Viability and Economic Study for Recovery of White Liquor From Black Liquor in Small Paper Mills

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Paper industry being one of the most important industries plays a signficant role in the overall economic development of our country. It is assumed that the demand for paper by the end of 20th century will be 42 lac tonnes/annum.

At present Indian paper industry is passing through a period of 'Survival of 'Fittest'. Major small paper mills are facing closure due to problems of raw material, non-availablity of trained man power, inadequate equipment facilities and ever increasing cost of fuel. Furthermore there is high cost of effluent treatment and non-recovery of cooking chemicals[1]. Hence careful planning is necessary for saving raw materials, chemicals, energy and cost of effluent treatment plant. The idea of this paper is to emphasis the long term benefits for the mills, national interest and social obligation in avoiding pollution control.

The economic aspects for the recovery of white liquor to black liquor are due to following reasons.

1. (a) Recovery of inorganic chemicals which can be further used to make up chemicals.

   (b) Saving in energy specially steam, inherent in the dissolved organic constituents of black liquor. The steam generated as a byproduct of this operation supplies more than half of the process requirement of steam as well as energy necessary to generate one half of pulp mills electrical requirments.[2]

   (c) Reduction in consumption of furnace oil.

2. To eliminate pollution both stream carried and air borne.

The effluent characteristics in a small paper mill of West Bengal is given here.

		With Soda Recovery system	Without Soda Recovery system
1.	Waste water volume in M^3/tonne	360	360
2.	Colour	Faint brown	Black
3.	pH	6	9
4.	Total solid Mg/LTR	1600	5500
5.	BOD Mg/LTR	340	1220
6.	COD Mg/LTR	1100	3600

The feasibility of recovery of white liquor from black liquor in small paper mills

For chemical recovery in small paper mills the mill should be designed as simply as possible. There is unnecessary of the technologically best process and most modern equipment. However the basic concept will be energy savings in the following areas (a) Evaporators, (b) Furnace, (c) Causticizers.

Taking the above considerations in mind and availability of the technology and equipment facilities in India the following scheme can be considered not worthy.

Generally the weak black liquor from washing plant is quite dilute containing 16 to 18%. Total solids (T.S) of both inorganic and organic materials which is first of all kept in a storage tank. From the storage tank, the liquor is sent to a pre-heater where the liquor is pre-heated before sending it into six long tubes multiple effect evaporators. The pre-heater is heated by condensate obtained from evaporators and the condensate from pre-heater can be used as boiler water.

Now the weak black liquor is concentrated upto 45% T. S. in multiple evaporators using steam from

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recovery boiler. At that concentration the viscosity of black liquor is generally Newtonian[3]. Furthermore too high solids also limit the capacity of evaporators and leads to plugging of evaporator tubes[4]. According to recent[5] studies, scaling in evaporators become predominant at a critical solids content of about 50% and such impurities as silica or alumina salts also contribute considerably to the scaling.

Hence for avoiding risk of scaling and eventually plugging of the evaporator tubes for higher concentration of solids the liquor is concentrated upto 58% T.S. in Direct Contact evaporator using the sesible heat in the flue gas from the furnace.

The malodorous gases evolved from Direct Contact evaporator before sending it into chimney is passed through Electrostatic precipitator to avoid pollution in air. The liquor is now kept in mixing tank.

After the addition of sodium sulphate in the mixing tank to make-up for the chemical losses in the system, the black liquor is burnt in the recovery furnace. In the furnace, heat from the combustion of organic liquor constituents is utilised for generation of steam and the sodium salts are recovered as smelt.

The green liquor from storage tank is now sent to a tank where the liquor is subjected to causticizing treatment with lime to convert sodium carbonate in the smelt to sodium hydroxide while at the same time calcium hydroxide is converted to calcium carbonate. It has been found that addition of large excess of lime is avoided since excess of lime increases the difficulty of washing alkali from the sludge. Theoretically 53 parts of lime are required to react with 100 parts sodium carbonate but in actual practice additional lime is added to compensate for impurities in the lime and to provide an excess of about 5% lime for speeding up the reaction[6].

