Process Modification in Kamyr Vapour Phase Continuous Digester For More Uniform Cooking And Alkali Reduction

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ABSTRACT: The main driving force during the last two decades for development in kraft pulping field has largely been related to environmental concerns. In the production of bleached pulp, increase in the degree of delignification has made it possible to gradually decrease or totally end the use of chlorine in bleaching. This has drastically reduced the discharge of organochlorine compound. The new concept of modified or low kappa cooking has made it possible to reach and out-of-digester kappa number up to 10 or even lower. The following rules have been postulated for successful modified pulping:-

(i) Lower alkali concentration in the begining and higher towards the end of, as compared to standard kraft cook.

(ii) The highest possible sulphide concentration in the begining of and through the main part of the bulk delignification.

(iii) Low lignin concentration and ionic strength in the last part of cook.

(iv) Lower temperature in the last part of the cook.

Somehow it has unfortunately not been possible to follow all these rules in the one and same process. In continuous cooking it has so far not been possible to attain high sulphide concentration in the begining. Very effective process has however come up in which the washing zone is also used for cooking, the so called isothermal cooking.

In the most and advanced batch cooking system the superbatch process, the rule regarding low lignin concentration and low iomic strength is not satisfied. It is therefore most likely that we in the future, will see a new process combining the ideas from the isothermal and superbatch system.

Hindustan Paper Corporation, Nagaon Paper Mill, Jagiroad is one of the giant integrated pulp and paper project in India, has an annual installed capacity of 100000 MT writing and printing paper. This is basically a socio-economic project installed in North-East zone of the country for development and upliftment of this backward area. The Government of India decided to install two paper project in this zone namely Nagaon Paper Mill and Cachar Paper Mill with approximate capital outlay of rupees 300 crore for each project in the year 1978 in Brahmaputra and Barak Valley respectively considering the abundance of basic raw material i.e. Bamboo in whole of the North-East zone.

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In pulp mill we have vapour phase continuous cooking plant supplied by M/s Kamyr AB, Sweden using alkaline sulphate process to pulp bamboo. Chips are charged in the digester after measuring by chipmeter and through Low Pressure Feeder, steaming vessel, High Pressure Feeder, Top circulation and Top separator.

Quantity of chips can be regulated by varying the chipmeter revolution, depending on production target. Entire cooking chemical (white liquor) is charged at digester top alongwith chips. Medium pressure steam (10.5 Kg/cm^2) is directly added at digester top for maintaining the cooking temperature.

The continuous digester is a vertical, cylindrical pressure vessel of volume 610 M^3. Its height is 56 Meter and diameter varies from 2.4 Meter to 4.2 Meter from top to bottom. It is designed for an average production of 326.2 BDTPD and maximum 376.1 BDTPD. Unbleached pulp with average pulp yield of 45.6% at 21% active alkali charge as NaOH.

Strainers are provided at different levels inside the digester for maintaining different cooking conditions. Internal Hi-Heat counter current Diffusion washing facility is provided for better washing.

Spent cooking liquor (Black liquor) is extracted from extraction zone strainers and flashed in flash cyclones to bring down pressure and temperature, afterwhich it is transferred to Soda recovery plant for chemical and heat recovery. Liquor and chips levels are maintained in the digester by extraction and pulp blowing. Chips and liquor levels are measured by Y-gauge and pnuematic differential pressure transmitters.

RESULTS AND DISCUSSION

Bamboo is different from the wood for pulping purpose in the sense that it possess nodes after regular interval, which are difficult to cook. In drum type klockner chippers the feed roller sets are provided to crush the bamboo before chipping so that nodes are converted into chips form. Mainly two bamboo species Muli (Melocane Bambuscides) and Hill Jatty (Oxytenthera Pervifolia) are being used. Cooking experiments were carried out at Kamyr laboratory and alkali demand for these species was determind 21% active alkali as NaOH with 20% sulphidity on B.D. chips i.e. 466 Kg active alkali per ton of unbleached pulp at 45% yield and 18-20 kappa number. When we cooked the bamboo to the permangnate number of 15-16, which is a normal cook for writing and printing grade paper, it was observed that cooking was very non-uniform and percentage of reject was very high which was not possible to handle in the present screening system. As a result and to keep mill going, we have to cook to lower permangnate number i.e. 10-11, to get an uniform cook. Although we did have uniform cook but our alkali consumption was extraordinarily high and we have to charge active alkali to the extent 27-28%, there-by loosing pulp yield which was varying between 38-42% and alkali charge was coming 650 Kg per ton of unbleached pulp.

