Need For Efficient Kraft Chemical Recovery Boilers To Generate Green Power

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ABSTRACT

Initially, the kraft chemical recovery boiler was an essential part of the pulp production process as it recovers and regenerates cooking liquors. With the rising energy costs and the security of supplying the future are causing the paper industry to re-think their overall energy strategy. In the past, the value of surplus energy was marginal compared to the price of pulp, but today paper mills are actively seeking process solutions that can help them generate a surplus of "green energy" that can substitute energy from grid power and purchased fossil fuels, which saves revenue. Critical to this energy self-sufficiency is a recovery plant capable of maximising the production of thermal energy while also efficiently recovering chemicals for the fiber line. The need of the hour is to have a recovery boiler that not only recovers chemicals and generates power efficiently, but also does this in a safe, reliable, and environmentally sound process. At ITC PSPD, Unit: Bhadrachalam ,two old recovery boilers are replaced with two state - of - the - art chemical recovery boilers which also augment green energy.

Introduction

The invention of the recovery boiler by Mr. G. H. Tomlinson in the early 1930s was a milestone in the advancement of the kraft process(1).Recovery of chemical and energy from black liquor is both an economic necessity and an environmental compulsion. The handling of black liquor is today guided by these parameters. From only recovery of energy(like an aerobic process) to only recovery of chemical(like in Roaster smelter) to day's trend is for more efficient recovery of chemicals and energy in more cost effective and esuriently manner. These drivers have looked at conventional recovery systems for improved performance and newer/novel recovery systems.

The recovery boiler process has several unit processes:

- Combustion of organic material in black liquor to generate steam.
- Reduction of inorganic sulphur compounds to sodium sulfide, which exits at the bottom as smelt .
- Production of molten inorganic flow of mainly sodium carbonate and sodium sulfide, which is later recycled to the digester.
- Recovery of inorganic dust from flue gas to save chemicals.
- Production of sodium fume to capture combustion residue of released sulphur compounds .

The developments in conventional chemical recovery system aim at improving black liquor quality, evaporation, combustion, causticisation, lime re burning, better environmental care through NCG handling, water system closer. Today's modern pulping and recovery systems are self sufficient on thermal power and further improvising their operations to recover untapped green power in their system from black liquor.

What is Green Power?

Black liquor is a liquid by-product of chemical pulping. It is burned to generate renewable heat , power and recycle chemicals. Thermal energy from kraft black liquor is regarded as CO_2 neutral. The capability to produce surplus energy, which can be used for other purposes as green energy, is also enticing. The black liquor contains more than half of the energy content of the wood fed into the digester of a kraft pulp mill (2). While the puling process is complex , the most salient takeaway is that black liquor is a renewable, carbon neutral fuel and it is also being considered as " Second Generation Fuel ". In short, the more black liquor that we can process and burn with much more efficiency, the less fossil fuel we need to support the Paper mill. The goal is to continue to find new ways to reduce our reliance on fossil fuels. Independence from fossil fuels not only lowers greenhouse gas emissions but helps to isolate the mill from fluctuations in energy prices and making the paper industry a more profitable and sustainable.

Steps Taken In Development Of Chemical Recovery Boilers

The chemical recovery boiler is an essential part of the pulp production process as it recovers and regenerates cooking liquors. Right from its inception, improvements are being made over the past and it will continue further.

First Recovery Boilers

Mr. Tomlinson's work in this field in the year 1930, paved way for the production of first generation recovery boilers. It was the first recovery equipment where all processes occurred in a single vessel. The drying, combustion and subsequent reactions of black liquor all occur inside a cooled furnace. Secondly the combustion is aided by spraying the black liquor into small droplets. Controlling process by directing spray proved easy. The first recovery boilers had horizontal evaporator surfaces, followed by super heaters and more evaporation surfaces. Some features of the original recovery boiler have remained unchanged to this day. The use of Kraft recovery boilers spread fast as functioning chemical recovery gave Kraft pulping an economic edge over sulfite pulping(3).The first recovery boilers had sever problems with fouling.

