Evaporation Problems in Bamboo Black Liquor

*P. K. SURI, V. N. CHAUHAN, A. P. SHUKLA, A. P. SETH

INTRODUCTION

In an integrated Pulp and Paper Mill, an efficient Soda Recovery unit forms the back-bone of its economics. 1% recovery in a 100 TPD unit would mean a saving of about Rs. 7.5 lacs/year and because of the soaring prices of chemicals in the present days, the black liquor is considered to be a "BLACK GOLD". Besides, an efficient recovery is also considered significant from the point of view of environmental pollution control.

Evaporation of the black liquor forms a vital part of the chemical recovery operation and an efficient evaporation system goes to make the chemical recovery efficient. In this paper, an attempt has been made to focus the attention on the basic considerations and factors responsible for an efficient evaporation. Few of our practical experiences in this direction, specially with regards to "Scaling Problem" in evaporators, where raw material like Bamboo having high silica content compared to soft wood, have been incorporated.

Usually the black liquor with 10-14% solids, known as weak black liquor, is received in the evaporator plant and evaporated to a solid content of 50 to 63% depending upon the working conditions of the individual mill. In the mills provided with direct contact evaporators like cascade or cyclone the total solids concentration of the liquor discharged from the evaporator plant is generally maintained around 45-50%. In their absence, the evaporator's discharge is around 60-63%.

FACTORS CONTROLLING EVAPORATION

Following factors influence the efficiency and smooth running of the evaporation plant ;—

i) Physical and Chemical characteristics of black liquor.
ii) Rate of heat transfer,
iii) Scale formation.

*J. K. Paper Mills, Jaykaypur, Orissa.

i) **BLACK LIQUOR CHARACTERISTICS :** Black liquor is a complex product and its characteristics depend upon its organic and inorganic constituents. For a particular mill, as per the raw materials, cooking conditions as well as the quantity and quality of the cooking liquor remain practically constant, the characteristics shall also remain constant with minor variations unless otherwise directly or indirectly major changes are made in the operating conditions. However, they may vary from mill to mill.

The physical properties affecting the performance of the evaporation are as under :

a) Density
b) Viscosity
c) Surface tension, and
d) Boiling point elevation

The relation obtained between viscosity and rise in boiling point V/S total solids at different temperature obtained at the mills, shown in graph 1 & 2 respectively, indicates that with the temperature, viscosity decreases but with increasing solids, the viscosity increases. The increase in viscosity affects the evaporation process and tends to aggrevate the scaling problem.

A control on the foaming tendency of the black liquor will minimise the chemical losses at the first stage. It is well known that in bamboo sulphate black liquor, foaming is more pronounced at lower concentrations. Hence, it is imperative to obtain good working efficiency in Pulp Mill with minimum dilution, enabling this black liquor to be available at higher concentration 18% total solids concentration is considered to be ideal, which though is generally not practicable but a close vicinity could be preferred. With the reduction in foaming tendency, steam requirement for evaporation is also reduced.

ii) **HEAT TRANSFER CO-EFFICIENT :** Evaporator performance mainly depends on the quantity of heat transferred through the tubes'