Overall production was suffering due to non-availability of sufficient cooking liquor, high steam consumption, low unbleached pulp yield, inferior quality pulp and high variable cost. Number of foreign and Indian experts visited our plant to study the problem & suggested ways and means to reduce alkali consumption, but they were not very effective.

The main reason is that under conventional overhead cooking, the entire caustic charge is given in the begining and initial caustic concentration is high. As cooking proceeds alkali concentration goes down causing non-uniform cook and consequently higher reject.

To overcome this problem, overhead cooking process can be modified by varying cooking conditions to improve the delignification selectivity, favouring the delignification reactions and minimizing the cellulose, hemicellulose degradation reaction to increase the selectivity of the cook.

(a) The alkali profile throughout the cook should be level. A high alkali concentration at the begining of the cook should be avoided and a somewhat increased alkali concentration at the end of the cook should be maintained. For this chemical addition can be split at two or more than two places. Due to sequential application of white liquor, the caustic profile during cooking remains more uniform than the conventional cooking.

Due to initial higher concentration and afterwards sharpfall in caustic profile in conventional cook lot of caustic goes as waste for acid neutralization and availability of caustic for cooking in later part of

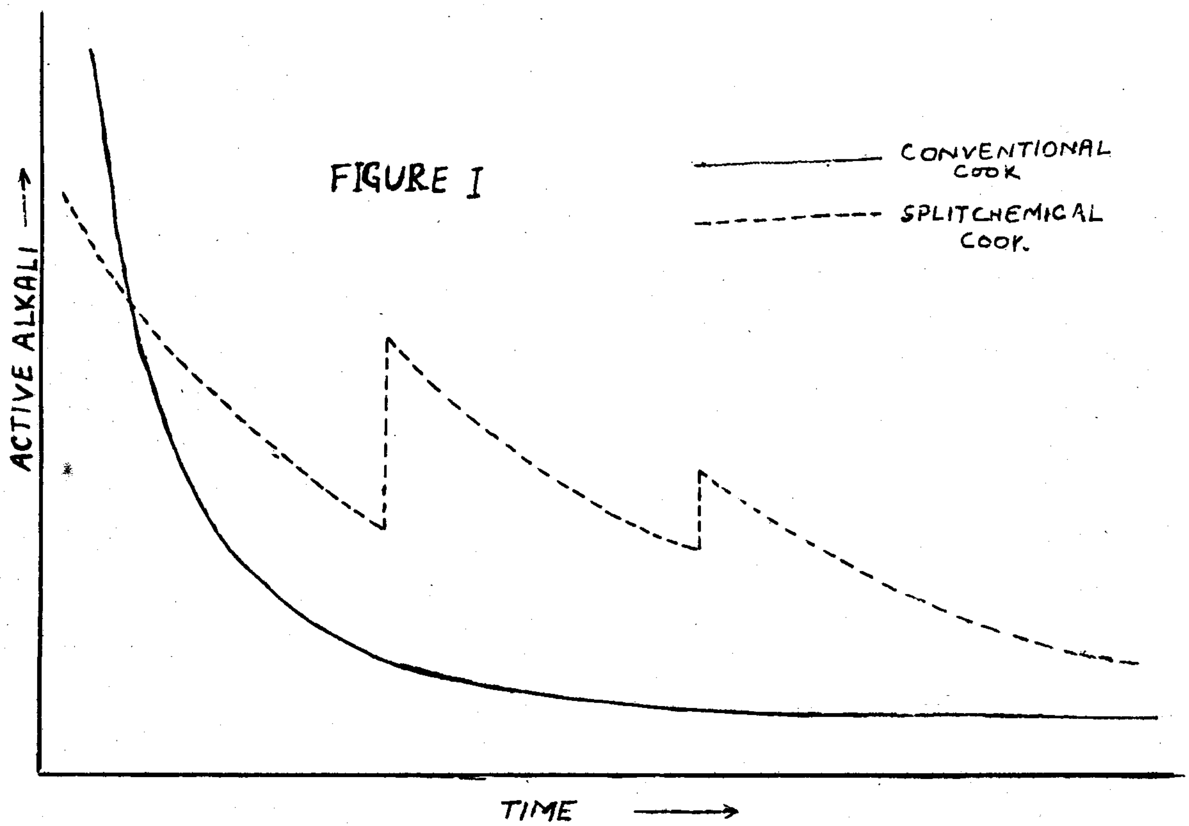
FIGURE I
CONVENTIONAL COOK
SPLITCHEMICAL COOK.
ACTIVE ALKALI
TIME

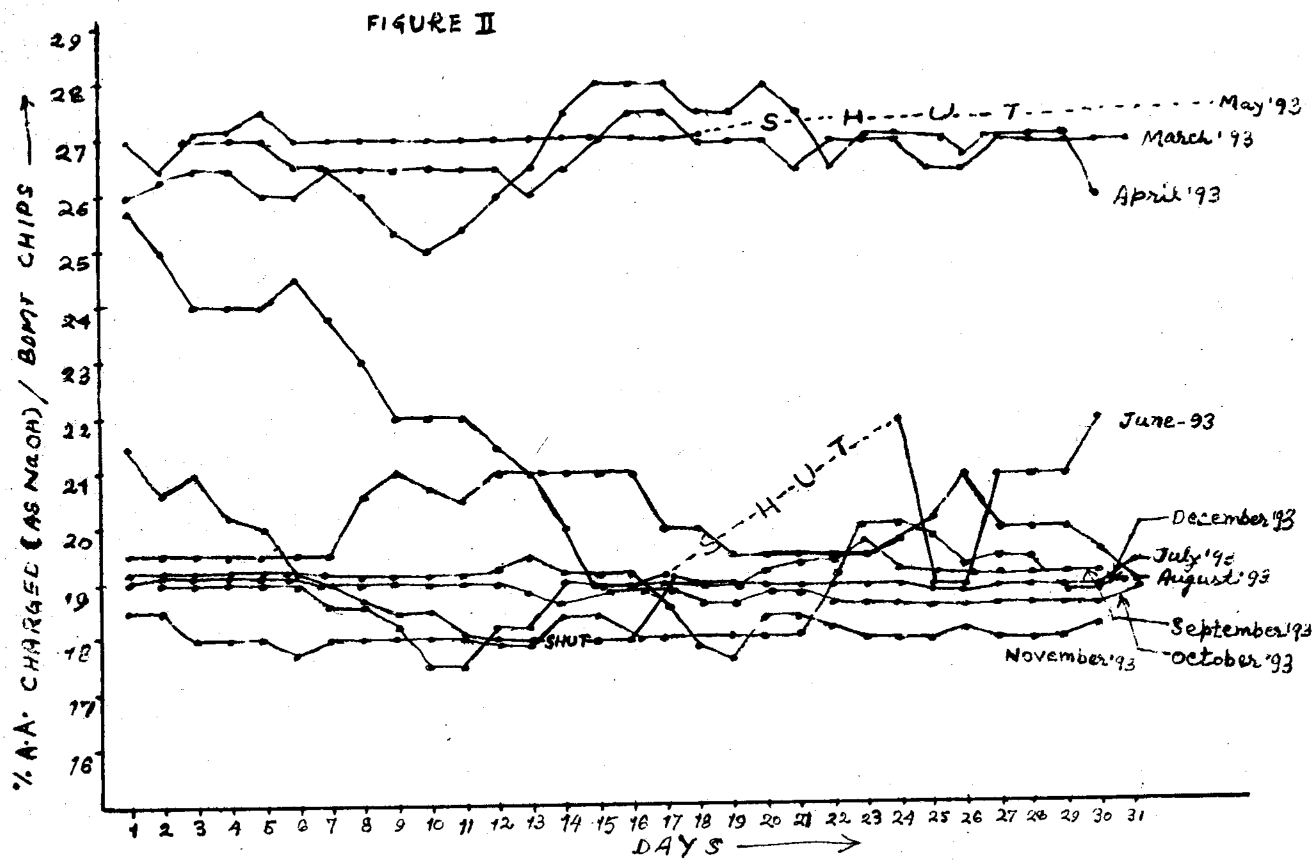
FIGURE II
% A.A. CHARGED (AS NaOH) / BDMT CHIPS
29
28
27
26
25
24
23
22
21
20
19
18
17
16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DAYS
May '93
March '93
April '93
June-93
December '93
July '93
August '93
September '93
October '93
November '93
S-H-U-T
SHUT

