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PROSPECTS OF ORGANOSOLV PULPING OF BAGASSE

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Introduction

Pulp makers and researchers in many parts of the world are looking for a number of processes that could help the pulp and paper industry in energy savings, cutting operating costs, lowering chemical requirement and meet the environmental restrictions to mill effluents.

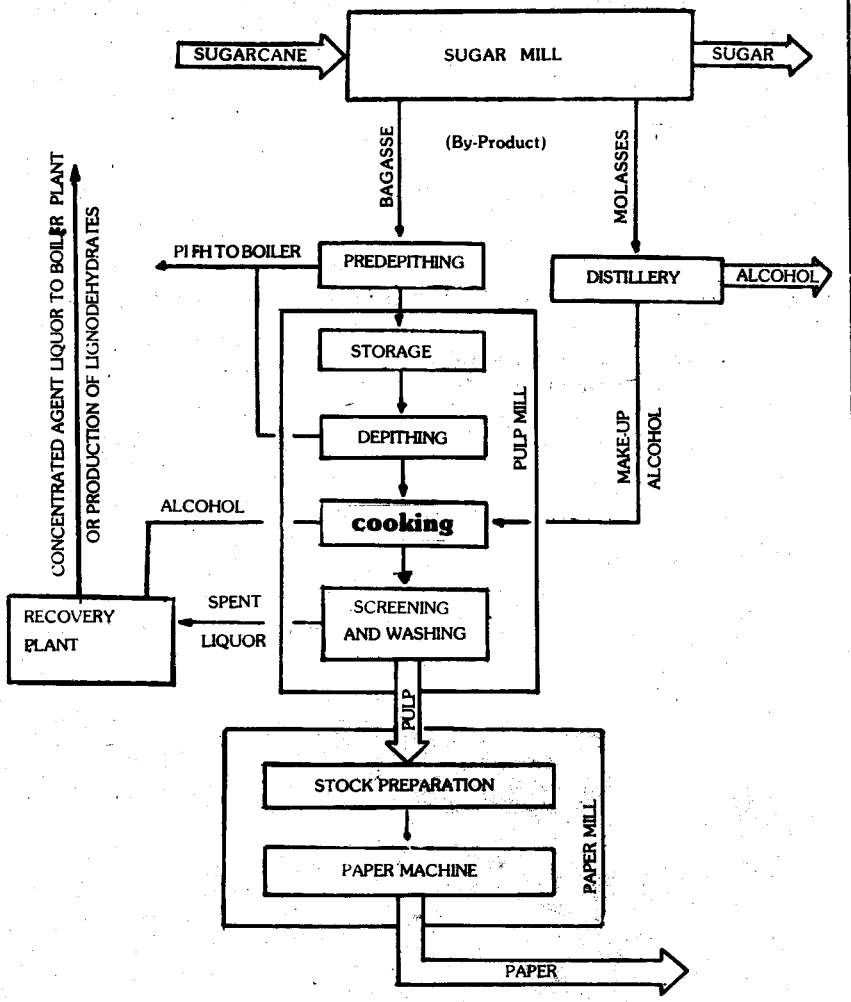
Very promising alternative, specially to non-wood fibre pulping category, is alcohol pulping or organic solvent pulping.

Organic solvent pulping has recently been gaining attention because of its lower pollution load, higher pulp yield, easier recovery for solvent and better utilization of by-products.

The studies on its pulping mechanism, commercial feasibility have been reported[1-5]. Some experts[6,7] found that organic solvent pulping afforded a preferential removal of lignin and retention of carbohydrate. These processes serve even better in case of grasses and agricultural residue because of their very open structure and lower lignin content.

Lind quist and Irrulegui[8] have given the hypothesis of linking sugar mills and distilleries, with pulp and paper mill into integrated industrial complexes with high economical yield and self sustained energy requirement. The preliminary view of integrated sugar and paper is shown in Fig. 1 where the sugar mill remainder bagasse would be destinate to pulp and paper mill.

FIG. - 1



PRELIMINARY VIEW OF INTRGRATED SUGAR AND PAPER MILL

This would make small mills using bagasse to become competitive, since traditional recovery boiler will not be required, as alcohol could be recycled in high ratio, while the waste liquor may be consequently used as fuel or as raw material for ligno derivatives production.

The present paper is a preliminary work to see the feasibility of organosolv pulping of bagasse, especially to ethanol water cooking with different catalyst. Obtained pulps have been analysed and compared with conventional pulps.

Experimental:

Depithed bagasse meal which has passed through 40 mesh but retained on 60 mesh was analysed for lignin and pentosan content determination. All the cookings were performed in 316 stainless steel bombs of 150 ml capacity. The bombs were heated in a polyglycol bath.

Various pulping at different maximum temperature level, time at maximum temperature, with varying catalyst percentages were studied. Pulps were analysed for yield, kappa number, percentage lignin content and percentage pentosan content.