The causticized and clarified solution (to remove dregs) is now sent to a tank where the temperature is maintained at 102°C by passing steam. The causticized reaction ordinarily goes to about 90 to 95% completion. Increasing the concentration reduces the degree of conversion of sodium carbonate but increasing the temperature speeds up the reaction[6] inspite of the fact that calcium carbonate is more soluble at higher temperature. Hence experimentally found that temperature around 102°C is more suitable for completion of reaction.

The fully causticized liquor is pumped into white liquor clarifier cum storage tank where the lime sludge is continously removed from the bottom and clean liquor, called white liquor is removed from the top. The clear white liquor is sent to the digesters for cooking the raw material to be pulped.

The sludges from the clarifier is mostly calcium carbonate but considerably sodium hydroxide is present and this is recovered by washing on two lime mud washers. The weak wash water from the lime mud whsher is used for dissolving the smelt from the black liquor recovery furnace. Washing in an efficient two-stage washing process reduces the soda content of the sludge from about 22% to about 0.5% on a dry lime mud basis[7].

The lime sludge leaves the vacuum filter at 55 to 65% solids which is disposed off. The justification for not to reburn the sludge for recovering the lime for use in causticizing is that this sludge contain impurities like silica and iron which form a gelatinous slow setting floc in white liquor that not only makes white liquor clarification difficult but will aggrevate operation of mud washing and kiln operation. Furthermore there is necessary pollution control equipment for the particulates and gases evolved from lime Kiln which adds extra cost of the total cost. So the process of reburning of calcium carbonate is not economic in India. In foreign some mills, the carbonate sludge is not reburned but it is refined into a grade of carbonate suitable for the filling of paper[7].

2. Lime requirement and cost of lime

Basis→24 hrs/day, 330 days/hr.

Feed 15000 kg/hr at 17% T.S.

Therefore Lime requirment→$2400 \times 1.3 = 3120$kg/hr.

Quantity of caustic at a rate of 16%=2400kg/hr.

Available lime percentage is 60 considering 3% free lime.

The amount of lime required per kg of recovered caustic is 1.3].

1.3 t of 60% available CaO is required per ton of recovered caustic and cost of lime is Rs. 800/-MT.

Economics of Installation of the Recovery Unit

	Item	Number	Capacity	Cost
1.	Weak black liquor storage tanks	2	Cylindrical Mild steel tanks, lagged outside, 200 m^3 capacity each.	20 lacs
2.	Pre-heater	1	4 pass shell and tube heat exchanger. Liquor handling capacity 20000 kg/hr and rise in temperature will be 7°C.	50 lacs
3 a.	Evaporators with flash chamber (one)	6	The area of the each evaporator is 72m² and the number of tubes in each evaporator are	45 lacs
b.	Surface type condenser	1	160. The length of steel tube is 4560 mm	10 lacs
c.	Barometric leg with steam jet ejector	1	and the tubes are 254 mm in diameter.	1 lac
4.	45% semithick liquor storage tanks	2	Cylindrical, Mild steel, lagged outside and internally heating arrangement, 50m^3 capacity.	5 lacs
5.	Direct contact evaporator (cyclone type)	1	—	6 lacs
6.	Electrostatic precipitator	1	—	10 lacs
7.	Mixing tank	1	Cylindrical, Mild steel, lagged outside and fiettd with agitator, 5m^3 capacity.	75,000
8.	Recovery furnace	1	75,000kg/day total solid handling capacity.	175 lacs
9.	Smelt dissolving tank	1	Cylindrical, Mild steel, 10m^3 capacity, smelt cooling and smelt breaking arrangement.	1.0 lac
10.	Green liquor storage tank	1	Cylindrical, Mild steel, tank, 25m^3 capacity, outside lagged and filted with heating nozzles.	1.5 lacs
11.	Slaker	1	65.000kg/day caustic production capacity, cylindrical both sides conical ends M.S. shell internally fitted rake spinal.	40 lacs
12.	Reaction tank	1	Cylindrical, Mild steel, lagged outside and fitted with agitator, 3200m^3 capacity outside fitted with steam nozzle.	13 lacs
13.	Classifier or Rejects refiner	1	Rejects grits of screen size 28 cm diameter.	1 lac
14.	White liquor clarifier cum storage tank	1	Cylindrical, Mild steel, 2200m^3 capacity out of which 200m^3 for white liquor.	25 lacs
15 a.	Lime mud washer No. (1)	1	Cylindrical, Mild steel, 1500m^3 capacity fitted with rake.	20.5 lacs
b.	Lime mud washer No. (2)	1	Cylindrical, Mild steel tank, 1500m^3 capacity and tank is fitted with rake.	17.5 lacs
16.	Sludge filter	1	Filteration capacity 4500kg sludg per hour.	8.5 lacs
17.	Lime crusher	1	Crushing capacity 3000 kg per hour.	5 lacs
18.	Pumps	—	—	10 lacs
19.	Air compressor	—	—	2 lacs
20.	Piping, insulation	—	—	2 lacs
21.	Electrical	—	—	2 lacs
			Fixed cost = Total	494.75 lacs
			Taxes and Insurance (2% of Investment) =	9.89 lacs