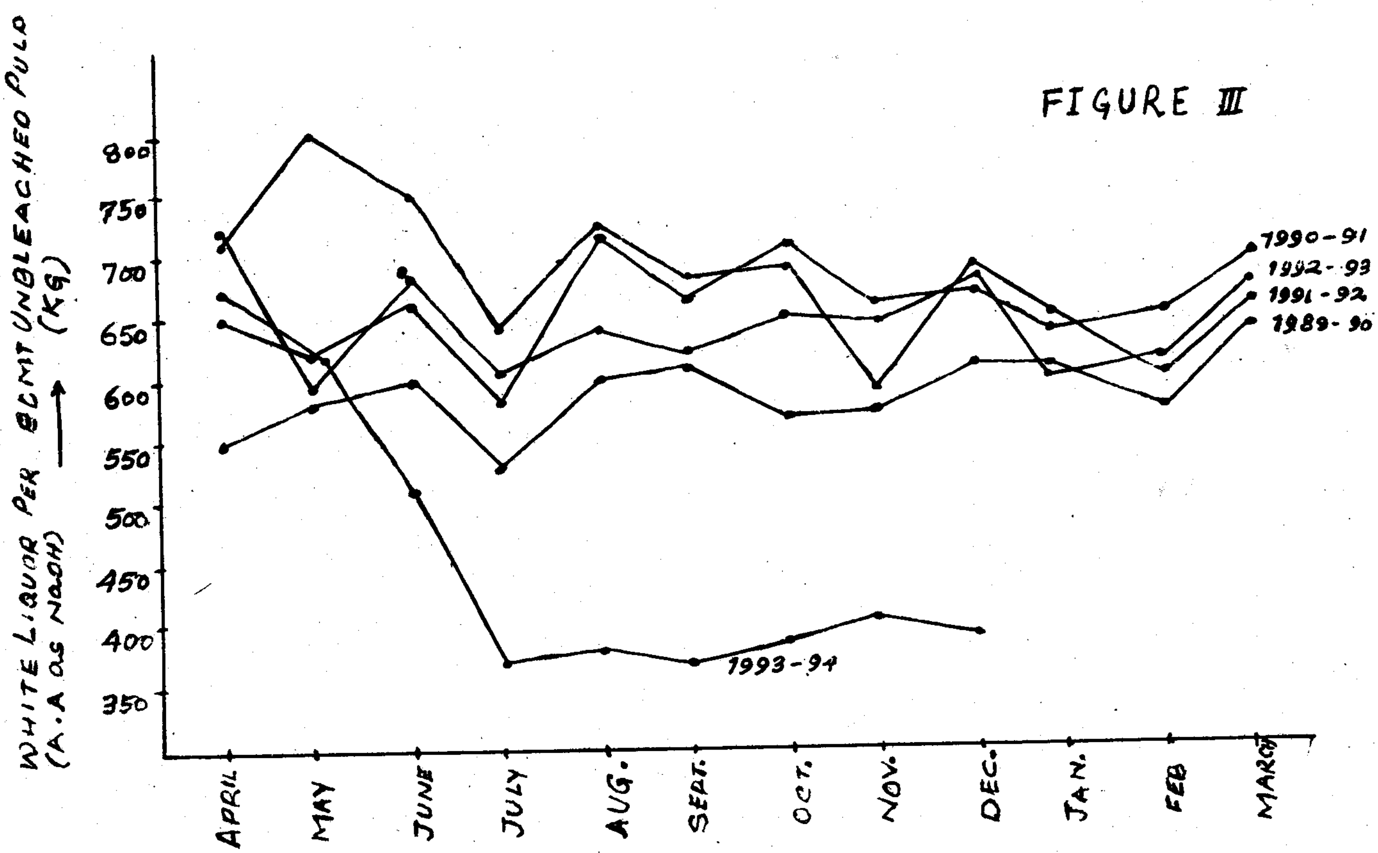
FIGURE III
WHITE LIQUOR PER BDMT UNBLEACHED PULP (KG) (A.A as NaOH)
800
750
700
650
600
550
500
450
400
350
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB
MARCH
1990-91
1992-93
1991-92
1989-90
1993-94

