

Practices and experiences in chemical recovery

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HISTORY

The Andhra Pradesh Paper Mills expanded from mere 3000 TPA production to 90,000 TPA has naturally its own experiences in recovery starting from Conventional Roaster and Smelter to a full-fledged Recovery Boiler operation with the chemical recovery as low as 40% to as high as 90% respectively.

In black liquor evaporation equipment from 1 T/hr in Voith long tube evaporator changed to short tube evaporator of Rosen Blad and finally 92 T/hr modern Free Flow Falling Film (FFFF) evaporators of Rosen Blad design.

In chemical recovery furnace side from Roaster type furnace to 127 T/day FCB make boiler in 1965, further added with 2 Gopi Smelters (WAGNER TYPE) and then replaced by 270 T/day AVB make Recovery Boiler in 1981.

In causticising from batch type causticising to continuous causticising with capacity increase as phase-wise expansion of the mills demanded.

In this paper an effort has been made to describe the present status of the chemical recovery system.

PRESENT STATUS :

The APP Mills is presently running the following equipments in the recovery section with an over all Recovery efficiency of 90 plus %.

In the Free Flow Falling Film (FFFF) Evaporator, the liquor film progresses downward on the outside of vertical plate type heating surface. The evaporator comprise a liquor distributor system, heating element,

vapour body (optional) and a separator system. The heat transfer coefficients of FFFF evaporators are relatively higher, and systems raising concentrations upto 62% solids are in operation. In the rising film type conventional evaporators, the concentrations rarely exceed 50-52% due to lower temperature differentials.

The evaporator system is provided with seven evaporator bodies. The first effect has three elements out of which two are in service while the third one is under cleaning at a time. The plant has a water evaporation capacity of 92 TPH when fed with 114 M³/hr of weak liquor at 15% concentration to produce 23 M³/hr of black liquor at 62% concentration or 31 M³/hr of concentrated black liquor at 48% solids. As both Recovery Boilers are equipped with direct contact evaporators, the product liquor is presently being extracted only at 48% concentration from the evaporators.

Presently two chemical Recovery Boilers are running. Chemical Recovery Boiler No. 1 (Fives Coil Babcock, France) is of 127 TPD of black liquor solids burning and is in operation since 1965. Chemical Recovery Boiler No. 2 (AVB make) is of 270 TPD black liquor solids handling capacity and is in operation since 1981. The basic design parameters of the recovery boilers are--

	Recovery Boiler No. 1	Recovery Boiler No. 2
Dry Black liquor Solids firing capacity	: 127 TPD	270 TPD
Superheater steam pressure	: 32 Kg/cm ²	33 Kg/cm ²
Temperature	: 340°C	420°C
Steam generation	: 14 T/hr	34 T/hr

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The causticising section consists of two parallel streets and can handle 40 M³/hr and 20 M³/hr respectively. The green liquor clarifier is common for both the streets.

Each street consists of, a slaker, 3 stage causticisers, white liquor Clarifier, Recausticiser, Primary and Secondary mud washers. 3rd Stage mud washing is conducted in a typical two tray mud washer common for both the streets followed by two mud filters.

Filtration of black Liquor :

Normally 40 mesh SS wire cloth is mounted on brown stock washers and certain amount of fine fibre escape along with black liquor. To avoid formation of lumps in the evaporation, the black liquor is being refiltered on 120 mesh side hill screens (stationary). This has improved the runnability of Evaporators.

Free Flow Falling Film Evaporator :

The modern and India's first installation of 4F Evaporator has given the higher steam economy i.e., 6.0 with 7 effects. It can handle more difficult black liquor of different proportions of bamboo and hardwood to a concentration as high as 62% for direct firing. However, with the limitation on furnace economiser and the installation of direct contact evaporator presently the liquor is withdrawn at 48% solids concentration.

Free flow falling film Evaporator reduces stream pollution, consumes less power and condensate segregation i.e., 96% of the condensate could be odour free. Also due to its basic design feature of plate elements with convex dimples it maintains fairly high and uniform heat transfer coefficient as the plates can be kept clean by intermittent condensate boiling.

Process Description :

The Rosenblad Falling Film Evaporator is a seven effect seven body system. All bodies are essentially the same except for size. Each vessel is equipped with heating elements, heating elements supports, a liquor distribution system, steam inlet and vent headers, and a vapour entrainment separator.