Amount of recovered caustic $= 2400 \times .88$ kg/hr.

Lime requirement $= 2400 \times .88 \times 1.3$ kg/hr.

Cost of total lime require $= \frac{2400 \times .88 \times 1.3 \times 24 \times 330 \times 800}{1000}$

$= 17.4$ lacs.

3. Salt Cake requirement and cost

Salt cake ———→ 9000 kg/day

[Salt cake reqirement will be 9000 kg/day while cooking liquor sulphidity 18% and percentage recovery 88%].

$$\text{Cost} = \frac{9000 \times 330 \times 4000}{1000}$$

$= 11.88$ lacs

$= 12$ lacs (approx).

4. Furance oil requirement and cost

Daily requirement for normal run is 1000 litres/day and one shut down and start up extra oil requirement will be 2000 litres/day.

The justification of using oil instead of coal and wood is that it gives less amount[8] of sulphur and ash when burned than coal and wood. Other reasons for using oil are

(a) Start up (b) Melting down and stopping (c) To sustain the furnace heat and to clear out blocked air passage.

Every care is to be taken to minimize the consumption of furnace oil during start up and shut down. Fuel cost (estimated) per annum = 3 lacs

5. Fresh water requirement and cost

For producing 25×10^3 kg of caustic 2000 m^3 fresh water required. So per kg of caustic, water

requirement $= \frac{2000}{25 \times 10^3}$

$= .08\ m^3$

Hence water requirement in recovery plant

$= 08 \times 2400\ m^3/hr.$

$= 192\ m^3/hr.$

Water cost = Rs. 1/m^3

∴ Water cost $= 192 \times 24 \times 330 = 1.5$ lacs per annum.

6. Power requirement and cost of power

Generally for different mills power requirement per kg of required caustic is 0.6 KWH.

∴ Power consumption of the recovery plant

$= 0.6 \times 2400$

$= 1440$ KWH

Power cost 1440 KWH and Rs. 1/KWH

$= 1440 \times 24 \times 330 \times 0\ 8 \times 1$

= Rs. 91.2 lacs.

7. Steam requirment and Steam cost

(a) For evaporator = 2074 kg/hr (From steam calculation)

(b) Process steam = 220 kg/hr.

Generally for different mills process steam requirement per 100 kg of Total solid 0.36 kg/hr.

(c) Steam requirement in causticizing plant = 480 kg/hr.

Generally for different mills in causticizing plant 20 kg. of steam requires for 1 kg. of caustic.

Hence total consum 2774 kg/hr.

∴ Steam cost 2774 kg/hr and 0.50 paise/kg.