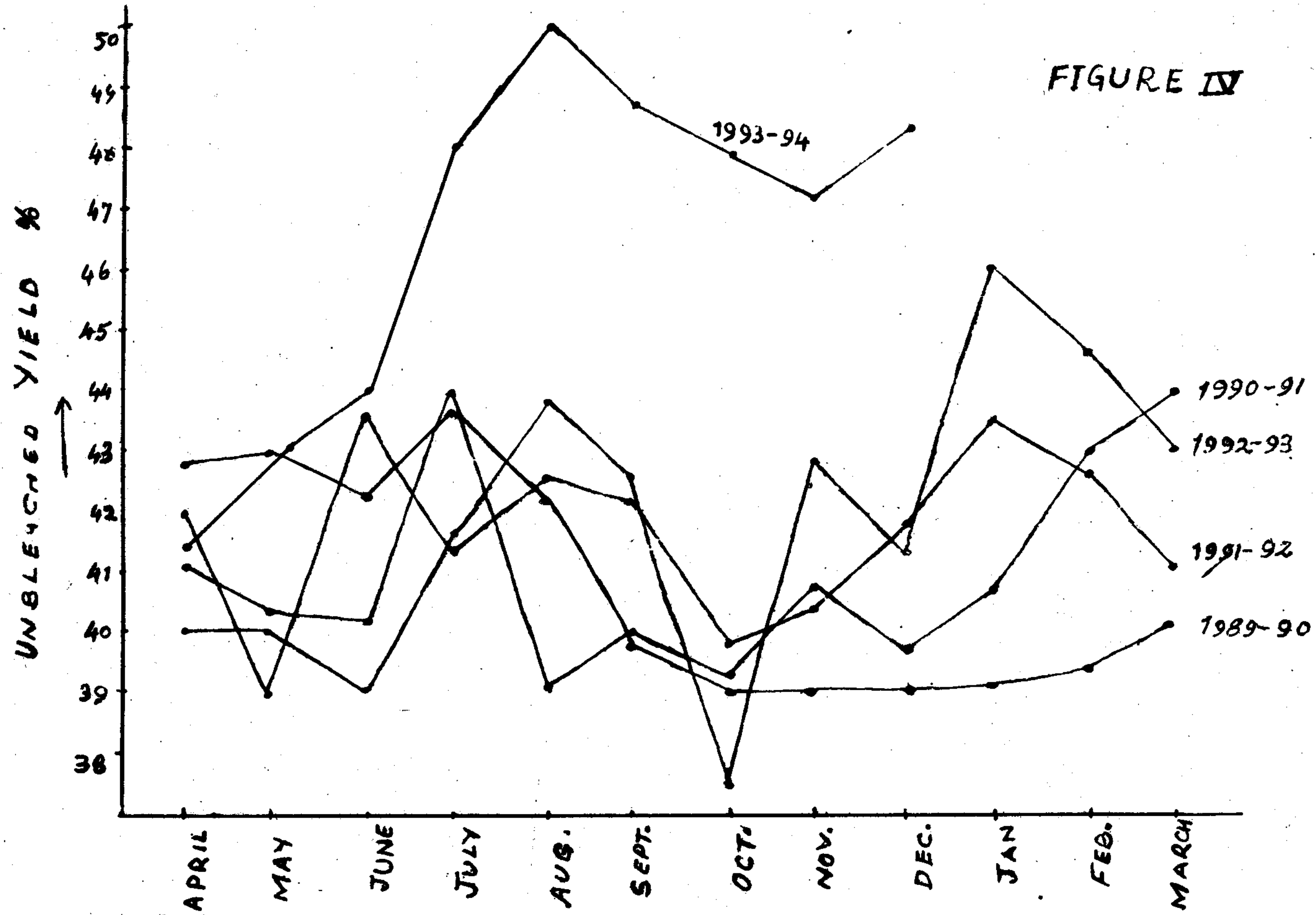
FIGURE IV
UNBLEACHED YIELD %
50
49
48
47
46
45
44
43
42
41
40
39
38
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN
FEB.
MARCH
1993-94
1990-91
1992-93
1991-92
1989-90