Entire plan of work could be categorised as under:

1. Delignification with different organic solvents.
2. Delignification with ethanol water system.
3. Delignification with ethanol water system using acid as catalyst.
4. Delignification with ethanol water system using alkali (NaOH) as catalyst.
5. Delignification with ethanol water system using NaOH with Anthraquinone as catalyst.

Finally one cook was performed in laboratory autoclave. Pulp was analysed for lignin, pentosan content and kappa number. This was beaten in PFI mill and handsheets were made on British Sheet Former under standard conditions. The sheets were tested for various strength properties, and compared to Soda Pulp.

Results and Discussions:

TABLE - 1

Lignin content in bagasse meal	= 23.1 %
Pentosan content in bagasse meal	= 28 %

The first series of experiments by three different organic solvents at identicial solvent water ratio, bath ratio and time at maximum temperature could give an overall view of their respective selectivity towards delignification, Referring to table-2. Ethanol gave the best results out of three common and widely accepted solvents. The kappa number is lowest, 57 with relatively higher yield. The experimental data are very much in concurrence to results obtained by Kleinert(1).

TABLE - 2

Organic Solvent	Organic solvent water	Liquor to wood ratio	Max. temp °C	Yield %	Kappa No.	% decarbo
Ethanol	1:1	1:10	180	79.8	57.0	31.5
Methanol	1:1	1:10	180	78.9	59.7	23.3
Butanol	1:1	1:10	180	73.2	62.3	28.4

Based on these results, and as reported in literature also, that ethanol water system gives better delignification rate at favourable conditions and has easy recovery[2], it was decided to carry out further experiments with ethanol as basic organics solvent at different conditions, catalysts for delignification.

Delignification with Ethanol Water System (EW)

As can be seen from Table-3, the pulps obtained with a mixture of ethanol water at different maximum temperature viz. 160, 170, 180 and 190°C for retention time of 1 and 2 hrs. at same wood to liquor (1:10) and ethanol water ratio of (1:1) can be classified as semichemical pulps due to its high yield and kappa no.

The results show that:

(i) Pentosan loss is more at higher temperature i.e. 180 and 190°C, if time is longer, 2 hr.

(ii) The drop in Kappa Number is not so significant as yield. The loss of yield is therefore related to loss of pentosan content. Fig. 2 shows a very sharp increase in % decarbohydralization.

TABLE - 3

S.No.	Ethanol water	Bath ratio	M. temp. ^0C	Time at M. temp.	Yield %	Kappa No.	% decar-bohyd.
1.	1:1	1:10	160	1 hr.	94.5	138	9.4
2.	1:1	1:10	160	2 hr.	87.7	126	—
3.	1:1	1:10	170	2 hr.	85.4	113.5	25.3
4.	1:1	1:10	180	2 hr.	67.3	110.0	65.7
5.	1:1	1:10	190	2 hr.	62.1	104.8	67.2

Effect of Acid and Alkali on EW cooking

Sarkanen[9] could get good catalytic effect on delignification of cotton wood during ethanol water cooking system, however, the experimental results by H2SO4 as catalyst are not very promising, as depicted in table-4. Increased percentage of H2SO4 increases delignification extent (which is otherwise very low) but at the cost of relatively higher loss of pentosans. The cooking conditions for this set of experiments were the same i.e.

solvent: Water = 1:1,
bath ratio 1:10
Max. Temp. 180°C.

Results have been shown graphically also in figure 3, 4, 5 and 6.

TABLE - 4

Sl. No.	% H2SO4 on Bagasse	% Yield	Kappa No.	% Delignification	% Decarbo
1.	.05	79.6	74.9	4.8	24.62
2.	.15	80.8	68.6	10.35	22.63
3.	.2	75.6	60.8	18.28	46.25

The following table-5 shows the results of cooks carried out with mixture of ethanol water alkali system (AE Cook). The temperature and time of treatment were varied with NaOH percentage keeping same at that maximum temperature.

The perusal of results when compared to that of Table-3 (EW cook) shows that by addition of small quantities of NaoH on raw material (from 2-8 %) increases its selectivity with respect to lignin probably because the concentration of NaOH needed to hydrolyze the B-aryl ether linkage in ethanol water pulping is much lower than the one in soda pulping[10]. It is because of the above reason that kappa number has reduced substantially from 138 to 52 when comparing EW cook to AE cook.

Extent of delignification and decarbohydralization has shown graphically in Fig. 8 and 9 respectively.

Carbohydrate dissolution by alkali ethanol cooking shows the similar trend as in delignification but the amount on weight percent basis dissolved is relatively less, as the alkali dose is changed to higher level. With rise in temperature the carbohydrate dissolution increases and the effect is more at temperature above 180°C.

