Experience with Direct Contact Evaporators in Recovery System at Seshasayee Paper & Boards

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SUMMARY

Direct Contact Evaporators in kraft recovery system recover the sensible heat escaping out of the recovery furnace. Apart from recovering sensible heat, Direct Contact Evaporators help in partially recovering the chemicals escaping out of the recovery boiler. Seshasayee Paper and Boards' experience with the operation and maintenance of Cyclone Evaporator, Venturi Scrubber Evaporator and Cascade Evaporator are discussed in detail in this paper. With the experience with the above three types of Direct Contact Evaporators, Seshasayee Paper and Boards are of the opinion that the Cascade Electrostatic Precipitator secondary recovery system is most advantageous.

INTRODUCTION

The sensible heat in the flue gas from a chemical recovery boiler is advantageously recovered for concentrating the black liquor that is sent to chemical recovery boiler by the use of direct contact evaporators. The concentrated black liquor is extracted out of multiple effect evaporators at 40–45% solids. For mills like S P B using tropical hardwoods to the extent of 60% in pulping along with bamboo it is not possible to maintain a concentration above 40% from multiple effect evaporators on a sustained basis due to viscosity and scaling nature of the black liquor. For stable recovery furnace operating conditions, it is essential to have a concentration of 60–65% solids for black liquor fired in the recovery boiler, and the increase in concentration in all Indian mills is achieved by the direct contact evaporator. Though water removal and concentration of the black liquor is the main function of a direct contact evaporator, it has a secondary function to recover partly the carried over sodium chemicals from the flue gas. Secondary evaporators working in conjunction with a fume recovery device like the venturi scrubber of electrostatic precipitator constitute the secondary recovery system in the recovery cycle.

In the direct contact evaporator the black liquor and the flue gas are brought into intimate contact and a mass transfer of water vapour from the liquor to the gas across the liquor gas interface takes place. In this process of evaporation which is known as "adiabatic humidification" heat and mass transfer take place simultaneously.(1) The design of a direct contact evaporator requires that adequate liquor film surface be provided for the desired heat and mass transfer. If black liquor is sprayed or splashed on a hot surface to expose a thin film, the quantity of liquor splashed must be sufficient for continuous wetting of the surface so that a thin film of liquor is always available to avoid drying up of black liquor solids which may lead to spontaneous combustion with undesirable consequences. The black liquor has to be kept in continuous agitation or movement to prevent local over concentration and to avoid precipitation of alkali lignin compounds as a result of lowering of pH of black liquor consequent to absorption of CO_2 and SO_2 which reduces the solubility of dissolved solids(2).

Direct contact evaporators in Kraft Recovery system are of three types :

i) The cyclone evaporator
ii) The cascade evaporator
iii) The venturi evaporator scrubber

CYCLONE EVAPORATOR

The cyclone evaporator is a vertical cylindrical vesel with a contical bottom (please see Figure—I). The flue gas is admitted through a tangential inlet near the bottom and flows in a whirling helical path and leves the cylinder through a concentric re-entrant outlet.

Fine droplets of black liquor is sprayed across the tengential flue gas inlet to obtain intimate mixing with high velocity flue gas. The droplets are thrown to the walls of the cylinder by centrifugal force. Recirculated liquor (wall wash liquor) flowing down the wall carries the liquor droplets along with a

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substantial amount of dust which has been collected from the gas, to the conical bottom of the cyclone. Sufficient liquor is recirculated to the wall wash nozzles at the top of the cyclone evoporator through savco strainers to keep the interior wall continuously wet preventing localised drying of black liquor solids on the surface. Normally the cyclone recirculation pump is designed to have about 10–19 circulation per minute of the liquor in the cyclone evaporator pump. By adjusting the quantity of the spray liquor at the inlet it is possible to control the evaporation or conversely the desired flue gas temperature drop.

CASCADE EVAPORATOR

Cascade evaporator (please see Figure-2) is a direct contact heat transfer device employing a rotating bundle of tubular elements which serve to pick up liquor for contact with flue gases. While rotating the bundle at a peripheral speed of nearly 1 m/sec, the tubes pass through a bath of black liquor contained in the lower portion of the evaporator housing thus causing the tubes to be coated with black liquor. As the tubes rise above the liquor bath, they contact hot flue gases passing in between the cascade evaporator tubes, effecting the evaporation of water from the liquor. Simultaneously a scrubbing action takes place whereby a substantial amount of the enterained dust in the flue gas is collected in the cascade evaporator. Rotation of the tube bundle cause continuous scrubbing of the dust from the tubes and permits rewetting of the bundle with fresh liquor for further contact with the hot gas stream(1). The attendant agitation assures complete mixing and circulation of the entire liquor body. The concentrated liquor is withdrawn through a flow box mounted on the side of the cascade. The number and arrangement of the tubes to provide the amount of total contact surface required depends upon the weight and temperature of the gas and the weight of water that must be evaporated from the liquor.