The Evaporator heating elements consist of 915 mm × 7315 mm stainless steel dimpled plates. The "live" steam to be condensed flows upwards inside the plates while the liquor to be concentrated is distributed on the outside of the elements in a falling film configuration. As steam condenses inside the elements, heat is transferred through the heating surface to the Falling Liquor Film because the pressure on the liquor on vapour side of the elements is maintained below that on the "live" steam side, the liquor film boils. The vapour evolved from the boiling liquor film escapes horizontally from the heating surface and then flows via the conduit formed by the vapour body. The generated vapour passes through vertical vane in impingement type mist entrainment separators and becomes the 'live' steam for the succeeding effect. Prior to the leaving the effect, vapour passes through the mist eliminators. These collect entrained black liquor on curved vertical vanes arranged in a rectangular box frame in staggered banks.

Liquor Flow :

Feed liquor flow is controlled by an FRC. The hot feed is flashed in an internal flash tank (IFT) in the fifth effect. The vapour from this IFT flashes directly into the vapour body of the fifth effect and becomes 'live' steam for the sixth effect.

Liquor from the IFT in fifth effect flown by gravity and level control to a second IFT in sixth effect. The liquor in this second IFT flashes directly into the vapour body of the sixth effect. The resulting vapour becomes 'live' steam for the 7th effect. The remaining feed from the second IFT is then gravity fed directly into the seventh effect with level control.

Evaporator effects 2nd through 7th are each equipped with a transfer pump. These pumps are used for transferring liquor on over flow type level control from the evaporator pump to the distribution tray of the preceding effect.

The first effect (concentrator) is divided on the liquor side into three sections. One section is 'washed' with liquor from the second effect at 32% solids. The remaining two sections perform all of the evaporation.

Transfer of liquor from section to section in the first effect is by gravity flow from circulation pump suction of one section to circulation pump suction of the succeeding section.

Heavy liquor is removed from the section performing the final concentration through a level control valve and flashed in the product liquor flash tank (PLFT) to its end concentration of 62% dissolved solids. Product liquor is pumped from the PLFT on level control to the product liquor storage tank.

Steam and vapour flow :

Fresh steam enters the steam chest of two of the three heating sections making up the first effect. Fresh steam pressure to first effect is controlled by pressure control (PRC) valve in main steam line. Each section of the first effect is vented to the atmosphere through vent valves.

Vapour boiled off from liquor in the first effect becomes the 'live' steam for the second effect. This process repeats itself down through the seventh effect. Vapour generated in the seventh effect is condensed in the surface condenser.

The sixth effect, seventh effect and the surface condenser incorporate split heating surfaces. The first section is designed to condense 90% of the incoming vapour, while the second section condenses the remaining 10% steam. Steam flowing vertically upwards through the first section elements is in the continuous counter current contact with steam condensate flowing by gravity downward in the elements. Consequently the quantity of volatile contaminants in the steam fraction is continuously enriched by volatiles distilled from the condensate (liquid phase) into the steam (vapour phase).

The 10% steam vented from the top of the main condensing section to the second pass section contains 69-70% of the BOD and malodorous compounds.

As a result the condensate in the main (first) section is effectively steam stripped and no further clean up is required.

Since approximately 80% of total BOD and malodorous compounds comes off with the first 30% of the total evaporation (which is generated in the sixth and seventh effects) only the sixth and seventh effects and surface condenser require split heating surfaces.

Vapour generated in the seventh effect is condensed in the surface condenser. The surface condenser consists of forty five (45) 915 mm 7315 mm, 90 mm dimpled plate heating elements. Included in the heating surface distribution are the elements which make up the vacuum system inter-condenser and gas cooler. Vapour leaving the seventh effect condenses inside the elements giving up its latent heat to cooling water flowing on the outside of the elements in a falling film. The cooling water thus served as the ultimate heat sink for the system.

Normally, the seventh effect pressure will operate at about 99mm Hg absolute. The pressure in the seventh effect is dependent upon the ability of condense steam (or transfer heat) in the surface condenser. Heat transfer in the surface condenser is controlled by cooling water flow rate and temperature.