Improvements Made In Air Flow System

To achieve smooth operation and low emissions, the recovery boilers` air system needs to be properly designed. Air flow system developments are continuous and have been continuing and will continue as long as recovery boilers exists. Currently the new air flow systems have achieved low NOx emissions and are still working on lowering fouling. Table 1.shows the generation wise development of air flow systems in chemical recovery boilers. The first generation air flow system was developed in the 1940s and 1950s consisted of a two level arrangement; primary air for maintaining the reduction zone and secondary air below the liquor guns for final oxidation. The recovery boiler size was 100 – 300 TDS (tons of dry solids) per day. and black liquor concentration 45 – 55 %. Frequently to sustain combustion, auxiliary fuel needed to be fired. Primary air was 60 – 70 % of total air with secondary the rest. At all levels, the openings were small and design velocities were 40 45 m/s. Both air levels were operated at 150°C. Liquor gun or guns were of oscillating type. Main problem was high carryover, plugging and low reduction. Third generation air flow system was the three level air with stationary spraying . Use of about 50 % air as secondary gave hot and stable lower furnace (4). Higher black liquor solids 65 – 70 % started to be in use. Hotter lower furnace and improved reduction were reported. With three level air and higher dry solids the sulphur emissions could be kept in place.Fig.1.,shows the three level air flow system in the recovery boiler and the chemical reactions taking place at each stage. Fourth generation air flow systems are the multilevel air and the vertical air. As the feed of black liquor dry solids to the recovery boiler have increased, achieving low sulphur emissions is not anymore the target of the air system. Instead low NOx emissions and low carryover were the new targets. Presently this is type being done with big sized recovery boilers.

TABLE 1 .

DEVELOPMENT OF AIR FLOW SYSTEM

AIR FLOW SYSTEM	OBJECTIVES
1st. Generation	Stable burning of black liquor
2nd. Generation	+ High reduction
3rd. Generation	+ Decrease in Sulphur emissions
4th. Generation	+ Low NOx
5th. Generation	+ Decrease in fouling of boiler banks & super heaters

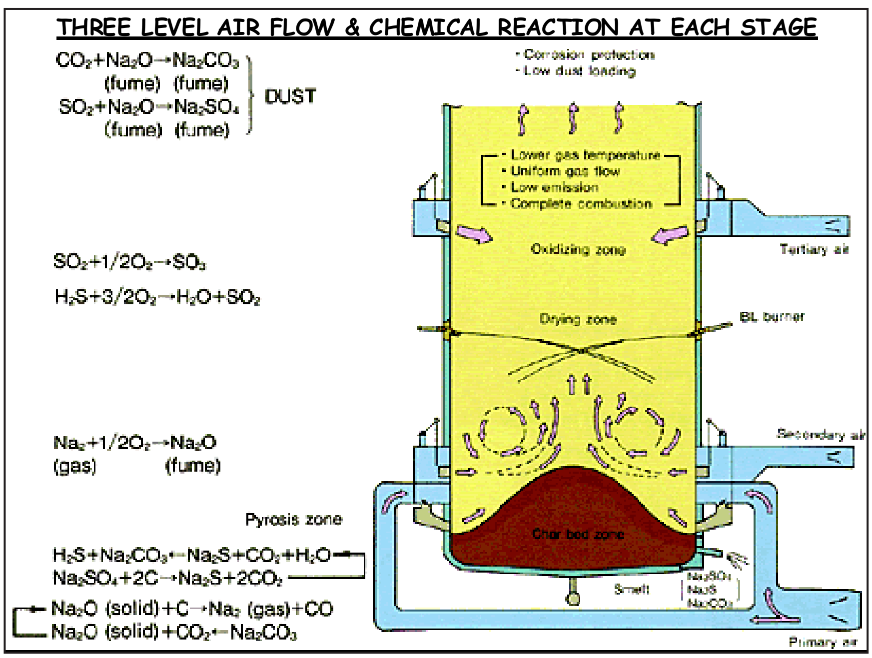

Fig. 1.

Dryness Of Black Ligour

Black liquor is a mixture of organics, inorganics and water. Typically the amount of water is expressed as mass ratio of dried black liquor to unit of black liquor before drying. This ratio is called the black liquor dry solids. If the black liquor dry solids is below 20 % or water content in black liquor is above 80 % the net heating value of black liquor is negative. This means that all heat from combustion of organics in black liquor is spent for evaporating the water it contains. The higher the dry solids, the less water the black liquor contains and the hotter the adiabatic combustion temperature. Black liquor dry solids have always been limited by the ability of available evaporation system (5).

High Temperature And Pressure Recovery Boiler

Development of recovery boiler of higher steam pressure and higher temperature was rapid at the beginning. By 1955, not even 20 years from birth of recovery boiler highest steam pressures were 10.0 MPa (62 – 64 Kg/cm²) and temperature around 480°C. The pressures and temperatures used then backed downward somewhat due to safety. Presently, pressure and temperatures are being increased in higher capacity boilers of above 1000 TDS/day by use of better alloy steels as materials of construction (6).