VENTURI EVAPORATOR SCRUBBER

The cyclone evaporator and cascade evaporator are devices to recover the sensible heat in the flue gas for concentrating the black liqor fed to the recovery furnace. The chemicals carried over in the flue gas is completely recovered by separate venturi scrubber or electrostatic precipitator. The venturi evaporator scrubber (please see Figure-3) as the name indicates, performs two functions, recovery of sensible heat from the gas for concentration of black liquor to be fired in the furnace, and recovery of chemicals from the flue gas. Babcock & Wilcox, USA developed the venturi scrubber evaporator by working in close co-operation with Thilmany Pulp and Paper Company, USA(3). The first venturi scrubber evaporator was installed in USA in 1953.

Flue gas from the recovery boiler passes through a rectangular venturi throat where the gas velocity increases as a result of the reduction in cross section. Black liquor is introduced to the system at two locations. The feed or make up liquor from the multiple effect evaporators at a concentration of about 42% is injected at the throat of the venturi, where the flue gas velocity is maximum. The venturi utilises the energy of the high velocity gas to atomise the make up liquor which is injected at the throat at an angle of 90° to the gas stream. The dust particles in the flue gas collide with and adhere to the liquor droplets. The mixture of flue gases and concentrated black liquor droplets with their dust particles are centrifugally removed and drained to the sump of the cyclone separator. The concentration of liquor collected in the sump varies from 60–65% depending upon the differential across the venturi, temperature of flue gas entering the venturi and the quantity of make up liquor added to the venturi scrubber evaporator. The concentrated liquor from the cyclone sump is pumped through a sarco strainer. Part of the rejects from the sarco strainer goes to the salt cake mixing tank and the remaining back to the cyclone sump. The liquor that has been filtered in the sarco strainer is devided into two portions-one portion going to the wall wash nozzle and the other portion for the steam atomized nozzle at the conversing portion of the venturi throat. In venturi scrubber evaporator the flue gas is cooled to about 95°C.

EXPERIENCE OF SESHASAYEE PAPER AND BOARDS

Seshasayee Paper and Boards have gained considerable experience in the operation and maintenance of cyclone evaporator, venturi scrubber evaporator and cascade evaporator. The mill initially started production in 1962 as an integrated Pulp and Paper mill with a modern recovery unit. The recovery boiler to handle 90% of black liquor solids per day with a steam raising capacity of 15 t/h at 150 psi, was supplied by Babcock & Wilcox, USA and it was having a cyclone evaporator for secondary evaporation. Black liquor at a concentration of 45% from multiple effect evaporator was further concentrated to 62% in the cyclone evaporator before being sprayed into the recovery furnace. The temperature of the flue gas entering the cyclone was 630°F and outlet temperature was 330°F. The cyclone made of half inch thick mild steel plate was 23′ 8″ in height and 9 ft in dia. The cyclone circulation pump had a capacity of 1300 l/min at 43 m head and it made about 19 circulations per minute of the black liquor in the sump. The ID fan had a capacity of 26360 kg/h and was driven by a motor of 60 H.P. The cyclone evaporator worked smoothly for six years. The mill did not experience any operating or maintenance problem during the period, and the unit worked as a very efficient direct evaporator recovering the sensible heat from the flue gas concentrating the black liquor to the desired level to maintain stable furnace conditions. But as there was no fume recovery either in the form of an electrostatic precipitator or venturi scrubber, the overall chemical recovery was only 84%. To improve the chemical recovery percentage the mill decided to go in for venturi scrubber evaporator in 1968. Accordingly a suitable venturi scrubber evaporator was ordered on Babcock

& Wilcox, USA. The additional equipment involved in converting the cyclone evaporator to a venturi scrubber evaprator were:

a) Venturi throat
b) Steam atomised Venturi headers
c) Make up liquor headers
d) Sarco strainers for concentrated liquor
e) 420 HP double stage ID fan in place of single stage ID fan with 60 HP drive. The new ID fan had a variable speed drive, a steam turbine
f) Atmospheric relief dampers to open in case of failure of liquor to venturi throat, to avoid heavy draft in the furnace.