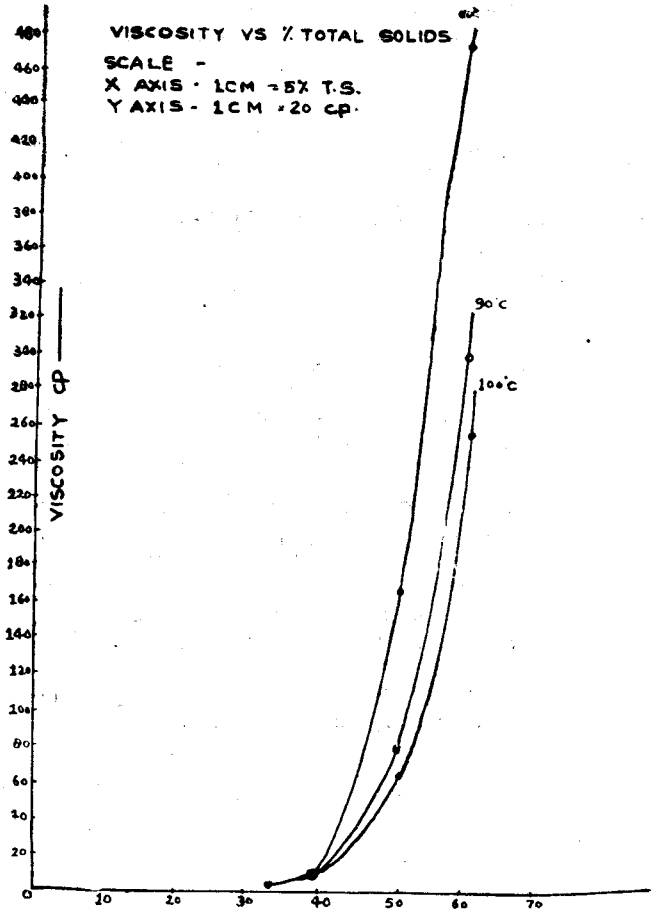

Fig. 1 % Total Solids

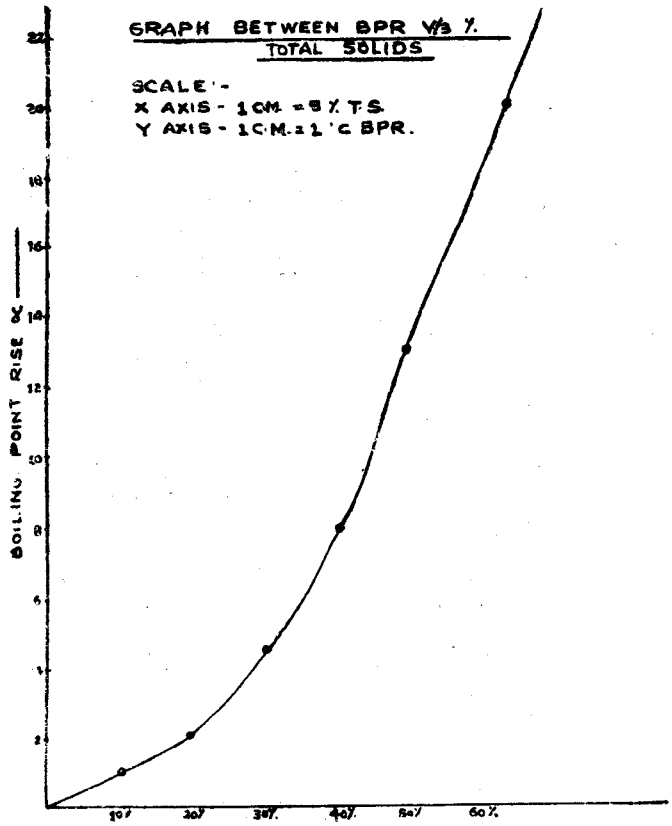

Fig. 2 % Solids

surface, which in turn depends on heat transfer co-efficient which is higher when we start with clean tubes after cleaning the evaporator tubes. It gradually decreases with the increase infouling i.e. scaling of tubes which gradually increases as the evaporation proceeds till next tube cleaning is takenup. The heat transfer coefficient is given by the following formula—

$$\frac{I}{U} = Rc + Rw + RLF + Rs$$

Where

U = Overall heat transfer coefficient.
Rc = Steam condensate film resistance.
Rw = Tube wall resistance.
RLF = Stagnent liquor film resistance.
Rs = Scale resistance.

In a particular evaporator plant, Rc, Rw & RLF are constant for a particular black liquor. Hence scaling is mainly responsible for change in overall heat transfer coefficient at any time. Resistance of scale formation is calculated by the following equation.

RS = est

Where

e = coefficient of scale formation.
s = average amount of water evaporation in Kg/hr/m^2 of heating surface.
t = Time difference between two cleanings, hrs.

