. In addition to the usual data on bleaching chemicals consumption, pulp viscosity, strength, shrinkage during bleaching and brightness stability, an attempt is made to obtain meaningful information on pollution load from each sequence as denoted by BOD, COD and TSS.

DISCUSSION AND RESULTS

Table—I lists the cooking conditions, pulp yields and black liquor characteristics for obtaining bamboo kraft pulps of 15 and 24 permanganate number respectively. The screened unbleached yield at the permanganate number of 15 is 47% as against 51.4% for the pulp of the permanganate number of 24.

BRIGHTNESS STABILITY AND EFFLUENT QUALITY

Tables—IIA, IIB, IIIA, and IIIB give the data on bleaching conditions and the final pulp brightness, post colour number and viscosity as well as on the effluent characteristics in CEHH, CHEH, CEHP, CEHD, HCEH, CEDP and CEHDP sequences for both the unbleached bamboo kraft pulps of 15 K No. & 24 K No. Predictably, the post colour number is about on point lower in case of the lesser K No. pulp. For instance, in CEHH and CEHP sequences, the post colour number of the final pulp is 6.1 and 3.8 respectively for the 15 K No. pulp, as against 7.8 and 4.4 respectively for the 24 K No. pulp.

As regards effluent quality, the total effluent load to the sewer (same quantities of water were used in bleaching the 15 K No. and 24 K No. pulps to attain the same final pulp brightness in the bleaching sequences studied) denoted by TSS, BOD and COD is lower in the softer and more delignified pulp. For example, in the most commonly used CEHH sequence, TSS, COD and BOD 1 day values are 57 Kgs/ton, 195.1 Kgs/ton and 16 Kgs/ton repectively for the 15 K No. pulp, as against 74 Kgs/ton, 231.6 Kgs/ton and 20.3 Kgs/ton respectively for the 24 K No. pulp.

It may be seen from the above results, it is possible to obtain pulp at 82 brightness in four stage bleaching sequence without dropping pulp quality, as denoted by viscosity. However, to obtain pulps of 85 PV brightness without loss of pulp strength, a five to six stage multistage bleaching sequence will be needed. In one such sequence chosen in the present study, viz., CEHDP sequence, the final pulp brightness obtained was 84.5 PV at a post colour

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number of 2.0 for the 15 K No. pulp as against 85PV brightness at a post colour number of 2.4 for the 24 K No. pulp. The effluent load in CEHDP sequence, as measured by TSS, COD and BOD values is 67.7 Kgs/ton, 194 Kgs/ton and 15.5 Kgs/ton respectively for the 15 K No. pulp, compared to 73.5 Kgs/ton, 210 Kgs/ton and 19 Kgs/ton respectively for the 24 K No. pulp. It can thus be seen that the higher the final pulp brightness, the lesser is the pollution load to the sewer from the pulp mill, while using an extra stage of bleaching and less degrading bleaching chemicals like chlorine dioxide and hydrogen peroxide.

TABLE–I

COOKING CONDITION, PULP and BLACK LIQUOR ANALYSIS FOR 15.0 K No. AND 24.0 K. No. PULPS

Sr. No.	Particulars			Results.
I.	**Chips Classification**			
	28	mm %		1.7
	28+21	mm %		3.6
	—21+16	mm %		20.5
	—16+7	mm %		48.5
	— 7+4	mm %		19.4
	— 4	mm %		6.3
	Acceptable chips	%		92
II.	**Cooking Condition**:		For 15.0 K No.	For 24.0 K No.
	Chemicals as Na_2O (TAA)	%	20.0	15.0
	Time to 105°C	Min	45	45
	Time at 105°C	”	45	45
	Time 105°C to 160°C	”	90	60
	Time at 160°C (Max Temp)		120	90
	Bath ratio (chips to liq)		1:2:5	1:2:5
III.	**Pulp Yield on OD Material**			
	Unscreened yield	%	47.8	53.2
	Screen rejects	%	0.8	1.8
	Screened yield	%	47.0	51.4
IV.	**Unbleached Pulp K No.**		15.0	24.0
V.	**Black Liquor Analysis**			
	pH		11.8	11.0
	Temperature	°C	29	29
	Total Solids	%	12.8	10.5
	Organic (as such at 900°C)	%	53.0	49.0
	Inorganics (,, ,,)	%	47.0	51.0
	TTA as Na_2O	g/L	45.26	43.4