cook goes down resulting higher reject, non-uniform and poor quality pulp.

In split addition initial charge of caustic neutralize the acid formed and starts the reactions while second and third part of caustic reactivate the good quality pulp at lower caustic charge.

(b) The concentration of dissolved liquor and sodium ion in the chips should be low, especially in the final phase of cooking.

(c) The temperature should be low in the initial and final phase of the cook.

Keeping these facts in mind we wanted to introduce them in plant scale. Modifications were done in the system to add alkali after trim circulation zone via C-6 pump concurrently and in Hi-Heat washing zone via C-8 pump counter currently. Earlier temperature in Hi-Heat washing zone was maintained 130°C which after modification increased to 150°C, to convert washing zone into cooking zone. To keep top circulation line flush cleaned the same volume of Black liquor extracted from digester, added along with white liquor which contains residual active alkali of 9-10 gpl as Na_2O.

This splitting of the alkali addition at digester top, C-6 zone and C-8 zone considerably reduced the bath ratio in the digester and consequently steam consumption came down. After the system was stabilized it was observed that we could reduce the chemical consumption from 27% active alkali as NaOH to 19% active alkali as NaOH on B.D. chips with consequent rise in the yield from an average 40% to 50% on B.D. chips.

Total alkali charge to digester came down from 640-650 Kg active alkali as NaOH to 370-380 Kg active alkali as NaOH per ton of unbleached pulp.

Higher yield of pulp obtained as most of the yield loss occuring in the kraft process results from alkaline peeling reactions of the carbohydrates. These reactions which proceed via a β- alkoxycarbonyl elimination mechanism, predominate upto 150°C. Above 150°C the degradation is primarily caused by the cleavage of glucoside bonds by hydroxyl ions which produce new reducing end groups that can be peeled. Minor losses are also caused by the dissolution of water-soluble carbohydrates such as galactons and arabinogalactons. Also the acetyl group of the carbohydrates are lost in the kraft cook.

The black liquor recycling might have increased the concentration of hydrogen sulphide (H_2S) in the early stage of cooking system which may have stabilized the carbohydrate by reducing the alkali sensitive aldehyde end groups to hydroxyls or carboxyls groups. Thus, the yield increase results mainly in an increased retention of hemicelluloses and alkali sensitive cellulose.

CONCLUSIONS

Split chemical addition apart from increase in yield and reduction in chemical showed following distinct advantages:-

(i) Better steam economy

(ii) More uniform pulp

(iii) Possible extended delignification

(iv) Concentration of black liquor to the evaporation plant was increased, which further reduced steam consumption.

(v) Kappa variation in the digester were minimized.

(vi) Pulp showed good uniformity, resulting in improved values of tensile, tear and burst strength.

(vii) Lower rejects resulted in higher screened yield.