$= 2774 \times 0.50 \times 24 \times 330 = 10.99$ lacs

8. Maintenance spare cost = 2.50 lacs

9. Labour cost

Modern recovery plant the labourers requirement will be 70.

Expences for labour per year = Rs. 25,000

Total expences = Rs. 25000×70

= Rs. 17.5 lacs.

∴ Total cost = 660.72 lacs.

10. Pollution control cost

For a new mill the capital expenditure for environmental control for both air and water to 10-12.5% of the total capital cost of the mill.

∴ Total cost including pollution control

= 726.79 lacs

Cost of recovered caustic per annum

Total cost excluding equipment cost

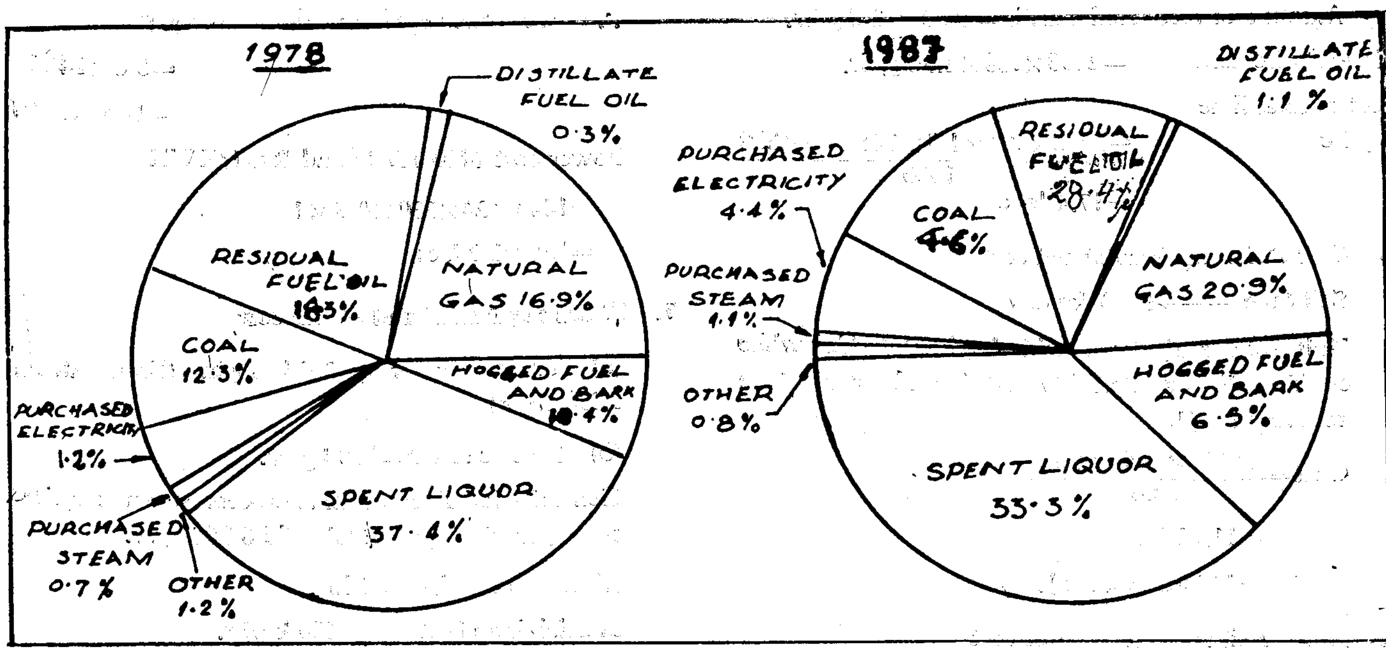
= 726 79—494.75

= 232.04 lacs ...(1)