BLEACHED YIELD AND STRENGTH

The strength properties of the unbleached bamboo kraft pulps of 15 K No. and 24 K No. are shown at six different levels of freeness in Tables IVA and IVB. At all the levels of freeness, the harder cooked pulp possesses higher strength than does the softer pulp even at a lower sheet density at a given freeness, indicating that there was considerable degradation in the cook to obtain the 15 K No. pulp. Pulp degradation is probably the reason for a much lower yield of 47.8% for the 15 K No. pulp, compared to 53.2% for the 24 K No. pulp. At 80 PV brightness, in CEHH bleaching sequence, the bleached yields are 41.4% for the 15 K No. pulp and 43.4% for the 24 K No. pulp.

The bleached pulp from the higher K No. pulp has higher strength, at the same brightness level, in all the bleaching sequences studied in the present investigation. Tables—VA and VB list the strength results at 250 ml (CSF) for the bleached pulps of 15 K No. and 24 K No. for all the seven bleaching sequences. CEHD and CEDP pulps have the highest strength in case of both the 15 K No. and 24 K No. pulps. In general, in all the bleaching sequences, the burst factor and breaking length dropped during bleaching, whereas tear factor remained about the same as double folds improved marginally. However, in CEHD and CEHP bleaching sequences, the bleached pulp strength is close to the unbleached pulp strength. For example, at 250 ml (CSF), the unbleached bamboo kraft pulp of 24 K No. has a breaking length of 6600 Metres, a burst factor of 51.5, a tear factor of 113 and a double folds of 425. The CEHH bleached pulp (of the 24 K No. pulp) has a breaking length of 5750 M, a burst factor of 46.0, a tear factor of 100 and a double folds of 446 for the CEHH sequence, whereas the CEHD bleached pulp has a breaking length of 6190 M, a burst factor of 50.3, a tear factor of 106.6 and a double folds of 510.

CHANGE IN PULP STRENGTH DURING CEHH BLEACHING

Table–VI lists the strength values of the regular mill kraft pulp (23±1 K No.), in CEHH bleaching. All the pulp samples are of mill pulps and represent the steady state operations. Unbleached bamboo kraft pulp here had a brightness of 24 PV and attained 42 PV brightness during chlorination, fell to 34 PV during alkaline extraction and attained 78 PV and 82 PV brightness values in the first and second hypochlorite bleaching stages respectively. It is interesting to note that the strength properties improved during alkaline extraction and were the highest for the pulp of this stage. In subsequent hypochlorite bleaching, the pulp strength, fell, thus, if one can tolerate a relatively darker pulp with about 35 PV brightness, the highest pulp strength in kraft pulping, stronger than unbleached kraft, could be obtained in alkaline extraction.

In CEHH bleaching, the viscosity values for the above pulp were 20.7 CP for the unbleached pulp, 24.8 CP for the chlorinated pulp, 22.5 CP for the extracted pulp, 9.5 CP for the first stage hypo pulp

TABLE—IIA

BLEACHING CONDITIONS AND RESULTS FOR VARIOUS SEQUENCES (15 PERMANGANATE NUMBER)

Bleaching Sequence	C	E	H	H	C	H	E	H	C	E	H	P	C	E	H	D
Chemicals on OD pulp, %	5.5	2.0	2.0	0.5	5.5	2.0	2.0	0.5	5.5	2.0	2.0	0.5	5.5	2.0	1.75	0.5
Consistency, %	3	10	10	10	3	10	10	10	3	10	10	10	3	10	10	10
Temperature, °C	27	60	45	45	28	45	60	45	28	60	45	70	27	60	45	70
Retention Time, Min.	25	120	120	150	25	120	120	150	25	120	120	150	25	120	120	150
pH	1.9	11.0	8.0	8.3	2.2	8.3	10.4	8.8	1.9	11.0	8.1	9.2	1.9	10.3	7.6	4.5
Bleaching losses on OD Pulp, %				12.1				12.0				12.1				11.6
Brightness, oPV				81				81				82				81.5
Post Colour Number				6.1				6.3				3.8				4.4
Viscosity (0.5% CED), cps				8.5				8.9				12.1				13.7
Effluent Characteristics																
pH	3.8	9.0	7.5	7.6	2.6	7.6	9.3	8.2	3.8	9.0	7.5	7.6	3.8	9.0	7.5	7.0
Total suspended solids, Kg/T	14	18	13	12	14	13	12	9.0	14	18	13	9.8	14	18	13	10
COD, Kg/T	60	69	41.5	24.6	61	56	40.5	25	60	69	41.5	16.8	60	69	41.5	17.6
BOD 1 day at 37 °C, Kg/T	4	5	4	3	4	4.5	3.5	2.5	4	5	4	1.5	4	5	4	1