TABLE - 5

Sl. No.	Temp. °C	Time at max. temp hr.	NaOH %	% Yield No.	Kappa nification	% Delig- Hydratiza-	% Decarbo- tion %
1.	160	2	2	79.69	88.1	32.1	46.21
2.	180	2	2	77.4	88.5	35.39	50.79
3.	190	2	2	75.8	84.5	52.54	58.58
4.	160	2	4	74.2	76.3	54.83	63.69
5.	180	2	4	72.6	68.9	56.76	66.81
6.	190	2	4	72.0	66.1	57.74	68.11
7.	160	2	8	73.4	58.6	60.43	65.66
8.	180	2	8	72.5	55.2	64.38	68.41
9.	190	2	8	72.1	52.5	66.46	74.00

TABLE 6

Sl. No.	M. Temp. °C	Time at max. temp hr.	NaOH %	% Yield No.	Kappa nification	% Delig- Hydratiza-	% Decarbo- tion %
1.	160	2	2	90.4	46.2	37.930.56	
2.	160	4	2	87.7	27.6	43.04	41.43
3.	160	2	4	84.4	26.2	51.56	38.51
4.	160	4	4	81.2	25.4	54.81	41.42
5.	160	2	8	77.9	21.9	64.78	42.70
6.	160	4	8	73.6	19.6	73.76	47.74
7.	180	4	8	69.5	19.2	77.03	—

Ethanol Water cooking in presence of Alkali and anthroquinone (AEAQ):

The results of cooks carried out with ethanol water alkali system in presence of small quantities of anthraquinone (0.05%) are shown in Table-6. the table depicts the results with varying percentage of NaOH at different maximum temperature levels with same amount of anthraquinone water to alcohol and bath ratio.

Comparing the results of table 5 and 6 for the same level of NaOH dose the delignification is better with the additon of AQ. Kappa number improves to a very convenient level of 22. Delignifiation increases upto 77% and carbohydrate dissolution is reduced from 68% to 42%. It is evident that selectivity of Alkali Ethanol AE/Alkali Ethanol Anthraquinone AE-AQ pulping is higher than that of Soda/Soda anthraquinone pulping. The reason is that the AQ leads to cleavage of B-0-4 linkage of lignin into free guaiacyl phenoxy[11], which is not found in soda pulping[12] and may not be present in AE pulping[13].

Figure 11, and 12 shows change in % delignification and decarbohydralization as a function of alkali charge, respectively in both A E and AE-AQ, cook. It is evident that increse in carbohydrate retention is far better as compared to % delignification in AE-AQ. Thus a better pulp with higher yield is resulted. Effect of alkali kappa No. has been shown in Fig. 13 for both AE and AEAQ cook.

Physical Properties of AE-AQ Pulp:

The physical properties of unbleched pulp at 39°SR value are listed in Table-7. They are compared to soda pulp.

TABLE - 7

Propety	AE AQ Pulp	Soda Pulp
°SR	39	30
Kappa Number	27	32
Basis wt.	59	60
Burst index k Pam^2/g.	3.1	1.9
Tear idnex m Nm^2/g	2.7	2.6
Tensile index Nm/g.	53	49
Double fold	56	--
Brightness % Elrepho	30	24

Perusal of results depicts the superiority of AE-AQ pulp to that of soda. Properties like burst index and tensile index are higher exhibiting good bond formation after beating in PFI mill (ref. table-7). Tear index has not shown any appreciable difference being a property related to fiber length and intrinsic strength.

It has been observed that AQ is soluble at room temperature in Ethanol water alkali system and consequently can start acting as catalyst sooner than in soda liquors, where it becomes soluble only at higher temperature.

The brightness of this AEAQ was found to be 30 which was better than soda pulp, this may be because of good catalytic selectivity and synergistic effect of ethanol and alkali AQ[14]. They could not only inhibit the condensation reaction of lignin fragments but could degrade condensed lignin as well giving a lower kappa number.

Conclusion:

(i) Ethanol water system is comparatively better delignification system for bagasse, than other organic system.

(ii) Pulps prepared with a mixture of ethanol water only are semichemical type, since reported high yield and high kappa number.

(iii) Sodium hydroxide enhances delignification inhibit condensation but acid gives more degradation to carbohydrate.

(iv) Pulping of bagasse with ethanol water alkali system in presence of anthraquinone gives higher yields, lower kappa number at lower alkali consumption level.

(v) Strength properties and brightness are better than soda pulp. Thus the AE-AQ pulp is easily bleachable chemical pulp.

