Experiences With Different Secondary Recovery Systems

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The various secondary chemical recovery systems installed with recovery furnaces and their operational problems are discussed. An economic study reveals that it is not economical to instal an electrostatic precipitator unless efficiency of an electrostatic precipitator is more by 3.0% than the counterpart venturi scrubber evaporator. For ease of operation, flexibility to handle higher loads and pollution abatement the electrostatic precipitator can be preferred if a 95% efficiency is guaranteed.

Introduction

In any pulp mill adopting kraft process, or for that matter any chemical pulping process, the recovery of chemicals generally holds the economic balance. It is estimated that every one percent chemical recovery in kraft mill reduces the cost of production by about five rupees per tonne of pulp. In the overall recovery of chemicals the furnace carry over losses itself are over 15%. Of these about 90% should be recovered at the secondary recovery system. Thus, the contribution of secondary chemical recovery alone in cost reduction is about seventy rupees per tonne of pulp. This shows the potentiality of the secondary recovery system in cost reduction. Further, with the adventof environmental conciousness among both public and Governmental authorities and rising prices of make-up chemicals, it has become all the more important to have an efficient secondary chemical recovery system.

A typical estimate of loss of chemicals at various stages in a chemical recovery plant is given in table 1.

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Table 1.

Stage	Range of losses of chemicals as Sodium Sulphate lbs/tonne of pulp.	% loss
1) Brown stock washer	30—45	2.0—3.2
2) Evaporator condensate	1—2	0.1—0.2
3) Losses with soap	25—35	1.8—2.4
4) Furnace stack	30—45	2.0—3.2
5) Dissolver stack	15—20	1.0 - 1.4
6) Miscellaneous	15—25	1.0—1.8
Total	116—170	7.9—12.2

Range of percent recovery that can be anticipated is 92–87.8.

For efficient recovery these losses should be maintained at the above levels. Successful attempts were made in case of evaporators by installing demister pads to bring down losses to a low level of 0.1 from 1.0 lbs. sodium sulphate per tonne of pulp. Similarly installation of separators have helped in reducing the dissolver vent losses to the level of 0.5 lbs. sodium sulphate per tonne of pulp thereby increasing chemicals recovery to the previously unbelievable figure of 92%.

In all the secondary recovery systems the attempt is to arrest the dust carry over from the flue gases. Aggregates and condensibles are removed at hopper near boiler and economiser passes. The rest of the flue gases contain chemicals about 250 lbs. sodium sulphate per tonne of pulp. The particle size of the dust ranges from 0.2 to 0.3 micron. It is estimated that about five million particles of this size are accomodated in one cubic centimeter of dust. This gives an inlet dust loading of 10 gm/cu. m. The function of the secondary recovery system is to recover this dust economically.

The available secondary recovery systems are :

1) Electrostatic precipitators of different kinds each claiming superiority over the other.
2) Venturi scrubber and separator.
3) Venturi scrubber evaporator.
4) Electrostatic precipitator, washer and scrubber combination.

These systems are briefly described below :

Electrostatic Precipitator

Perhaps this is the oldest secondary recovery system. As recorded in the history it is Fedric G. Cottrell who developed this process in the year 1906. But it was in the year 1940 that it was accepted and found wide commercial application in paper industry. In India the first electrostatic precipitator came into operation in the year 1955. Economic level of recovery efficiency at precipitator is 95%. Modern specifications prescribe 98-99% efficiency for reducing the environmental pollution. Thus, it became the most efficient of secondary recovery systems available. Most important in this system is the flue gas distribution along the width and breadth of the precipitator chamber. This avoids mechanical entrainment of the dust. The velocity should be about 2 m/sec. where the effective migration velocity of charged particle is maximum. Similarly the distance between the oppositely charged electrodes should be maintained uniform by giving allowance for thermal expansion. This will enable the unit to take up peak voltage. Higher moisture content in flue gas improves the precipitator performance. Combustible material should be less than 0.5% for efficient running. This avoids flash overs.

In India the precipitators generally operate below 150°C. Lower temperatures are to be avoided so that the dew point of flue gases, which gives rise to serious corrosion problems, is not reached. Many a precipitator have deteriorated due to this factor.

The disadvantage of this unit is higher heat losses through the stack of gases resulting in lower thermal efficiency. Further, to get optimum performance from the electrostatic precipitator, the furnace conditions should remain stable and oil should scarcely be used. The auxiliary fuel burning equipment should be efficient enough to ensure complete burning of the oil. It was our experience that when unburnt carbon particles accompany the flue gases there were explosions in the precipitators. This type of explosion goes unrecorded in the literature. When induced draft fan is installed after the electrostatic precipitator, it helps in operating the precipitator at slightly lower temperature and ensures clean gas to I. D. fan.