TABLE—IIB

BLEACHING CONDITIONS AND RESULTS FOR VARIOUS SEQUENCES (15 PERMANGANATE NUMBER)

Bleaching sequence	H	C	E	H	C	E	D	P	C	E	H	D	P
Chemicals on OD pulp, %	1.5	5.0	2.0	2.0	5.5	2.0	2.0	2.0	5.5	2.0	1.5	1.5	0.3
Consistency, %	10	3	10	10	3	10	10	10	3	10	10	10	10
Temperature, °C	45	29	60	45	29	60	70	70	28	60	45	70	70
Retention time, Min.	120	25	120	150	25	120	120	150	25	120	120	120	150
pH	8.8	1.8	10.8	8.8	1.9	10.6	4.7	9.9	1.9	10.6	8.8	5.1	9.6
Bleaching losses on OD pulp, %				12.1				11.1					13.0
Brightness, oPV				82				81					84.5
Post Colour Number				6.15				2.8					2.0
Viscosity (0.5% CED), cps				8.3				21.5					19
Effluent Characteristics													
pH	8.4	8.8	8.9	8.2	3.8	9.0	6.4	8.2	2.8	8.9	8.2	4.8	8.3
Total suspended solids, Kg/T	13	12	13	9	14	18	11	9	14.7	19	13	11	10
COD, Kg/T	58	59	44	29	60	69	20.8	16.8	59	67	39	16	13
BOD, Kg/T	4.5	3.5	3.5	3.0	4	5	2.5	1.0	4	5	4	1.5	1.0

TABLE—IIIA

BLEACHING CONDITION AND RESULTS FOR VARIOUS SEQUENCES (24 PERMANGANATE NUMBER)

Bleaching Sequence	C	E	H	H	C	H	E	H	C	E	H	P	C	E	H	D
Chemicals on OD pulp, %	8.0	3.0	2.5	0.5	8.0	3.0	2.5	2.5	8.0	3.0	2.5	0.3	8.0	3.0	2.5	1.0
Consistency, %	3	10	10	10	3	10	10	10	3	10	10	10	3	10	10	10
Temperature, °C	27	60	45	45	28	45	60	45	27	60	45	70	27	60	45	70
Retention time, Min.	25	120	120	150	25	120	120	150	25	120	120	150	25	120	120	150
pH	1.7	10.6	8.0	7.5	2.1	8.3	10.5	8.9	1.8	10.7	8.2	10.2	1.8	10.8	7.5	4.4
Bleaching losses on OD pulp, %				15.5				15.2				14.7				14.2
Brightness, °PV				81				80				81				80.5
Post colour No.				7.8				7.4				4.4				4.0
Viscosity (0.5% CED). cps				12.4				12.8				16.4				18.5
Effluent Characteristics																
pH	3.0	8.8	7.6	7.4	2.4	7.7	9.2	8.2	3.0	8.8	7.6	7.8	3.0	8.8	7.6	6.8
Total suspended solids, Kg/T	18	25	18	13	18	14	18	13	18	25	18	10	18	25	18	11
COD, Kg/T	75.2	81.6	48.8	26	66	51	50	31	75.2	81.6	48.8	20	75.2	81.6	48.8	22.4
BOD 1 day at 37 °C, Kg/T	5.5	6.0	5.3	4.0	5.5	5	4.5	3.5	5.5	6.0	5.3	2.0	5.5	6	5.3	1.5

TABLE—IIIB

BLEACHING CONDITIONS AND RESULTS FOR VARIOUS SEQUENCES (24 PERMANGANATE NUMBER)