The ducting, the venturi, the piping and foundation for the new ID fan were all made ready and erected during the running of the recovery boiler and hooking up of the additional equipment was done during the annual shut of the recovery boiler and was completed in less than two weeks. The venturi scrubber evaporator is being operated with a differential of 30″–32″ WG. A differential of 3.5″ WG is maintained across the cyclone separator. With these operating conditions the scrubbing efficiency has been quite satisfactory and with the installation oft the venturi scrubber evaporator, the overall chemical recovery efficiency improved to 89%–90%. After the installation of venturi scrubber evaporator the boiler outlet temperature went upto as high as 800°F due to overloading of the unit and also as a result of higher concentration of black liquor fired in the furnace. But even with such a high inlet temperature to the venturi the outlet temperature was 220°F. With cyclone the temperature drop was about 300°F and with the venturi scrubber evaporator the temperature drop is about 580°F. Thus the venturi scrubber evaporator improved the overall heat recovery of the unit. The recovery unit including the multiple effect evaporator was designed for handling black liquor solids from 65 t of pulp per day. But the unit including the multiple effect evaporator could handle black liquor solids from 100 t of pulp per day without any additional equipment other than venturi scrubber system because of the improvement in the overall heat recovery and of course by the reduction of black liquor solids sent to recovery per tonne of pulp by changes made in the pulping section. During the same period due to shortage of bamboo the mill had to step up the use of hardwoods to 40–50% for pulping along with bamboo and the outlet concentration of the multiple effect evaporators had to be reduced to 40% to avoid fast scaling and plugging of evaporator tubes. As the venturi scrubber evaporator could concentrate 40% liquor to 62% the operation of the furnace was not affected.

The venturi scrubber evaporator has been working very satisfactorily with higher heat and chemical recovery. But it has been our experience that corrosion in the cyclone, ducting to ID fan and the chimney increased considerably as a result of the lower flue gas outlet temperature and resultant condensation of sulphurous acid fume. Carry over from the venturi scrubber got deposited in the ducting and ID fan casing and impeller aggravating the corrosion. The black ash deposit caused jamming of the ducting and vibration of the ID fan due to inbalance. It became necessary to stop the unit once in 15 days to remove the deposits and to clean the ID fan impellers. The ducting and cyclone shell made of mild steel had to be changed in three years and the chimney was gunnited and ultimately was replaced by a stainless steel one. But the increased maintenance cost resulting out of heavy corrosionis easily offset by the increased benefit accruing out of improved chemical an heat recovery. The performance of the venturi scrubber was not appreciably affected even by overloading the recovery unit to 140% of capacity. Further venturi evaporator scrubber showed great flexibility in adjusting with any concentration of liquor fed to the venturi. Minor changes in inlet concentration of black liquor do not affect the outlet concentration to disturb the furnace operation. After two years of operation of the venturi scrubber evaporator there was an accident. While stopping the furnace for cleaning the boiler passes and screen tubes, the venturi feed pump tripped and in a matter of minutes the cyclone outlet temperature shot up and all the adhering black ash in the ducting, cyclone, ID fan impeller dried and a spontaneous combustion took place partially damaging the ID fan. The recovery unit had to be stopped for five days for repairing the fan. As a safety measure an automatic water spray is now provided at the outlet duct of cyclone separator which opens when the temperature of the outlet gas reaches 240°F. With this safety arrangement the venturi scrubber evaporator has been operating satisfactorily for the last eight years. Before the introduction of the venturi evaporator scrubber there used to be quite heavy particulate amission from the chimney Over and above recovering sensible heat from the flue gas, the chemical loss and nuisance considerably reduced as a result of the installation of venturi scrubber.

As part of a major expansion which the mill undertook in 1976 increasing its paper production capacity from 35,000 t/year to 55,000 t/year, a new recovery boiler was procured from M/s Gotaverken, Sweden. This unit with a capacity to handle 135t per day of black liquor solids is having all the latest design features. The secondary evaporation in this boiler is achieved by a cascade evaporator with the following design specifications:

Diameter	3600mm
Length	2500 mm
Number of tubes	520
OD of tubes	63.5 mm
Water evaporating capacity	3520 kg/h
Liquor holding capacity	17 m^3
Drive	50 HP
Inlet temperature of flue gas	330°C
Outlet temperature of flue gas	160°C
Peripheral speed	1.18 m/sec

The fume recovery in this boiler is done by an electrostatic precipitator. The outlet temperature of flue gas from the cascade is high at 150°C as the inlet to the precipitator has to be min 150°C to avoid condensation of sulphurous vapours and corrosion of electrodes.