Modern Recovery Boilers

In the year 1980, an advanced version of recovery boiler was designed and is named as " RADIANT RECOVERY BOILER" . It is of a single drum design, with vertical steam generation bank and wide spaced super heaters. The construction of vertical steam generating bank is similar to the vertical economizer. Vertical boiler bank is easy to keep clean. The most marked change has been the adoption of single drum construction. This change has been partly affected by the more reliable water quality control. The advantages of a single drum boiler compared to a bi drum are the improved safety and

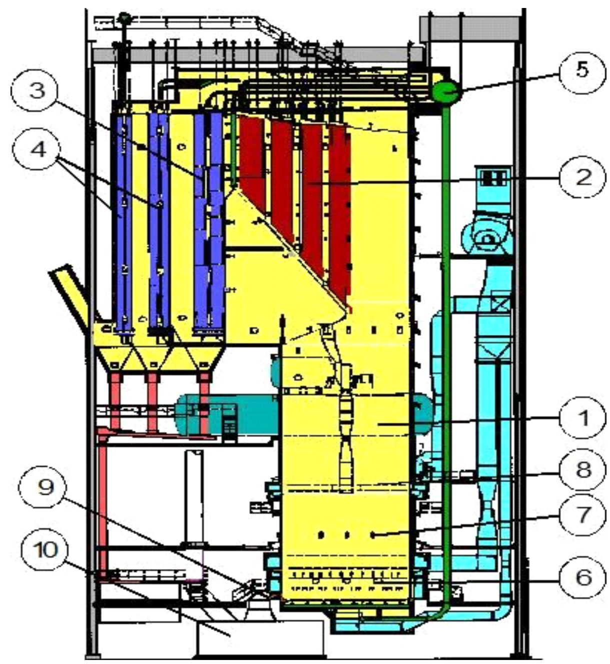

Fig- 2 A Modern Chemical Recovery Boiler

availability. The effect of increasing dry solids concentration has had a significant effect on the main operating variables. The steam flow increases with increasing black liquor dry solids content. Increasing closure of the pulp mill means that less heat per unit of black liquor dry solids will be available in the furnace. The flue gas heat loss will decrease as the flue gas flow diminishes. Increasing black liquor dry solids is especially beneficial since the recovery boiler capacity is often limited by the flue gas flow.Fig.2., shows the components in a modern recovery boiler. It consists of heat transfer surfaces made of steel tube; furnace-1, superheaters-2, boiler generating bank-3 and economizers-4. The steam drum-5 design is of single-drum type. The air and black liquor are introduced through primary and secondary air ports-6, liquor guns-7 and tertiary air ports-8. The combustion residue, smelt exits through smelt spouts-9 to the dissolving tank-10 (7).

Opting Of Modern Chemical Recovery Boilers By ITC-PSPD

With the increase in pulping capacity of the mill by installing "SUPERBATCH " pulping technology, there was a need to have advanced and modern chemical recovery system. To day, recovery boilers have gained the status of Power-Generating Boilers. With the cost of power becoming dearer, and the desirability to insulating the mill from dependency on power from State Electricity Board, two new " Radiant Type " Chemical Recovery Boilers of capacity 625 and 950 TDS/day are installed by replacing the old two bi drum chemical recovery boilers of lower capacity, to produce more power by generating steam at a higher pressure of 64 Kg/cm².to match with the steam requirement of turbogenerator.These boilers are of fifth generation and having three level air flow systems with a very efficient flue gas cleaning system. These boilers are of single drum with large economizers and without any direct contact evaporators. The total system is conservatively sized, providing allowance for additional solids input to the chemical recovery system from oxygen delignification operation of the fiber and sesqui sulphate from chlorine dioxide plant which are of lower calorific value.The steam generation,per tone of black liquor solids fired is high and the power consumption per tone of solids fired is also low. The recovery boilers are environment friendly with less emissions. The particulate matter emission is less than 80 mg / Nm³. The salient features of these recovery boilers are given in Table-2. Table-3., shows the operating parameters.

TABLE – 2 .