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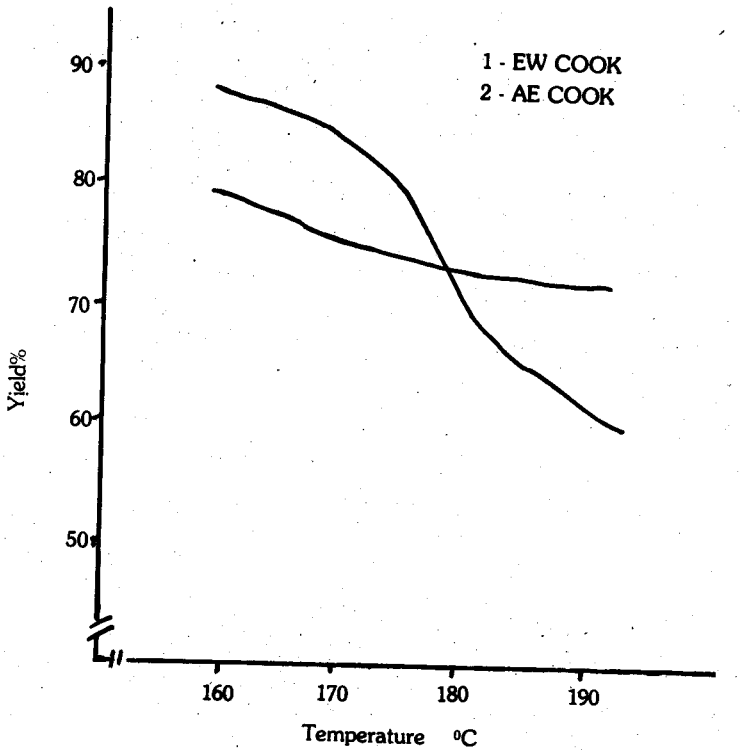
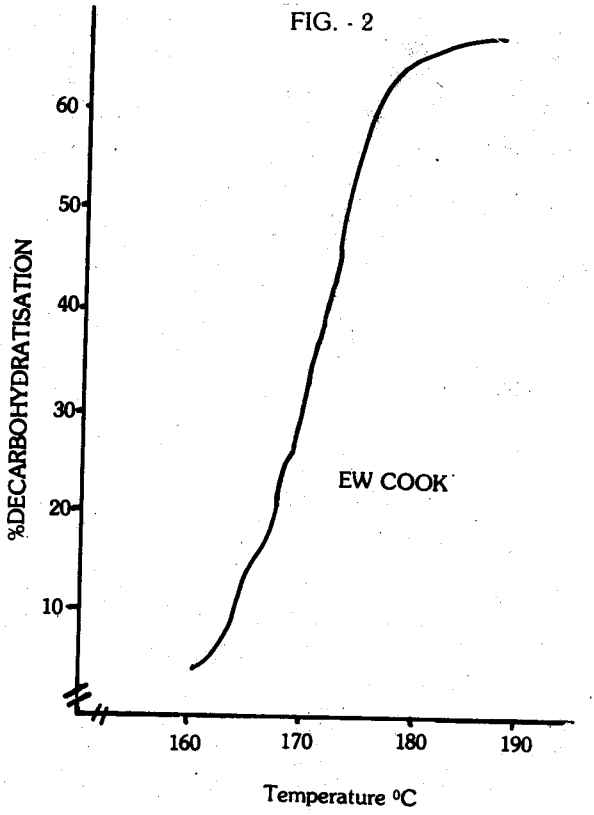
FIG. - 1