Rate of scale formation is directly proportional to percent total solids being processed in any evaporator body/bodies of the evaporator plant. The relation between scale resistance and percent total solids has been shown in graph No. 3.

iii) **SCALING** : The scaling properties of the liquor can be related to percent of inorganic salts present. It has been indicated that the most likely inorganic components precipitating out as scale are as follows:—

(A) Double salt—2 $Na_2SO_4 \times Na_2CO_3$
(B) Sodium Sulphate
(C) Aluminium Silicate
(D) Sodium Carbonate

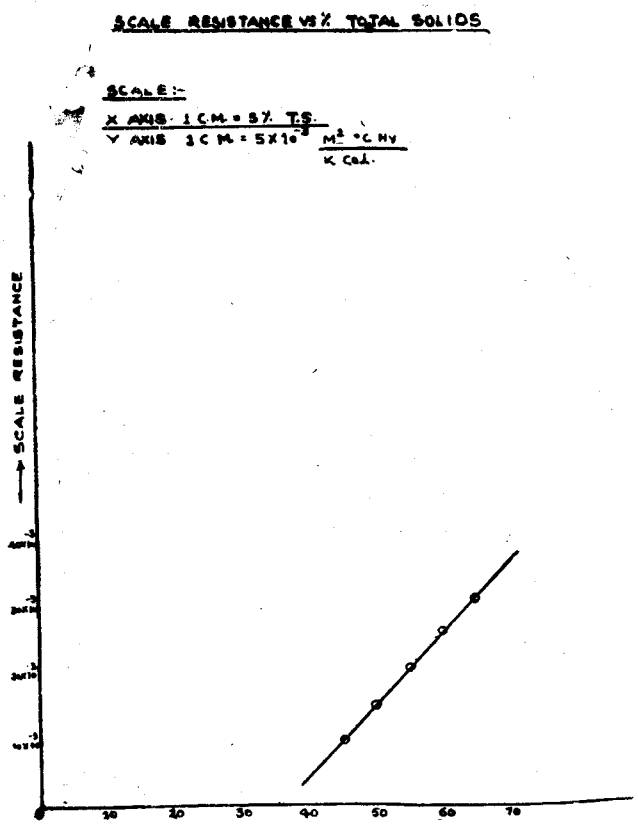

Fig. 3 % Total Solids

(E) Chromium Oxide
(F) Alumina Sulphate
(G) Calcium Silicate
(H) Soaps and Fibers

The first four start forming scale because their solubility fall down with rising temperature and concentration. Sodium Sulphate gives more trouble because of its concentration varying on account of fluctuations in the working of the Recovery Boiler furnace and is mainly responsible for the formation of $2\,Na_2SO_4 \times Na_2CO_3$ complex.

CAUSES FOR SCALE FORMATION

Any lag in the pulp mill operation directly or indirectly affects the black liquor quality and consequently the process of evaporation. Any change from the set conditions in cooking and washing may lead to operating troubles which are at times quite acute inviting lot of problems.

(i) Due to foaming it is very difficult to maintain the level in the body and as such tubes get dried resulting into scaling.

(ii) Lignin precipitation causing severe choking of tubes. This, in turn, adheres to the walls of the tubes and form scales though loose ones.

(iii) Liquor concentration and its effect on scaling– In recovery operation, it is an usual practice to evaporate the liquor to the desired concentralion before firing in recovery furnace. At times, the liquor is concentrated to 40–45% solids in multiple effect evaporator and then in the direct contact evaporator to 60–63% solids The analysis of Black liquor at different stages are given in table I.

An optimum concentration of 60–63% total solids can be obtained with long tubes vertical natural circulation evaporator. The heat transfer coefficient at 60% dry solids content is 400–600 K.Cal/m² hr.°c against 500–700 K.Cal/m² hr./°c heat transfer coefficient for 45% solids black liquor.