This new recovery unit was commissioned one year ago and the cascade has been working quite satisfactorily without any problem.

Now that SPB have one recovery boiler with a venturi scrubber evaporator and another with a cascade and electrostatic precipitator, it is felt a comparative assessment of the mill's experience with the two types of secondary evaporation and fume recovery will be interesting.

Both the boilers are of Babcock & Wilcox design with oscillating liquor spray on the furnace walls. The old boiler has a capacity to handle 90 t black liquor solids per day and is designed for a steam flow of 15 t/h at 150 psi. But the boiler has been handling about 140 t black liquor solids per day for the last six/seven years. The new boiler is designed for handling 135 t black liquor solids per day with a steam generation of 17 t/h at 400 psi.

INVESTMENT—The venturi scrubber evaporator with accessories at present day price will cost Rs12,00,000. The cascade with accessories and electrostatic precipitator has cost Rs 35,00,000. Investmentwise the venturi scrubber evaporator costs less than half as much the cascade electrostatic precipitator system.

SPACE— The venturi scrubber evaporator with ID fan occupies marginally less space compared with the cascade and electrostatic precipitator.

RECURRING OPERATING EXPENSES— The total capacity of the electrical equipment for the cascade and electrostatic precipitator system is 245 kW as below:

Cascade	45 kW
Precipitator	25 kW
Heater	25 kW
ID fan	150 kW

and the cost of power per day is Rs 1470.

The installed capacity of electrical equipment for the venturi scrubber evaporator system is 470 kW as below:

ID fan	375 kW
Venturi circulation	95 kW

and the cost of power per day is Rs. 2820 /-

The venturi evaporator scrubber consumes nearly double electrical power compared with the cascade and electrostatic precipitator. The recurring expenses on this account amounts to Rs 4,72,500/- per annum. The cost of 500 kg/h of steam for atomising the liquor at the venturi works out to Rs 1,26,000/- per year.

SULPHUR AND CHEMICAL LOSSES— It is the mill's experience that higher sulphidity is available from recovery boiler with the cascade and electrostatic precipitator system for the same amount of salt cake added maintaining the same throughout of liquor in the two furnaces.

This is possible due to the formation of H_2S and escape of part of this H_2S, with the flue gas unabsorbed ([4]).

$$Na_2S + CO_2 + H_2O \text{ — } Na_2CO_3 + H_2S$$

It is also known that methyl mercaptans are formed in the venturi scrubber ([5]) and part of it also may be escaping unabsorbed increasing the sulfur loss of the system.

$$CH_3S + CO_2 + H_2O \text{ — } HCO_3 + CH_3SH$$

As the mixing of flue gas and black liquor is vigorous in the case of venturi scrubber evaporator the formation of H_2S and CH_3SH and its escape from the system is more in the case of the venturi-scrubber.

The venturi scrubber evaporator has to perform two contradictory functions—absorption and evaporation. Evaporation and scrubbing do not go together, if the liquor to be evaporated is the same as that used for scrubbing the dust laden gases. Under the above conditions, a compromise between optimum scrubbing efficiency and optimum evaporation has to be accepted in the case of venturi scrubber evaporator.

THERMAL EFFICIENCY— The old Babcock & Wilcox recovery boiler though designed for 90 t of black liquor solids per day has been operating with 130-140 t of black liquor solids per day almost the same capacity as the new Gotaverken boiler. The temperature of flue gas going out of Babcock & Wilcox recovery boiler is 95° C and the temperature of flue gas going out of the Gotaverken boiler is 150° C. The extra sensible heat lost through stack in the Gotaverken boiler if converted into equivalent coal is 5 t of coal per day. At the rate of Rs. 200/t of coal at Erode, this works out to Rs. 3,50,000 per year. This is a major advantage with venturi scrubber evaporator.