It is experienced that the precipitator could be operated safely at lower temperature of 125-130°C, when cyclone evaporator is installed ahead of the electrostatic precipitator.

Hot precipitators operate at higher temperature around 300°C. These can be installed before an economiser. The clean gases to the economiser help in better heat transfer thus reducing the heat transfer area requirement and consequent installation cost. Further, the expensive cleaning system required usually for an economiser can be avoided. The efficiency of the unit is reported to be less by 2% due to the high temperature operation.

For smooth operation of recovery unit the electrostatic precipitator should incorporate :

1) bypass ducting to attend short breakdowns without interrupting furnace operation,
2) the ducting and chambers should be well insulated,
3) the procelain high tension insulators should be provided with positive draft of hot air to ensure that no dust and moisture deposit.
4) there should be enough provision for expansion of the plates to avoid bending and consequent flashing, and
5) the bottom scrapper should preferably be of continuous type.

The efficiency of electrostatic precipitator can be checked by stack gas analysis and by weighing the recovered dust.

The power requirement is about 10 KW per tonne of pulp including auxiliaries. Similarly, power requirement for I. D. fan is only 40 KW/tonne of pulp.

The high capital investment with around 20% foreign exchange requirement and large floor space and building required make this unit slightly an unattractive proposition. However, from a careful economic study, which is given in the Annexure, it can be seen that it is more economical in the long run.

Venturi Scrubber Separator

During the year 1947 venturi scrubber was developed. It efficiently removes the entrapped dust particles from the flue gases by scrubbing with water. The flue gases are passed through a venturi to develop a velocity of 75 mtr/sec. Water is sprayed at the venturi throat. The high velocity flue gases carry the water affecting thorough scrubbing. The chemical laden water is separated centrifugally in a following separator. With a differential pressure of 15-17 inches of water, an efficiency of 85–90% can be accomplished in dust recovery. Water is circulated back at the venturi at the rate of 1–2 lit/min/30m³ of flue gas. The water circulation, addition and extraction are balanced to get 30% solids concentration and this liquor is recycled either at cyclone evaporator or mixing tank. The useful heat energy obtained from cooling the gases from a temperature of 300°F to 165°F does not serve any purpose. Furthermore, thermal energy has to be spent to evaporate the water accompanying the recovered solids. Attempts were made successfully to use weak black liquor and weak white liquor in place of water to conserve energy. Weak white liquor helps in keeping the required residual active alkali concentration and pH with direct contact evaporators, to retard precipitation of silica.

The advantages of this system are

1) low space requirement
2) low capital investment, and
3) less moving parts thereby needing low operational and maintenance costs.

The various disadvantages are

1) high power consumption,
2) frequent clogging of spray nozzles,
3) overall low thermal recovery efficiency, and
4) serious corrosion problems.

Venturi Scrubber Evaporator

It is the latest development in secondary recovery systems. The separator in the venturi scrubber described earlier is integrated with the cyclone evaporator thus reducing the additional pressure drop and saving substantial capital investment. Water is replaced by semiconcentrated black liquor for flue gas scrubbing. To improve upon the atomisation for efficient scrubbing, steam is used. This reduced the differential required to be maintained for the same performance.

In the latest development dual manifold, in which at the secondary stage semiconcentrated black liquor is sprayed for further improvement, is incorporated. With a differential pressure of 30 inches an efficiency of 90 percent is claimed. The first commercial installation has come up in the year 1953 in USA and 1965 in India. This has become quite popular due to various advantages it offers over the earlier scrubbing systems. The exit gas temperature is brought down to a level of around 175°F– thereby increasing the thermal efficiency. This reduces the steam consumption by about 1.5 tonnes. Thus, practically the output concentration at the multiple effect eveporator could be reduced from 50 to 45% solids for the same steam generation from the boiler. This not only saves steam but also increases the operational efficiency of multiple effect evaporator. This lower solids content in the semiconcentrated black liquor reduces the black liquor viscosity. With this lower viscosity liquor it is possible to get the same recovery efficiency at lower differentials across the venturi throat. This reduces power requirement at I. D. fan. However, at 50% concentration of black liquor 1.5 t steam can be generated additionally. This will evaporate at least 5 tonnes of water at multiple effect evaporators in addition to generating 0.25 MW of power. Thus, this unit offers an increased overall thermal efficiency. It is also necessary to deduct the steam requirement for liquor atomisation which is about 700 lbs/hr/100 tonne of pulp per day. It is claimed that the thermal effiiciency of this unit is 3.6%higher than the electrostatic precipitator unit. It was experienced that due to high and varying moisture content estimation of losses from stack is dfficult. Further, the widely fluctuating nature of black liquor when mixed hardwoods are used, give rise to highly viscous liquor. As the draft employed is very low for such units, the black liquor temperature can be increased for reducing the viscosity of liquor. In order to keep the system highly alkaline to arrest silica precipitation, constant dosing of weak or strong white liquor had to be carried out. The mechanical filters provided on the strong black liquor circulation lines get damaged resulting in jamming of spray nozzles. With all this, on an average, it was estimated that the efficiency could not be increased beyond 90%.