Non Condensable Gas Venting ;

The non condensable system is used to remove gases evolved during the evaporation process. The system is equipped with large 'hogging jet' or start up ejector which will normally be used during start up only. A two stage jet exhaustor is used during normal operations. The jet exhaustors contain no moving parts. Dry saturated 10 kg/cm² steam enters the ejector head and passes through a nozzle inside the head. This creates a very high velocity steam jet which results in very low pressure (a high vacuum) at and just down stream of the nozzle. It is in this area that the non-condensable gas vent lines are connected. The non condensable gas steam flows into and mixes with the ejector steam in the diffuser section or 'tail' of the ejector.

The 'hogging' jet is so named because it is much larger than the two stage jet exhaustor. It is capable of moving much more condensable gas in a much shorter period than the two stage jets. When this start up ejector is running along with the two stage jets, it

'hogs' or removes the greater portion of the non condensable gas.

The jet exhausters establish the high vacuum in the vapour bodies prior to start up of the evaporator system by removing air (The principal non condensable gas at start up) it should take approximately 30 minutes to bring the evaporator to about 560 mm Hg vacuum at which time the 'hogging' jet will be shut down. The two stage jets will be able to handle the non condensable gas flow after start up.

During normal operation, it might be possible to valve off the smaller nozzle thereby saving approximately 122 Kg/hr of 3.5 kg./mm² steam.

Condensate Flow

Live steam condensate from the three heating sections making up the first effect flows through manual valves into the live steam condensate tank. The condensate tank is vented to the steam inlet piping. From the live steam condensate tank, the live steam condensate is returned to boiler by level control.

Condensate from the second effect is removed on level control and flashed into the condensate sump of the 3rd effect. This process is repeated for the 3rd effect also. From 4th effect onwards the condensate flows to the next effect without LIC's but high level is avoided by the Seal Pots provided in the circuit. As discussed earlier, the sixth and seventh effects contain main condensing sections and sections dedicated to condensing vapour from the internal FLFT Tanks. The main section contains condensates from the effects 2nd and 3rd and condensate produced from vapour from the 4th and 5th effects. These condensates are clean, low in BOD and are suitable for re use. The clean condensate flows from the seventh effect into the clean condensate tank (CCT). Condensate is pumped from the CCT on level control to the Pulp Mill, Causticiser, or drain. Prior to leaving the system, the conductivity of the steam is measured. Depending upon the conductivity, the steam is sent to one of these three routes, Route selection is made using manual change over valves. The temperature of the clean condensate is approximately 56°C. The CCT is

vented to the vapour duct between the 6th and 7 h effect.

Condensate from the second pass sections of the 6th effect, 7th effect and surface condenser combine in the foul condensate level tank. From there they are pumped from the system on level control. These can be pumped to pulp mill or to drain by changing over the valves and depending upon the requirement.

Comparison

The free flow falling film evaporator has the following advantages than the other type of evaporator run earlier in APPM.

Short Tube vertical Evaporator	4F Evaporator
1. 5 Bodies, 4 effects	7 Bodies, 7 effects.
2. One body can be always bypassed for cleaning.	No by passing arrangement.
3. Steam Economy 2.8 to 3.0	Steam Economy-6
4. Considerable loss during water boil out.	No chemical loss
5. Steam pressure has to be raised in 1st body as per the tubes fouling.	Uniform 1st Body steam pressure.
6. Maintenance very high	Minimum maintenance
7. Foul condensate - not separated.	Condensate split into a) Clean condensate b) Foul condensate
8. Down time was more due to body change overs at least twice in a month in each stream.	No such down time.
9. Man power requirement is more due to scale removal in the bodies.	Not needed.

4F EVAPORATOR DESIGN DATA

Water evaporator capacity	...	92 T/hr.
Steam consumption	...	15.43 T/hr.
WBL feed	...	120 T of WBL at 15% total solids
Clean condensate	...	89 m ³ /hr.
Foul condensate	...	3 m ³ /hr.
Live steam condensate	...	15 T/hr.
Product liquor as 62% T.S.	...	23.2 m ³ /hr.
Water consumption at surface condenser	...	840 m ³ /hr.