Depreciation of equipment $= 494.76 \times 0\ 3$

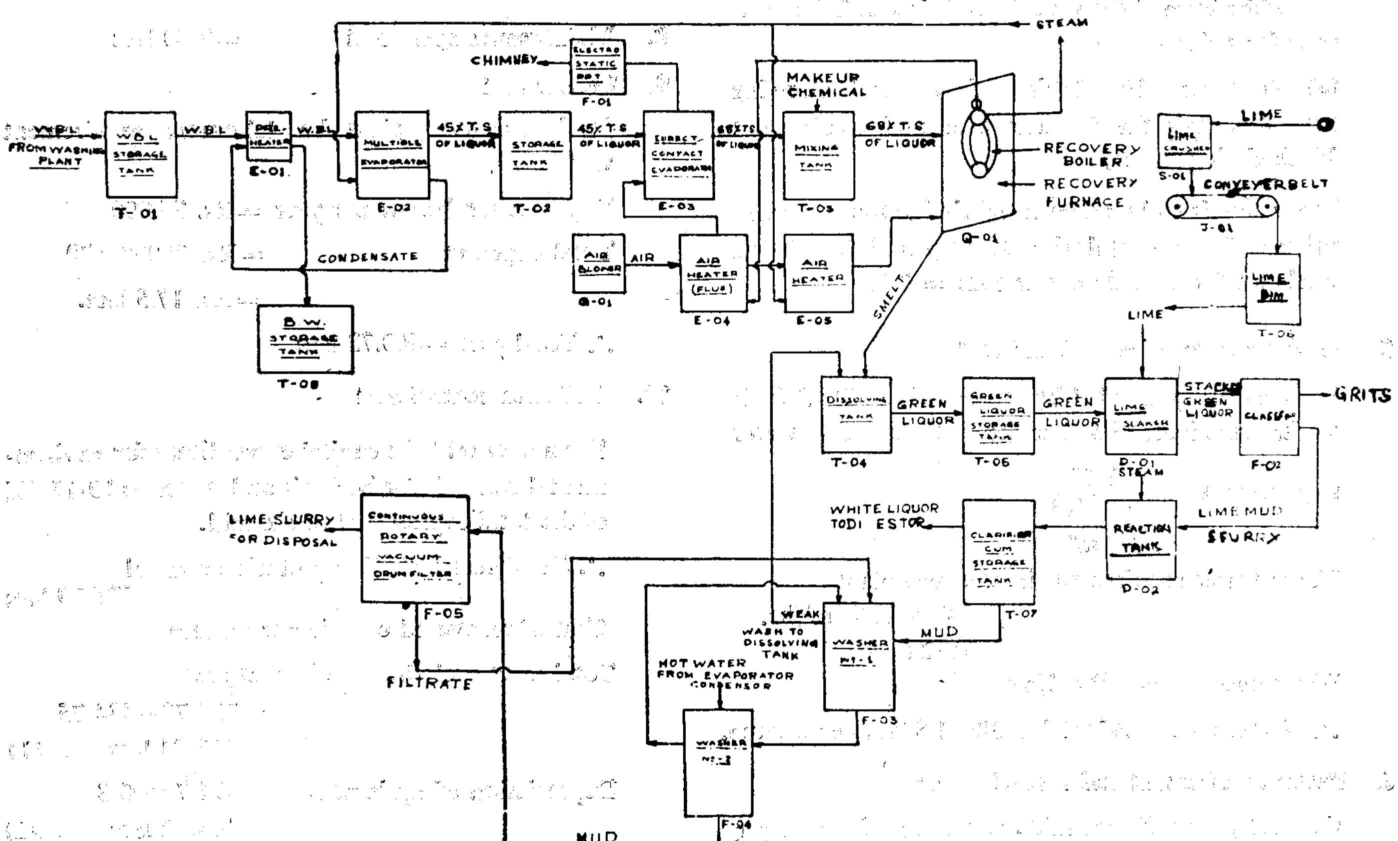
= 148.42 lacs ...(2)