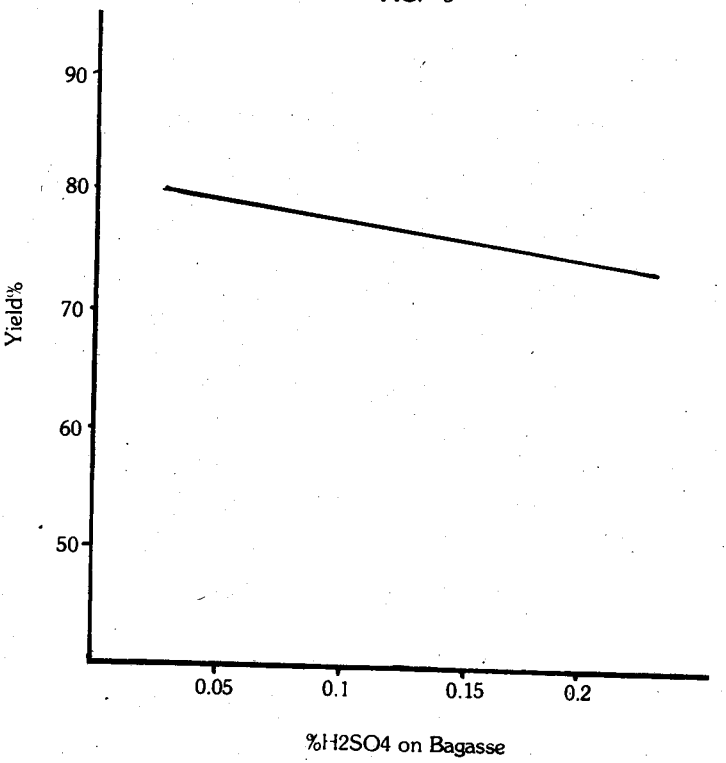
EFFECT OF TEMPERATURE ON YIELD

FIG. - 2



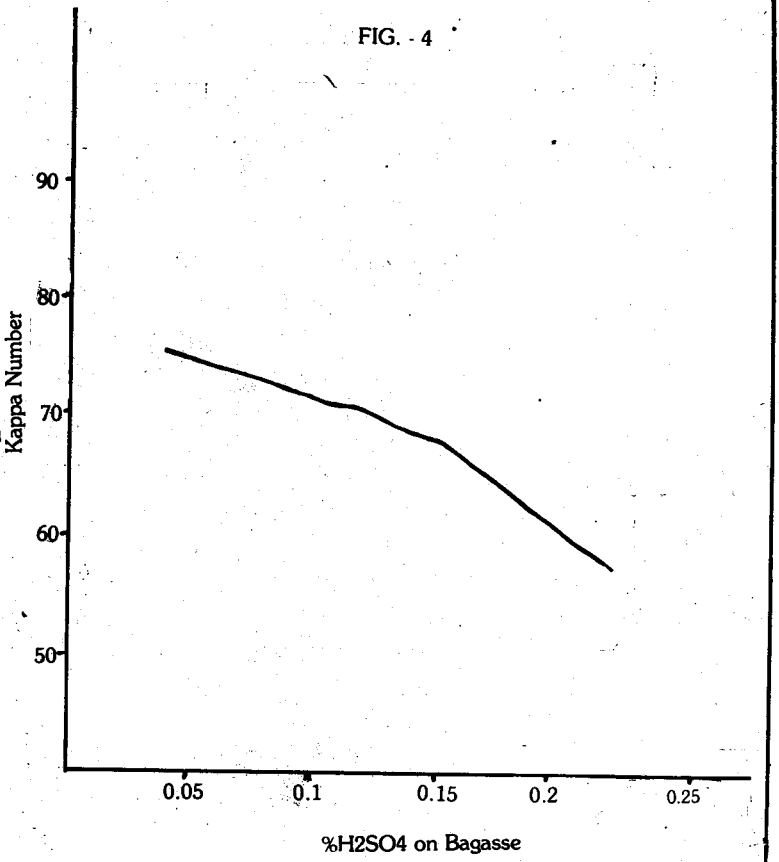
EFFECT OF TEMPRATURE ON DECARBOHYDRATISATION

FIG. - 3



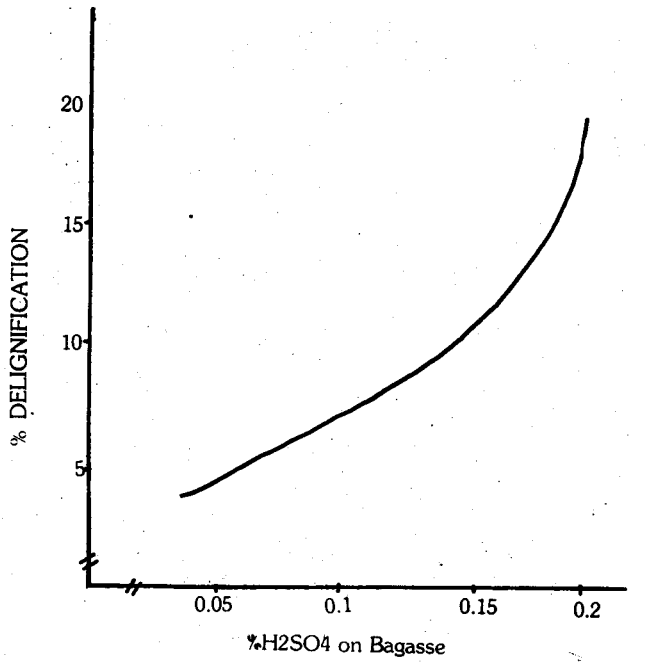