(viii) Lesser load on causticizing plant and hence low lime consumption per ton of paper.

(ix) Lesser chemical losses with grits and mud in causticizing plant.

(x) Due to higher pulp strength, paper quality has improved. Also loading of paper improved resulting less bamboo consumption per ton of paper.

In brief the above small modification of "split chemical addition" in cooking, brought down the chemical charge in digester below designed norms with improved pulp quality, lesser load on power boilers, chemical recovery system and changed the complete

Table-1

Raw Material - Bamboo Chips

SOURCE - 411-03 CONVEYOR BELT

Sl. No.								
1.	Bulk Density of Bamboo chips (Kg/m3)	180	180	169	180	180	180	180
2.	Cooking liquor Active Alkali (gpl as NaOH)	103.8	103.8	103.9	103.9	104.8	100.1	100.1
3.	Cooking liquor Sulphidity (%)	12.3	12.3	16.8	16.8	12.2	13.1	20.0
4.	Active Alkali charged (as NaOH %)	20.0	22.0	22.0	25.0	26.5	27.0	27.0
5.	Bath Ratio	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5
6.	Time to temperature 165°C (mins)	75	75	105	105	60	60	60
7.	Time at temperature 165°C (mins)	90	90	120	120	90	90	90
8.	Screen yield (%)	41.1	41.2	40.65	42.76	41.9	38.2	39.3
9.	Reject (%)	12.2	9.2	10.2	8.5	1.68	0.20	0.34
10.	Weak Black liquor							
	(A) R.A.A. gpl as Na_2O	8.9	12.8	8.9	10.4	18.6	12.0	16.0
	(B) T.T.A. gpl as Na_2O	46.5	44.2	34.1	40.0	47.4	74.4	74.4
11.	Permangnate No. (No.)	13.1	12.6	8.9	10.4	12.6	9.2	10.5
12.	White liquor consumption (Kg/MT of U/B Pulp)	458.8	534.0	541.0	584.6	632.5	706.8	687.0

economic scenario of our mill.

EXPERIMENTAL

The high alkali consumption was bothering us and we were trying to search in house solution of this problem. With our experience with bamboo cooking we were very much sure that alkali demand will not be so high, hence a series of laboratory experiments were conducted, which to our surprize were confirming the high chemical demand for the bamboo species we are using at the plant scale operation, which may be seen in table-I.

As we were not convinced with the laboratory trials conducted above we were of the opinion that these particular species of bamboo require a special treatment and this linked to our thinking either to go for two stage fractional cook or introduction of prehydrolysis stage. With this objective laboratory cooking trials were conducted with D.M. water and it was found that after the cook the pH of the water came down to 3.8.

Teble-2

Source-Bamboo Chips from 411-03 Conv. Bulk Density - 206 Kg/m^3

Sl.No.	Parameters		
1.	D.M. water analysis		
	- pH	6.3	6.3
	- $_TH$	Nil	Nil
	- Acidity ppm as H_2SO_4	3	3
2.	Prehydrolysis		
	- Bath ratio	1 : 3.5	1 : 3.5
	- O.D. chips (gm)	300	300
	-Water (ml)	1050	1050
	- Time to Temperature 165°C (mins)	120	120
	- Time at Temperature 165°C (mins)	300	300
3.	Results		
	- pH	3.7	3.8
	- $_TH$ (ppm as $CaCO_3$)	250	260
	- Acidity (ppm as H_2SO_4)	5100	5200
	- Normality	0.104	0.106
	- Equivalent NaOH in gm/litre	4.16	4.24
	- Equivalent NaOH in gms for 1050 ml	4.37	4.45
	- NaOH required to neutralize in Kg/MT of O.D. Bamboo chips.	14.56	14.58