OPERATION CONVENIENCE—The cascade operation is simple and needs less attention compared with the venturi scrubber evaporator. Because of the intimate and vigorous mixing with the flue gas the viscosity of liquor in the venturi scrubber evaporator goes up due to absorption of CO_2 and it is necessary to have a continuous dosing of weak white liquor to the venturi scrubber evaporator to avoid precipitation of black liquor solids. Venturi scrubber evaporator needs much more attention with regard to the concentration and outlet gas temperature compared with cascade which needs very little attention. But cascade evaporator needs a minimum inlet concentration which is higher than the venturi scrubber for

optimum performance, while venturi can tolerate considerable variation in the inlet liquor concentration even on the lower side and this aspect is important especially when multiple effect evaporators in SPB have to handle liquor from hardwoods to the extent of 60%.

CONCLUSION

Considering the experience of Seshasayee Paper and Boards, despite the higher investment and less thermal efficiency in the cascade evaporator-electrostatic precipitator system, the following facts militate against the installation of venturi scrubber evaporator :

(*a*) Higher operating expenses by way of higher power consumption.

(*b*) Higher sulphur losses and the consequent financial burden.

(*c*) Greater maintenance cost.

(*d*) More constant attention.

(*e*) Greater atmospheric pollution and nuisance to the surrounding community. As a matter of fact because of the atmospheric pollution, secondary evaporators are completely avoided in Scandanavian and North American kraft mills. They work their evaporators at 60-65% outlet concentration.

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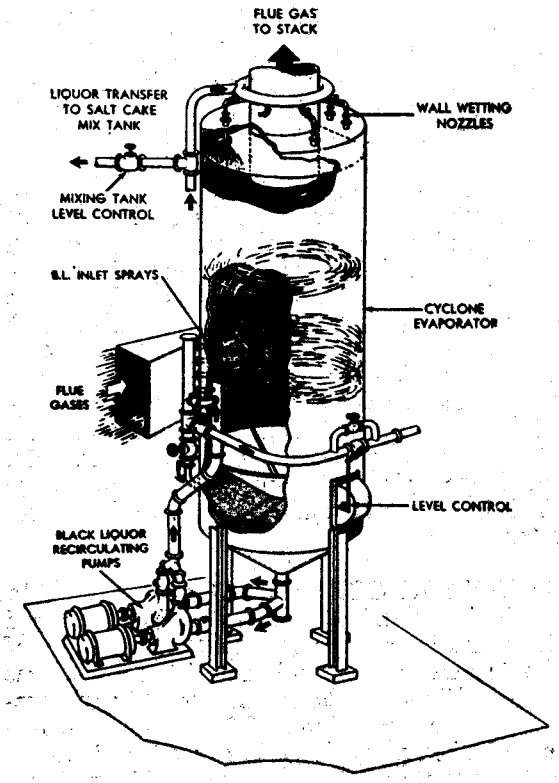

Fig. 1. Cyclone Evaporator

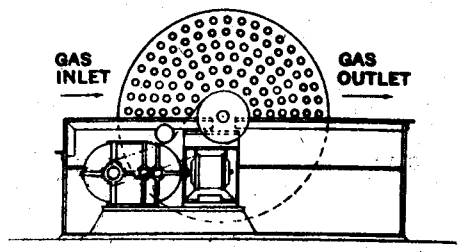

Fig. 2. Cascade Evaporator

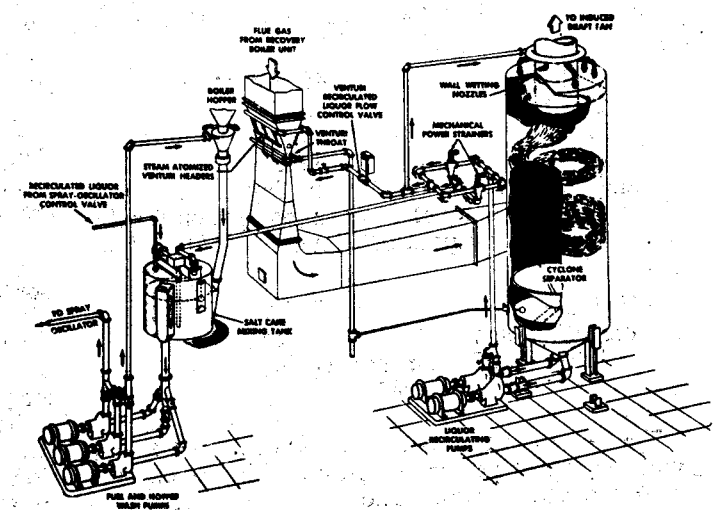

Fig. 3. Venturi-Evaporator Scrubber