EFFECT OF H2SO4 ON % YIELD

FIG. - 4



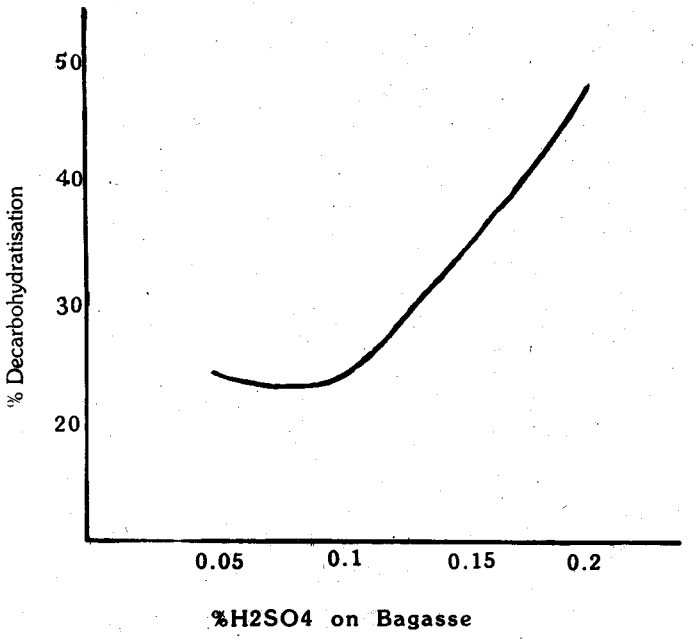
EFFECT OF H2SO4 ON KAPPA NUMBER

FIG. -5



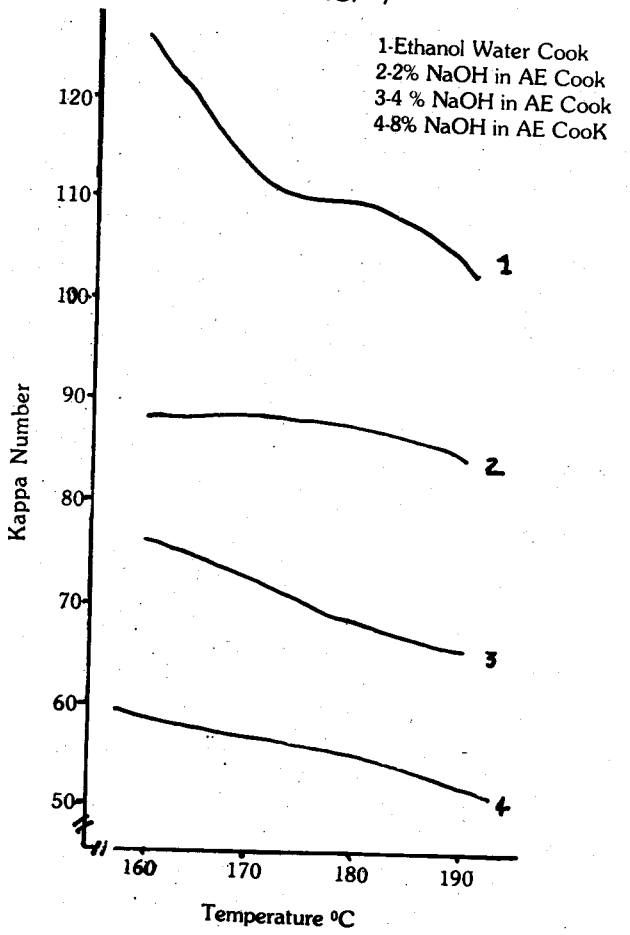
EFFECT OF ACID ON % DELIGNIFICATION

FIG. - 6.