Bleaching sequence	H	C	E	H	C	E	D	P	C	E	H	D	P
Chemicals on OD pulp, %	2.5	7.0	2.5	0.5	8.0	2.5	2.5	2.5	8.0	3.0	3.0	2.0	0.5
Consistency, %	10	3	10	10	3	10	10	10	3	10	10	10	10
Temperature, °C	45	29	60	45	29	60	70	70	29	60	45	70	70
Retention time, Min.	120	25	120	150	25	120	120	150	25	120	120	120	150
pH	8.7	1.9	10.7	8.7	1.9	10.2	4.8	10	2.1	10.7	8.6	5.3	9.8
Bleaching losses on OD pulp, %				15.7				14.2					15.5
Brightness, °PV				81				80					85
Post Colour Number				7.42				3.03					2.4
Viscosity (0.5% CED), cps				13.2				24					21
Effluent Characteristics													
pH	8.7	3.5	9.0	8.4	3.0	8.8	6.6	7.8	2.6	9.1	8.4	5.3	8.6
Total suspended solids, Kg/T	14	16	18.5	14	18	25	13	10	16	21	14	11.5	11.0
COD, Kg/T	61	62	53	35	75.2	81.6	23.2	20.8	67	69	41	19	14
BOD I day at 37°C, Kg/T	6	4.5	4.0	3.5	5.5	6.0	3.0	2.0	5	6	4.5	2.0	1.5

TABLE—IVA

PHYSICAL PROPERTIES OF 15 & 24 K No. UNBLEACHED BAMBOO KRAFT PULPS AT DIFFERENT FREENESS LEVELS

Particulars	15.0 K No. Pulp						24.0 K No. Pulp					
Initial freeness, ml CSF	660	660	660	660	660	660	660	660	660	660	660	660
Final freeness, ml CSF	660	550	450	350	250	150	660	550	450	350	250	150
Beating time, Min.	0	17	29	37	48	60	0	19	31	40	50	64
Breaking length, M	1765	3780	4940	5440	6300	6450	2015	4130	5290	5790	6600	6850
Burst factor (Mullen)	10.5	31.6	40.6	45.6	48.0	49.2	10.7	33.9	43.3	47.4	51.5	52.7
Tear factor (Elm)	100	126.6	120	113.3	106	100	100	133	126	120	113	100
Double folds (MIT)	3	68	201	294	396	443	3	85	216	348	425	472
Sheet Density, g/cc	0.4	0.5	0.52	0.57	0.6	0.62	0.39	0.48	0.50	0.52	0.57	0.60
Fiber Classification At Initial Freeness (Clark)												
+ 20 mesh %	39.5						40.2					
— 20 + 50 mesh %	20.0						21.5					
— 50 + 65 mesh %	8.0						8.2					
— 65 + 125 mesh %	4.2						4.5					
— 125 mesh %	28.3						25.6					

TABLE–IVB

PHYSICAL PROPERTIES OF 15 & 24 K No. BLEACHED (CEHH) BAMBOO KRAFT PULPS AT DIFFERENT FREENESS LEVELS

Particulars	15.0 K No. Pulp						24.0 K No. Pulp					
Initial freeness, ml CSF	660	660	660	660	660	660	670	670	670	670	670	670
Final freeness, ml CSF	650	550	450	350	250	150	670	550	450	350	250	150
Beating time, Min.	0	14	21	28	35	49	0	18	29	37	44	52
Breaking length, M	1915	3125	3630	4580	5290	5645	2015	3225	3830	4680	5750	6050
Burst factor (Mullen)	9.3	28.3	37.6	41.2	43.5	44.0	10.5	31.6	39.9	42.0	46.0	48.0
Tear factor (Elm)	93.3	113.3	110.0	106.6	93.3	86.6	86.6	120	117.3	107	100	98.5
Double folds (MIT)	2	60	222	281	414	430	2	65	363	378	404	449
Sheet Density, g/cc	0.41	0.53	0.57	0.62	0.66	0.69	0.4	0.52	0.57	0.61	0.65	0.68
Fiber Classification at Initial Freeness												
+ 20 mesh %	36.5						37.2					
— 20 + 50 mesh %	25.4						27.0					
— 50 + 65 mesh %	7.8						7.7					
— 65 + 125 mesh %	5.0						4.8					
— 125 mesh %	25.3						23.3					

TABLE–VA

PHYSICAL PROPERTIES OF BLEACHED PULPS AT 250 ml CSF (15.0 K No. PULP)