Table-3

Raw Material - Bamboo Chips from 411 - 03 Conveyor

BULK DENSITY - 200 KG/M³

Sl. No.	Parameters					
1.	Cooking liquor AA gpl as NaOH	83.2	83.2	93.6	93.6	93.6
2.	Cooking liquor sulphidity (%)	15.4	15.4	15.4	15.4	15.4
3.	W.B.L. pH	11.3	11.3	11.3	11.3	11.3
4.	W.B.L. R.A.A. (gpl as Na_2O)	7.8	7.8	7.8	7.8	7.8
5.	W.B.L. T.T.A. (gpl as Na_2O)	36.0	36.0	36.0	36.0	36.0
6.	Prehydrolysis using W.B.L. Bath Ratio	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5
7.	Time to Temp. 1650C (minutes)	120	120	120	120	120
8.	W.B.L. Analysis after prehydrolysis					
	- pH	9.7	9.7	9.8	9.7	9.8
	- R.A.A. (gpl as NaOH)	Nil	Nil	Nil	Nil	Nil
	- T.T.A. (gpl as NaOH)	9.6	10.0	18.2	18.2	18.8
9.	Cooking:-					
A.	Active Alkali charged as NaOH (%)	17.0	18.0	19.0	21.0	23.0
B.	Bath Ratio	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5	1 : 3.5
C.	Time to Temp. °C (minutes)	45	45	50	50	50
D.	Time at Temp. °C (minutes)	60	60	120	120	120
E.	Screen yield (%)	42.5	42.0	43.7	44.8	42.5
F.	Reject (%)	4.4	3.9	3.0	2.3	1.9
G.	WBL, R.A.A. (gpl as Na_2O)	16.1	18.4	9.9	12.8	16.9
H.	WBL, T.T.A. (gpl as Na_2O)	45.7	47.3	41.9	45.9	50.4
I.	K. No.	18.0	17.7	14.4	12.4	11.0
J.	Active Alkali consumption (Kg/MT of U/B pulp)	400.0	429.6	435.4	468.4	533.2

It may be seen from Table II that there is lot of acid formation during the cook which in the initial stage of cook is minimized by white liquor.

As addition of fresh water is not possible in continuous cooking system, it was thought of to neutralize the acid with back water from washing section. Laboratory cooking were carried out, first with back water, and after extracting spent liquor with alkali charge 19-21% active alkali as NaOH against normal plant scale consumption of 27-28% active alkali as NaOH. Permangnate number came down to normal range and rejects were much less as may be seen in below table:

After conducting the above experiments it was thought of if the active alkali charge will be partly replaced by strong black liquor extracted from digester and experiments were conducted in the laboratory replacing 5% of active alkali and 2.5% of active alkali by black liquor respectively.

Table-4

Cooking Experiment on bamboo chips using W.B.L. (Extraction Liquor)
Raw Material - Bamboo
BULK DENSITY - 192 KG/M³

Sl. No.				
1.	Cooking liquor Active Alkali (gpl as NaOH)	112.0	112.0	112.0
2.	Cooking liquor sulphidity (%)	18.6	18.6	18.6
3.	W.B.L. R.A.A. (gpl as NaOH)	14.5	14.5	14.5
4.	W.B.L. T.T.A. (gpl as NaOH)	40.0	40.0	40.0
5.	Active Alkali charged as NaOH (%)	25.0	20.0	22.5
6.	W.B.L. (Extraction liquor) charged as NaOH (%)	--	5.0	2.5
7.	Bath Ratio	1 : 3.5	1 : 6.2	1 : 4.66
8.	Time to Temp. 165°C (minutes)	90	90	90
9.	Time at Temp. 165°C (minutes)	120	120	120
10.	Screen yield (%)	39.1	40.6	40.6
11.	Reject (%)	0.83	1.7	1.0
12.	W. Black Liquor			
	(A) R.A.A. (gpl as Na_2O)	10.7	7.4	10.0
	(B) T.T.A. (gpl as Na_2O)			
13.	Permangnate number (No.)	8.0	11.1	8.9
14.	White liquor (AA) consumption Kg/MT of Unbleached pulp	639.3	492.6	562.5

The results were very much encouraging. Permangnate number came down to 9-10, percentage of reject came to normal range and cook was uniform.

ACKNOWLEDGEMENT

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