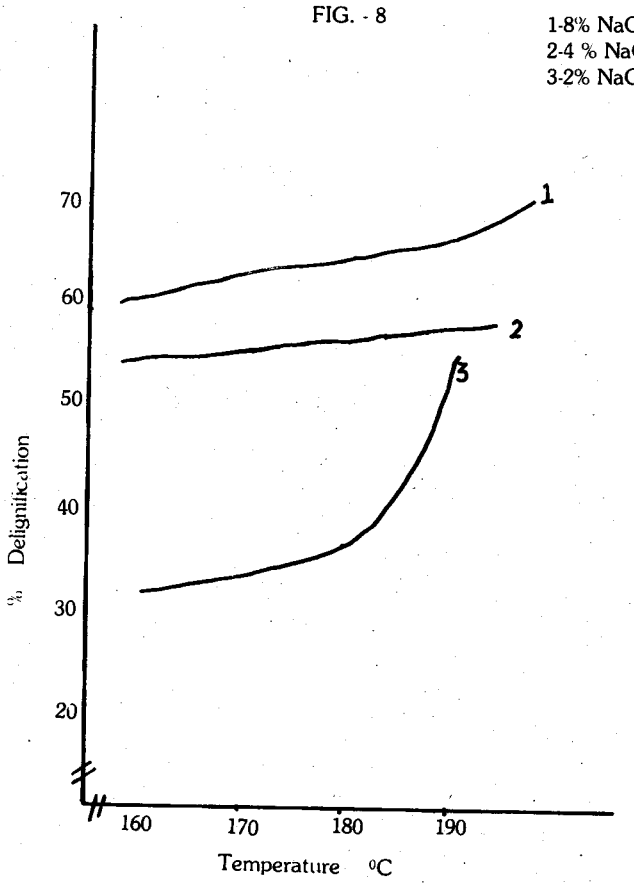
EFFECT OF ACID ON %DECARBOHYDRATISATION

FIG. - 7



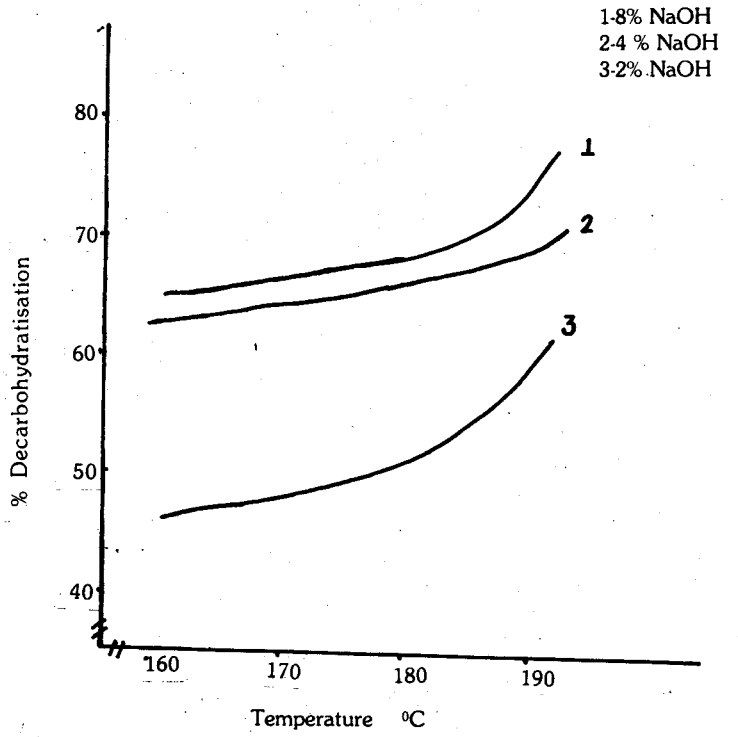
EFFECT OF TEMPERATURE ON KAPPA NUMBER IN AE COOK