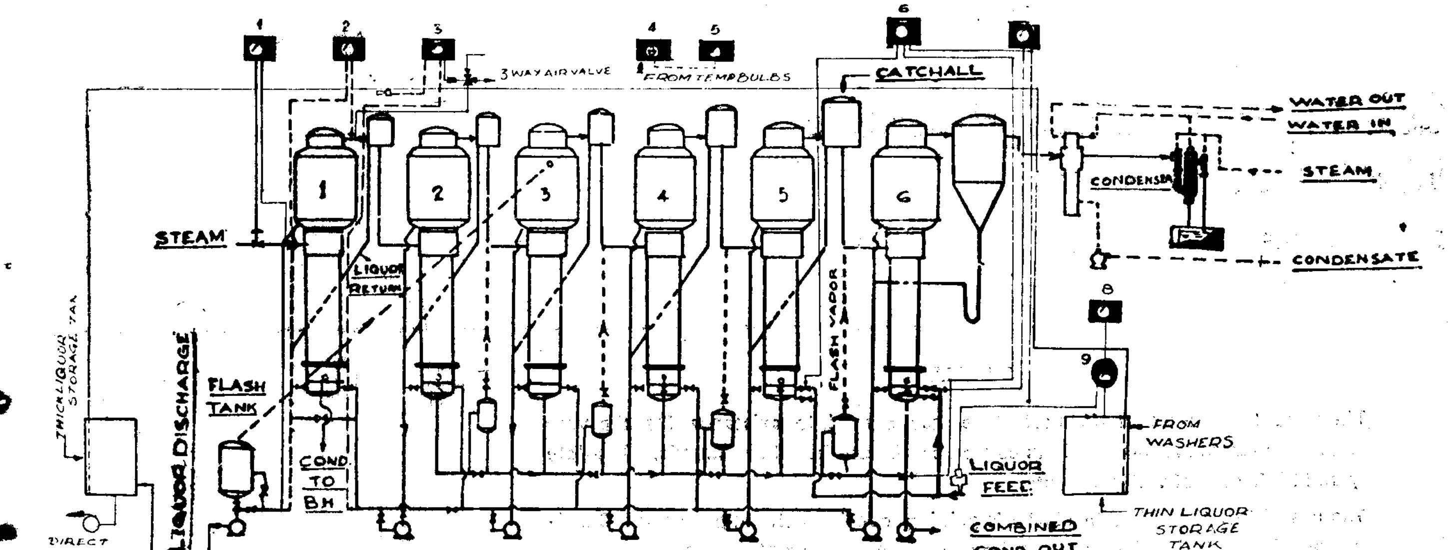
∴ Total cost = (1+2) = 380.47 lacs



Energy consumption : Pulp and paper industry.

PROCESS FLOW DIAGRAM OF RECOVERY OF WHITE LIQUOR FROM BLACK LIQUOR





Evaporator control system.

1. STEAM PRESSURE CONTROLLER, PNEAMATIC SET FROM 2
2. ELECTRONIC BOILING POINT RISE CONTROLLER
3. CONDENSATE CONDUCTIVITY CONTROLLER
4. AUTO-MANUAL TEMPERATURE SCANNING UNIT
5. ELECTRONIC TEMPERATURE RECORDER
6. THIN LIQUOR RATIO FLOW CONTROLLER
7. TOTAL THIN LIQUOR FLOW CONTROLLER
8. THIN LIQUOR DENSITY RECORDER
9. THIN LIQUOR DENSITY TRANSMITTER

Total recovery caustic per annum $= 2400 \times .88 \times 330 \times 24$

$= 16727040$ kg/annum

Cost per kg of recovered caustic $= \frac{38047000}{16727040} = \text{Rs.}2.37$

(Here cost of weak black liquor received from washing plant is not considered).

The economics for the abovementioned system have to worked out on individual basis and depend to a great extent of the location and cost of various inputs in each case. Furthermore, the cost of financing will play an important role in deciding the viability. Soft loan scheme if made available from the government counterpart to introduce installation of recovery unit, will play major role in final analysis.

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