S. No.	Bodies	1st	2nd	3rd	4th	5th	6th	7th	Surface Condenser
1.	Area Sq.mm	535m ² each	892m ²	892m ²	892m ²	892m ²	892m ²	892m ²	803m ²
2.	Spacing of elements mm	35mm	35mm	35mm	35mm	35mm	43mm	56mm	44mm
3.	Material of elements	SS304L	SS304L	SS304L	SS304L	SS304L	SS304L	SS304L	SS304L
4.	Number of Elements	3x30	50	50	50	50	50	50	44+1
5.	Size of Elements	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm	915mm x 7315mm
6.	Material gauge	16	18	18	18	18	18	18	16
7.	Circulation m ³ /hr rate	163.6	81.6	81.6	81.6	81.6	81.6	81.6	
8.	Heat transfer coefficient W/m ² °C	443/880	1488	1437	1363	1283	1596	1448	1476

4 FOPERATING DATA

Weak Black Liquor Flow	:	106m ³ /hr (as per flow meter)
Weak Black Liquor TW°	:	15
Weak Black Liquor Temp.	:	78°C
Product liquor flow (calculated)	:	32.5 m ³ /hr
Product liquor TW°	:	49
Product liquor Temp.	:	93°C
Steam flow	:	12.2 TPH (as per flow meter)
Live steam condensate Temp.	:	108°C
Clean condensate Temp.	:	60°C
Foul condensate Temp.	:	58°C
Water flow at surface condenser	:	420M ³ /hr. (as per flow chart)
Surface condenser cooling water Inlet/Outlet Temp.	:	30°C/48°C

S. No.	Particulars	1st	2nd	3rd	4th	5th	6th	7th	Surface Condenser
1.	Steam chest Pressure/Vacuum	0.4 Kg/cm ²	0	340 mmHg	450 mmHg	510 mmHg	560 mmHg	620 mmHg	680 mmHg
2.	Liquor Temp. °C Avg.	103	91	86	80	72	70	60	—
3.	Liquor TW°	A/B/C 30/47/42	40	33	30	28	27	24	—
4.	Vapour space Pressure/vacuum	0	325 mmHg	425 mmHg	510 mmHg	550 mmHg	600 mmHg	670 mmHg	—

The following schedules/practices are followed for better runnability of the unit.

- a) Periodical weak black liquor tanks cleaning once in 2 months to avoid fibre and unwanted material accumulation.
- b) Maintain a minimum level in weak black liquor tanks, so that sludge will not find entry into the evaporation unit.
- c) Minimum 3 hrs. condensate boiling daily.
- d) Dilute caustic circulation in 1, 2, 3, 4 bodies at 70 gpl and temperature 80-90 °C once in a month for a duration of 6 to 8 hrs.
- e) Periodical check up of liquor distributor plates for 1 to 2 bodies specifically once in a month.

The liquor strainer of 12 ϕ mm hole size was installed in No. 2 & 3 bodies circulation pumps delivery line to avoid any scale lumps getting recirculated.

Liquor distribution trays are aligned properly in such a way that the liquor falls exactly on the top of the elements and forms an effective film.

In the initial starting period (first 6 months) elements of 1, 2, 3, 4 bodies were cleaned with high pressure water jet to remove the scales but no cleaning of such nature has become necessary after taking aforementioned precautions and practising the Condensate boiling regularly.

Recovery Boiler :

Modification of CBL lines to directly fire the liquor while cyclone evaporators under water boiling. It is made possible that one of the CBL tanks will be made empty and filled with firing liquor 60-62% earlier two days period from the cyclone outlet itself at a rate of 2-3 M³/hr. The stored liquor from CBL tank taken through BL heater for firing, on cyclone water boiling day for about 8 hrs.

Firing range liquor return line provided to give smooth change over with out nozzle jamming.

Spray gun chikson joint supplied has been modified, so that leakages at joints are almost arrested.

Cyclone evaporator, which plays a major part in liquor circuit has been incorporated with following better practices and modification for smooth operation.

- a) Umbrella changed to SS material and wall wetting pressure is being maintained 1.2 kg/cm² to cater the inlet circulation and control of outlet temperature.
- b) Injection liquor introduced directly in to the sump to avoid spray fluctuation due to level control valve operation.
- c) Every 20 days water boiling.
- d) Cyclone Evaporator circulation pumps delivery line provided with SARCO filters to avoid lumps, thus averting jamming circulation nozzles.
- e) WWL spray arranged through the injection nozzles to take care of out let temperature during circulation pumps failure.
- f) $\phi 12"$ openings with a dummy flange arranged to manual cleaning of inlet and out let duct accumulations periodically in between water boiling schedules.

Ash mixing tank and salt cake mixing tank also given water boiling along with cyclone evaporator to avoid plugging of strainers.