FIG. - 8



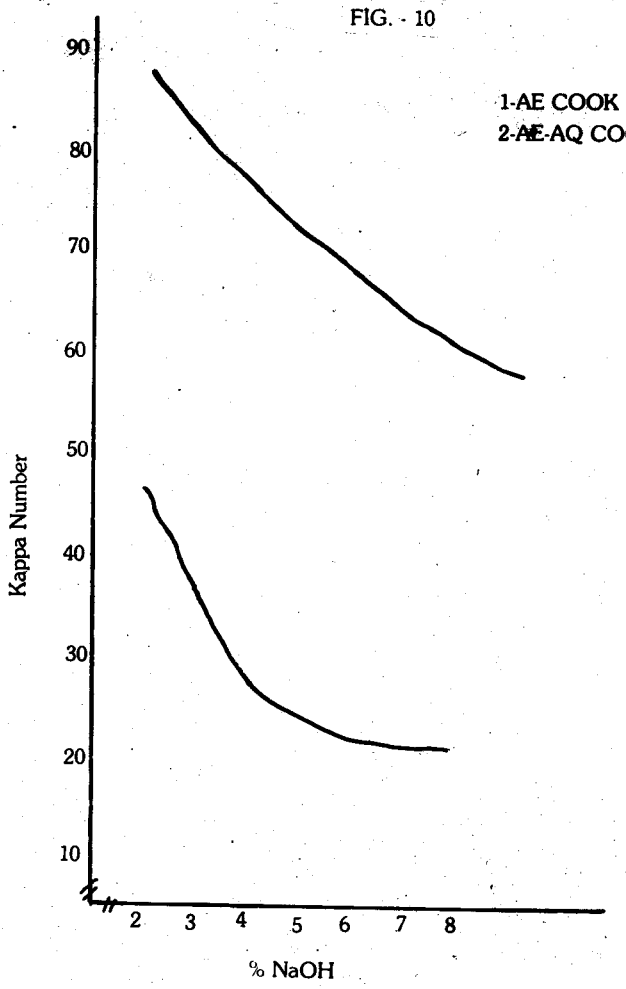
FEEFCT OF TEMPERATURE ON DELIGNIFICATION IN AE COOK

FIG. - 9



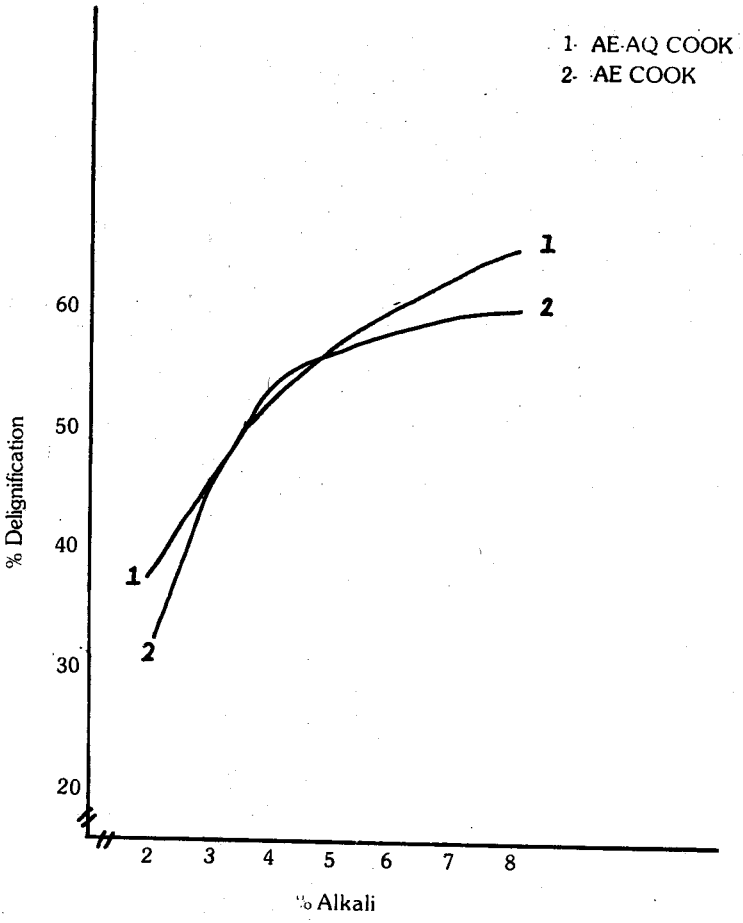
EFFECT OF TEMPERATURE ON DECARBOHYDRATISATION

FIG. - 10

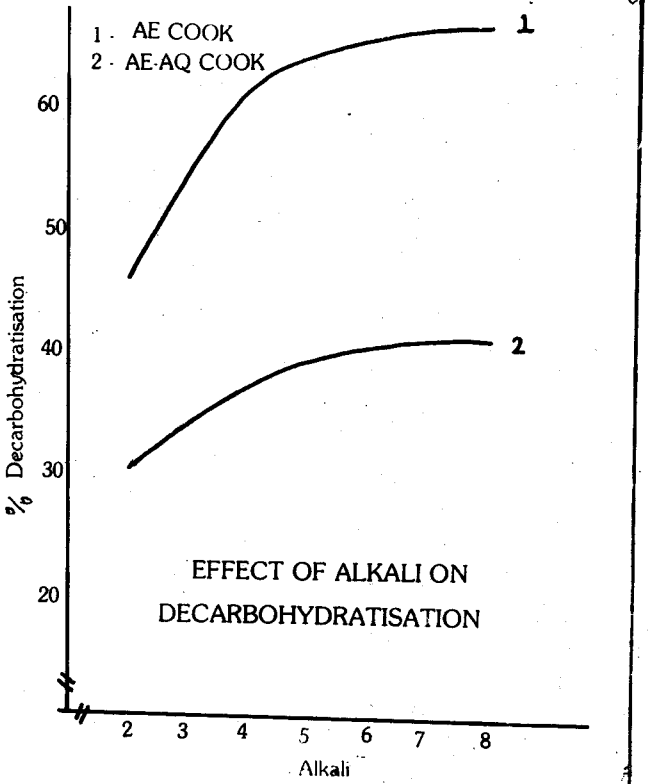


EFFECT OF ALKALI ON KAPPA NUMBER

FIG. - 11



EFFECT OF ALKALI ON DELIGNIFICATION



EFFECT OF ALKALI ON DECARBOHYDRATISATION

FIG. - 12

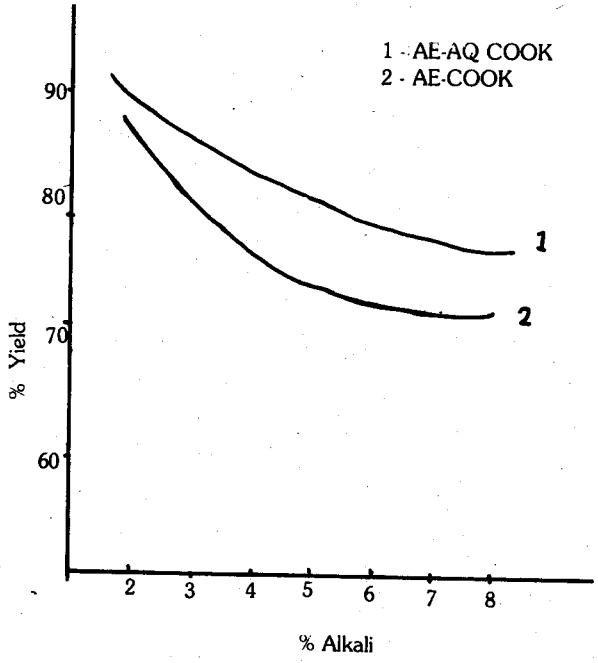


FIG. - 13 EFFECT OF ALKALI ON YIELD