The drop in heat transfer coefficient is mainly due to increased scale formation and higher viscosity which decreases the steam economy and effects the smooth and efficient running of the plant. Hence the increased scaling in case of 60–63% dry solids liquor nessitiates frequent weak liquor or water boiling. Analysis of scale from final effect is given in table No. 2

The main disadvantage with multiple effect evaporator discharging black liquor of higher concentration is the higher rate of scaling of the tubes, particularly in the effect in which the final evaporation of black liquor takes place and higher temperature of liquor has to be maintained because of its boiling point elevation and higher viscosity.

PROBLEMS IN EVAPORATOR DUE TO SCALING

Scaling in evaporator tubes inside or outside poses following problems—

(i) Lesser production rate due to reduction in evaporation capacity.

(ii) Lesser steam economy—more steam consumption per ton of water evaporation.

(iii) More down time.

(iv) Increased cost for frequent cleaning of tubes and boil-outs.

In course of normal operation of the evaporator, one has to keep a constant watch and not to allow the steam economy to exceed a certain set value based on the past performance.

TABLE—1 BLACK LIQUOR ANALYSIS

Particulars	Unit	Weak B.L.	Intermediate B.L.	Strong Black Liquor	Thick Black Liquor	Thick Black Liquor after Sulphate Mixing
Temperature	°C	60	70	70	70	102
Density	°TW	14	25	50	65	68
Total Solids	%	13-14	24.8	45.0	60.0	62.0
Organics	%	51	51	51	51	50
Inorganics	%	49	49	49	49	50
Free Alkali as NaOH	%	1.0	1.2	—	2.5	2.5
$NaOH+Na_2S$	%	12.5	12.5	12.5	12.5	12.5
Na_2CO_3	%	68	68	68	68	68
NaCl	%	1.1	1.1	1.1	1.2	1.2
Na_2So_4	%	10 5	12.0	13.0	13.0	20.0
SiO_2	gpl.	4–5	6 5–7.5	14–15	15–16	15–16
Na_2O (T.T.A)	gpl.	40	60	145	180	180

TABLE—2 SCALE ANALYSIS FROM IST EFFECT EVAPORATOR

Analysis on dry ba is		(103±2°C)
Los: on Ignition	=	12 20%
Water Soluble	=	6.98%
Acid Insoluble ((Silica)	=	43 02%
R_2O_3	=	4.88%
CaO	=	30.37%
MgO	=	0.80%

REMARKS :—

The scale appears to consist mainly of the Calcium Silicate associate with minor impurities of alkalies, R_2O_3 and Organic materials. The loss on ignition is mainly due to lignin deposited on the walls of the tubes.

Accordingly a time schedule has to be made for cleaning the tubes of either all the bodies at a time or one by one in case a spare body is available and has to be maintained strictly. Under no circumstances, this should be postponed for an opportunity, in which case the problem becomes so acute that desired quantity and concentration of thick liquor would not be possible at all leading to a forced stoppage for tube cleaning. Also with the delay in cleaning, scale becomes harder and harder and also thicker and thicker resulting in lower value of overall heat transfer coefficient which is inversely proportional to scale resistance. Consequently, there will be heavy financial loss due to lesser steam economy i.e. high steam consumption especially where the cost of steam is going high because of the prices of coal going up.

REMEDIAL MEASURES FOR AVOIDING SCALE FORMATION

i) **Disilification :** Although much work has been done at the laboratory scale for material like bamboo which contains high silica content from the black liquor, but so far no method has been found to be most practical.

ii) A certain amount of residual alkali in black liquor is a must to stabilise the alkali lignin. About 10 gpl free alkali as NaOH in thin black liquor is expec ed to avoid lignin precipitation. As and when this value goes down, caustic dosing is required to maintain the desired free alkali.

iii) The sulphate and carbonate content in black liquor has to be kept minimum by taking the following steps:—

(a) Sulphate can be reduced by maintaining the percentage reduction of salt cake not less than 90% by proper control of Recovery Furnace.