Particulars	CEHH bleached pulp	CHEH bleached pulp	HCEH bleached pulp	CEHP bleached pulp	CEHD bleached pulp	CEDP bleached pulp	CEHDP bleached pulp
Initial freeness, ml CSF	660	660	660	650	670	660	660
Final freeness, ml CSF	250	250	250	250	250	250	250
Beating time, Min	35	40	34	39	45	43	46
Breaking length, M	5290	5400	5400	5695	6090	6010	5900
Burst factor (Mullen)	43.5	43.9	44.5	46.2	48.3	48	46.1
Tear factor (Elm)	93.3	100	110	106.6	104	105	110
Double folds (MIT)	414	485	405	425	489	425	405
Sheet Density, g/cc	0.66	0.62	0.63	0.67	0.61	0.63	0.61
Fiber Classification At Initial Freeness (Clark)							
+ 20 mesh %	36.5	36.4	37.1	35.8	36.4	35.8	34.8
— 20 + 50 mesh %	25.4	21.5	22.3	27.0	27.4	26.9	20.5
— 50 + 65 mesh %	7.8	7.9	8.2	7.2	7.0	8.1	7.8
— 65 +125 mesh %	5.0	5.8	5.4	5.2	5.0	5.2	5.6
— 125 mesh %	25.3	23.4	27.0	24.8	24.2	24.0	31.3

TABLE–VB

PHYSICAL PROPERTIES OF BLEACHED PULPS AT 250 ml CSF (24.0 K No. PULP)

Particulars	CEHH bleached pulp	CHEH bleached pulp	HCEH bleached pulp	CEHP bleached pulp	CEHD bleached pulp	CEDP bleached pulp	CEHDP bleached pulp
Initial freeness, ml CSF	670	670	670	660	670	670	670
Final freeness, ml CSF	250	250	250	250	250	250	250
Beating time, Min	44	42	37	48	50	46	48
Breaking length, M	5750	5860	5860	6100	6190	6260	6100
Burst factor (Mullen)	46.0	46.8	46.9	48.4	50.3	51.0	47.1
Tear factor (Elm)	100	106	104	106.6	106.6	108	108
Double folds (MIT)	440	495	410	540	510	475	430
Sheet Density, g/cc	0.65	0.62	0.63	0.64	0.62	0.65	0.62
Fiber Classification At Initial Freeness (Clark)							
+ 20 mesh %	37.2	35.3	37.8	37.5	36.8	36.3	33.1
— 20 + 50 mesh %	27.0	22.4	21.2	26.8	27.2	27.2	22.6
— 50 + 65 mesh %	7.7	8.1	7.2	8.1	7.6	7.8	8.2
— 65 +125 mesh %	4.8	5.2	5.1	4.5	4.8	5.4	6.1
— 125 mesh %	23.3	29.0	28.7	23.1	23.6	23.3	30.0

TABLE—VI

PHYSICAL PROPERTIES OF AN UNBLEACHED KRAFT PULP DURING DIFFERENT BLEACHING STAGES (CEHH SEQUENCE)

Particulars	Unbleached Decker pulp	Chlorination (C)	Extraction (E)	Hypo Chlorite 1st stage (H_1)	Hypo Chlorite 2nd stage (H_2)
Physical Properties					
Initial freeness, ml CSF	685	680	680	670	670
Final freeness, ml CSF	250	250	250	250	250
Beating time, Min	46	49	47	37	34
Breaking length, M	6100	6020	6240	5850	5540
Burst factor (Mullen)	44.6	45.5	47.3	40.4	38.1
Tear factor (Elm)	90.3	90.7	95.4	81.3	79.0
Double folds (MIT)	215	372	442	185	82
Sheet Density, g/cc	0.61	0.62	0.62	0.64	0.66
Viscosity (0.5% CED), cps	20.1	24.8	32.5	9.5	8.5
Brightness, °PV	26	42	34	78	82
Post Colour Number				8.3	6.8
Fiber Classification					
+ 20 mesh %	36.0	37.3	37.5	34.4	35.2
— 20 + 50 mesh %	22.0	22.1	22.8	21.5	22.1
— 50 + 65 mesh %	8.3	7.	6.8	8.1	8.0
— 65 +125 mesh %	3.1	3.2	4.1	2.9	2 8
— 125 mesh %	30.6	30.2	28.8	33.1	31.9

and 8.5 CP for the second stage hypo pulp. The changes in viscosity thus show that there is maximum degradation of pulp during the first hypchlorite stage of bleaching in the traditional CEHH sequence.