Some of the practices like inter changing of pumps running and cleaning schedules are followed every day to keep the units in effective working condition. They are followed as under in a week :

- I. : 1. CE Circulation pump changing
2. CE inlet throat cleaning
3. JMW pumps water filter cleaning in A Shift.
- II. : 1. Oil burners cleaning
2. Sarco filters cleaning
3. JMW Pumps changing
4. Service oil pumps delivery filters cleaning

- III. : 1. Hopper checking
 - 2. CBL Pump changing
 - 3. Service oil pump suction filter cleaning
- IV. : 1. CE Circulation pump changing
 - 2. CE inlet throat cleaning
 - 3. Spare oil burners changing and overhauling of running burner
- V. : 1. JMW pumps changing
 - 2. Samples collection & sending to C. Lab.
 - 3. JMW pumps water filter cleaning A shift.
- VI. : 1. CBL Pumps changing
 - 2. Oil burners checking
 - 3. Spare oil burners changing and overhauling the running burners.
- VII. : 1. Hopper checking

Modification of oil burner nozzle, in such a way to divert the flame to the hearth stuff and complete the melting down. This has saved oil consumption and down time for hearth cleaning during stoppage and start up. Earlier hearth melting down was carried out by burner in PAP (Primary Air Port), but after lip modification, the melting down of operation could be from Secondary Air port.

Air heater elements changed with SS make and the fins are cleaned with water in shuts.

To avoid carry over, stuff falling on spray gun and to increase steam generation, the following steps were taken :

- a) Higher size nozzle of 22 mm introduced and stabilized. Liquor fired at low firing pressure i. e., from 3 kg./cm². to 2.5 kg./cm².
- b) Liquor firing temp. reduced to 117°-118° from 120° C and above.

The above practices resulted in generation of steam upto 30 tons per ton of solids. Further, following measures have helped to maintain better operating conditions.

More attention on controls like cyclone evaporator level, mixing tank level and B. L. secondary heater outlet temperature to keep the furnace under steady operation.

ESP auxiliaries like raddler conveyor etc. were covered with G. I. sheets to take care of climate changes and arranged interlocks to avoid breakdown,

Dissolver agitation with two numbers of agitators avoided use of strainer. But every 3 to 4 months transfer pumps suction and delivery are cleaned from deposits to avoid G. L. pumping problems during boiler running.

In Demister, water spray introduced in place of chemical spray on the pad provided. The original pad is removed and dissolver vent bottom bend being frequently cleaned to avoid surging of vapours to facilitate cleaning of spouts and its condensate spurting in the spouts.

Hood washing pipes modification avoided spillage of WWL on furnace front wall header which caused leakage of header.

Periodical checking of soot blow steam pressure of the critical zone soot blowers after the puppet valve and adjusting to 25-26 kg/cm² had greatly helped in reducing the jamming.

Causticising

To achieve green liquor temp above 95°C for better slaking, "on line" green liquor heaters were arranged, which eliminated the poor slaking.

Pulp Mill

Washing losses at pulp mill have been brought down to a moderate level of 22 kgs of Na₂SO₄ by bringing down the concentration of WBL by improving washing. It has become possible only after installation of 4F Evaporator unit having adequate capacity.

Digester preheater two pass floating head type, which frequently giving gasket failures, giving scope for the loss of chemical has been changed to three pass fixed head type preheaters.

Advantages :

The major advantages derived out of the practices/modifications have been as under :

1. With the installation of 4F Evaporators, steam consumption was brought down from 21 TPH to 12 TPH resulting in a saving of 9 TPH of steam.
2. Steam generation of New Recovery Boiler improved from 2.8 T/tonne of solids to 3.0 T/tonne of solids with the usage of higher size nozzle, with low firing temperature and with low firing liquor pressure.
3. Elimination of auxiliary fuel usage while cyclone evaporator and mixing tanks are under water

boiling, resulted in a saving of LSHS oil from 13.5 kgs/T of pulp to 9.5 kgs/T of pulp (4 kgs of oil/T of pulp-Net saving).

- 4 Increase of Green liquor temperature from 90°C to 95°C by installing on-line steam heater, reduced CaO content in grits and stones and Na₂O losses from 2% to 1%.
5. By bringing down the washing losses at brown stock washers and by the above mentioned steps, the over all recovery efficiency had improved by 1%.

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