(b) Carbonate can be kept low by maintaining to highest possible causticizing efficiency with lime, generally available with 60–65% CaO content. Causticizing efficiency can be easily maintained about 85%.

iv) The fiber content can be kept minimum by using a filter like malone to filter the same from thin black liquor.

v) The White Liquor should be free from suspended solids.

vi) Level in evaporator bodies—It is utmost important that level in all the bodies are maintained properly because scaling is faster due to drying of heating surface when tube is empty.

Now-a-days though evaporators are well equipped with level controllers but still one has to be cautious and ensure that controllers are working effectively. A physical check for the levels of the bodies during their running is essential.

vii) Cleaning Schedule of evaporator bodies Proper schedule for tube cleaning to be followed strictly and is to be supervised and checked thoroughly by a responsible person as possibility of a very thin layer of scale being left to act as catalyst for scale formation cannot be ruled out.

The time schedule is made for all bodies at a time when no spare body is available. In case of a spare body available, one body is cut off as per the schedule from the first three bodies, which are generally exchangeable and the rest of the bodies may be cleaned during maintenance shuts of Recovery Boiler.

viii) **Weak Liquor Boiling :** Weak liquor boiling should be done in all bodies for about 2–3 hrs. and 1–1½ hrs. in 24 hrs. operation in case of mild steel and stainless steel tubes respectively.

ix) **Stainless Steel Tube VS Mild Steel Tubes :** Regarding use of stainless steel tubes in evaporator, no hard and fast rule can be laid down because liquor condition vary from mill to mill. The selection of material depends on number of factors notably the sulphidity and stabilization of sulphur compounds in black liquor and its viscosity etc. on the heating surface and the possible effects corrosion by gases in certain areas.

As a general rule, sulphidity lower than 20% does not warrant the use of stainless steel tubes even in strong liquor bodies but in case of sulphidity over 25% its use particularly in concentrated liquor bodies gives considerable saving in the long-run. In the intervening range between 20-25% the use will depend upon the corrosive nature of the black liquor as some liquors may be more corrosive than others.

Although, it is undoubtly true that stainless tubes give more life compared to mild steel tubes, it is not very easy to give a reliable estimate of the life of tubes as it depends on several factors enumerated above, besides factors like the extent of washing out, mechanical descaling and the efficiency of removal of air and non condensible gases from the vapour steams. However, expected life of mild steel and stainless steel tubes could be taken as 5 years and 25/30 yrs. respectively.

ANTICIPATED DISADVANTAGES IN USING STAINLESS STEEL

Following disadvantage may be anticipated from the use of stainless steel.

i) Initially the scaling inside the tube may not be fast but after several tube cleanings the inside surface of stainless steel will become rough resulting in frequent scaling.

ii) Some may believe that since there is a difference between the coefficient of expansion of stainless steel and mild steel, there may be undue stresses and strains on the bodies of the evaporator and stainless steel tubes expanded in mild steel end sheets may not work satisfactorily.

EXPERIENCE AT OUR MILLS WITH STAINLESS STEEL TUBES

The experience in our mills, in running the evaporators with stainless steel tubes for about 7 yrs. We have found that scaling in stainless steel tubes is much lesser when compared to that of mild steel ones and the performance of evaporator is quite good.

The choking of evaporator tubes is experienced when the concentration of thick black liquor is increased beyond 55–60% solids. Earlier the mild steel tubes were getting scaled heavily even at 50% concentration. Daily shut down of plant was for 2–3 hrs. and cleaning was required even 18/20 days of final effect. Now with stainless steel tubes the scaling problem has reduced appreciably and weak liquor boiling is also reduced to 1–1½ hrs. from 2–3 hrs. Now interval between two cleanings has been increased to 20–25 days as compared to 18/20 days with mild steel tubes.

ACKNOWLEDGEMENT

The authors are thankful to the management of M/s. Straw Products Limited (J.K. Paper Mills) for kindly granting permission to present this paper.