The strength properties of the various grades of bamboo kraft paper grade market pulp manufactured at Central Pulp Mills are shown in Table–VII. Bleaching conditions including bleaching chemical consumption are listed here for 55 PV, 65 PV, 72 PV and 80 PV. bamboo kraft market pulps. As can be expected, due to its very high lignin content, 55 PV pulp has the highest post colour number at 20.4, as against the more purified and brighter pulp of 80 PV brightness with a post colour number of 7.5. Strengthwise, the market pulp of 65 PV brightness has the highest strength.

A BRIEF DISCUSSION ON MILL TRIALS

The following is a brief discussion of the mill trials at The Central Pulp Mills with (i) Low vs High K No. pulps, (ii) Use of Sulfamic Acid, (iii) Acid wash after last stage hypochlorite bleaching, (iv) CHEH bleaching sequence and (v) CEHP and CE/PHP bleaching sequences.

LOW VS HIGH K No. PULPS : Unbleached bamboo kraft pulps of 16±1 K No. and 22±1 K No. were bleached in the common CEHH sequence. The bleaching chemicals consumption was lower and the brightness stability better (post colour number 1.0 to 1.5 points lower with softer K No. pulp) but the cooking chemicals was higher and there was a production drop to the extent of 15% of the normal capacity (with 23 K No. pulp) mainly due to the bottlenecks in the capacity of the recovery section.

USE OF SULFAMIC ACID: Prior to using sulfamic acid, caustic was being used as buffer. After mill trials, with sulfamic acid (4% on hypo in each hypo stage coming to 1.0 - 1.5 kgs/ton for 80 PV brightness pulp), there was a saving in caustic consumption with a net gain of about 5 Rs/ Ton of bleached pulp. Also, bleaching temperatures could be kept higher, making it possible to go for 10–15% higher production, without losing pulp viscosity and strength.

ACID WASH AFTER LAST STAGE HYPO BLEACHING : Last stage hypochlorite bleached pulp gained in brightness by about 1.5 points and the post colour number dropped by around 1.0 point, when 0.50% H_2SO_4 was added to pulp, before going to final decker washer. Sulfamic acid probably acted in the way as SO_2 wash, regularly used abroad.

The effect of corrosion on long term usage of SO_2 or Sulfamic acid or hydrochloric acid is to be studied in greater detail before finally implementing this scheme.

CEHH BLEACHING SEQUENCE: A bleached pulp of a marginally higher viscosity than in regular CEHH sequence was obtained. The most visible effect was in mill effluent colour, which was much lighter than in CEHH sequence. However, control of bleaching to obtain a steady brightness of 81±1 PV with just one hypo stage after extraction posed problems.

CEHP AND CE/PHP SEQUENCES: A few trials were taken with CEHP and CE/PHP sequences. CE/PHP sequence produced a pulp of better brightness stability (post colour number of 4.0 as against 7.0 in the normal CEHH sequence and 6.0 in CEHP sequence). The final pulp brightness with CE/PHP was on the lower side, 79±1 PV as against 81±1 PV in CEHP and CEHH sequences. Acid wash after peroxide, improved brightness by about a point and post colour number dropped by 1.0 - 1.5 points.

CONCLUSIONS

1. Unbleached bamboo kraft pulp of a permanganate number of 15 gave pulps of better brightness stability and lower pollution load than did the pulp of 24 permanganate number, in all the seven bleaching sequences studied.

2. The unbleached and bleached yields were, however, lower for the 15 K No. pulp than for the 24 K No. pulp, at the same brightness level.

3. The pulp strengths of the 24 K No. pulp (Unbleached and bleached) were higher than those of the 15 K No. pulp in all the bleaching quences.

4. CEHD and CEHP bleaching sequences gave the strongest pulps, close to unbleached pulp in strength.

5. The higher the pulp brightness, the lower the post colour number and the higher the brightness stability. 80 PV brightness pulp had the lowest post colour number, whereas 55 PV brightness pulp had the highest post colour number.

6. Mill trials todate pointed to the following trends:

   (a) Lower K No. pulps will produce pulps of better brightness stability but production will drop.

   (b) Sulfamic acid usage in hypo bleaching keeps up viscosity while at the same time increasing bleached pulp production.

   (c) Acid wash helps to improve pulp brightness and stability by 1.0 to 1.5 points.

   (d) CHEH sequence gave a bleached pulp of almost the same quality as CEHH pulp but the effluent colour was considerably lighter.

   (e) CE/PHP sequence reduced the post colour number to 4.0 (as against 7–8 in case of CEHH and 6.0 in CEHP) but the brightness was mostly under 80 PV at that desirable post colour of 4.0.