The I. D. fan power requirement is nearly three times as compared to a similar unit employing precipitator. The maintenance cost on I. D. fan is also high. There is heavy dust agglomeration inside both the ducting and I. D. fan casing resulting in increased pressure drop and carry over of chemicals. The I. D. fan had to be arranged with an additional cleaning system, for keeping the blades clean and arresting vibrations. It was our experience that this unit is very sensitive to boiler overloading. As such, it was not possible to overload it more than 25% whereas electrostatic precipitator could be overloaded upto 50%. The corrosion, particularly at the venturi and outlet gas ducting, is heavy needing replacement within 2-3 years. Again, when liquors of higher concentration are fired, the circulation pumps at cyclone evaporator fail throwing complete system out of gear. It was, therefore, necessary to give a wash to this unit once a week. Thus, as described above the average efficiency realised does not exceed 85% The gases from the cyclone evaporator serubber pollute the atmosphere as is being experienced by two mills having such an installation.

Electrostatic Precipitator, Washer and Scrubber Combination

The general complaint about electrostatic precipitator installation with a recovery boiler is its low thermal efficiency. Attempts were being made to remove this complaint also. The low pressure drop washer scrubber is an outcome of these attempts. The vertical scrubbers employ washing of the outlet flue gases from the electrostatic precipitator in four to five stage columns. The water employed in first stages recovers the useful heat and is used in the process. The other stages help in recovery, the last traces of dust agglomerates from thc flue gases. It is claimed that with 7 inches of water differential, the efficiency of the combined system increases by 1% in addition to recovering heat. This type of units are still to be commercialised in India.

Economics of Different Systems

With these pros and cons, it was found necessary to make an economic evaluation of the existing systems. In view of the popularity, the electrostatic precipitator and venturi scrubber evaporator are considered (see annexure).

Conclusion

Unless there is an assured 3% additional efficiency over the venturi scrubber evaporator, it is not economical to instal an electrostatic precipitator. But in view of the flexibility of operation coupled with reduced environmental pollution the electrostatic precipitator offers, it may be advantageous to go for this unit in perference to venturi scrubber evaporator. New after scrubbers employ low pressure drop at the same time recovering both heat and chemicals at a nominal investment, thus making the electrostatic precipitator washer scrubber combination an economic reality.

Annexure

Basic :	100	Tons of unbleached pulp per day.		
Data :	1)	Flue gas chemical loading per ton of pulp.	Lbs.	250
	2)	Solids per ton of pulp	Tons	1.5
	3)	Flue gas per ton of solids	Tons	6
	4)	Basic temperature	°C	75
	5)	Cost of salt cake per ton	Rs.	700
	6)	Cost of Steam per ton	Rs.	20
	7)	Cost of power per unit	Paise	10

Equipment Data :

	Units	Electrostatic precipitator	Venturi scrubber evaporator
Average efficiency	%	90	85
Installation cost	Lakhs of Rs.	11	3
Out let flue gas temperature	°C	140	75
Power consumptiou	KWH/day	3000	12000
Calculations :			
Total salt cake recovered	t	10	9.45
Value of salt cake recovered	Rs.	7000	6615
Heat lost through stack	m Cals	17500	nil
Equivalent steam cost	Rs.	700	nil
Cost of power	Rs.	300	1200
Cost of steam for atomising	Rs	nil	158
Depreciation & interest on investment	Rs./day	628	172
Net saving	Rs./dav	5372	5085

This shows that installing an electrostatic precipitator offers a higher saving of Rs 287/–per day. The saving gets balanced only when the difference in efficiency is about 3.3%. When the efficiency of venturi scrubber evaporator has come to a standstill at 90% the electrostatic precipitator manufacturers are quoting 98% efficiency to suit clean environmental demands of the modern day.