SALIENT FEATURES OF RECOVERY BOILERS OF ITC-PSPD

- **Single Drum " RADIENT TYPE ''**
- **Water walls of gas tight construction**
- **Screen less boilers**
- **Direct firing with no direct contact evaporators**
- **Stationary firing of black liquor**
- **Three level air flow system**
- **Easy smelt flow system**
- **Vacuum water flow system for spout cooling**
- **Dry ash collection systems at boiler banks and economisers**
- **Better burner management system for safe firing**

TABLE – 3.

OPERATING PARAMETERS OF RECOVERY BOILERS AT ITC-PSPD.

PARAMETERS	CFB-3	CFB-4
•Black liquor firing capacity (TDS/DAY)	625	950
•Black liquor Conc. At BLR %	75	75
•Black liquor calorific value (kcal/kg)	3000	3000
•Steam generation (T/Hr.)	90	137
•Steam pressure (kg/cm²)	64	64
•Steam temperature ºC	480	480
•Air temperature at primary ºC	160	160
•Smelt reduction efficiency	94 – 98	94 – 98
•Flue gas temp. at B / B inlet ºC	550	550
•Flue gas temp. at econonomiser in let ºC	415	415
•Flue gas temp. at ESP in let ºC	170	170
•Oxygen content in flue gas %	3	3

Future Of Recovery Boilers As Bio-Refineries

One school of thought suggests that in future, all recovery boilers will become black liquor gasifiers to generate green energy, where the black liquor will be burned along with oxygen, which helps in reducing the flue gases volume drastically. The molten smelt will be removed and used as existing. Since control firing is done with oxygen, very small quantity of carbon dioxide is formed, which is absorbed and the flue gases will become synthetic gases--mostly hydrogen and carbon monoxide as the primary product from black liquor gasification. Fig.-3., shows this new process of black liquor gasification. Fig.4., shows the likely hood of future Bio - refinery mill. The hydrogen gas generated in the process will be used directly in fuel cells or converted to more conventional

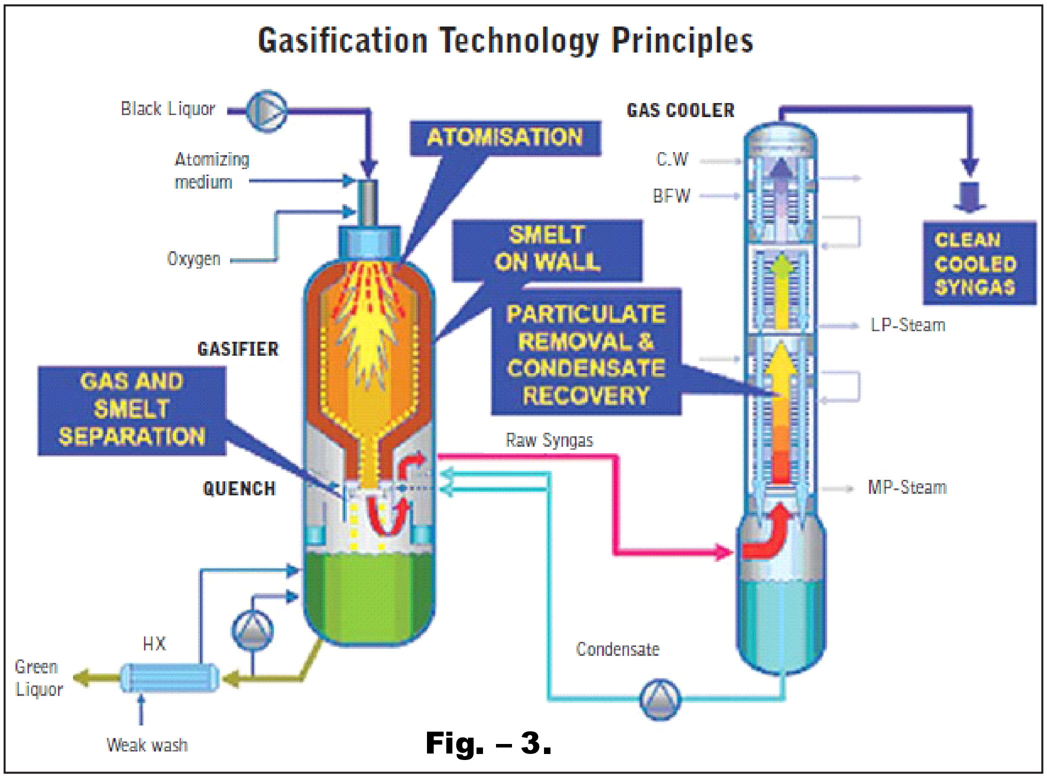

Fig. – 3.

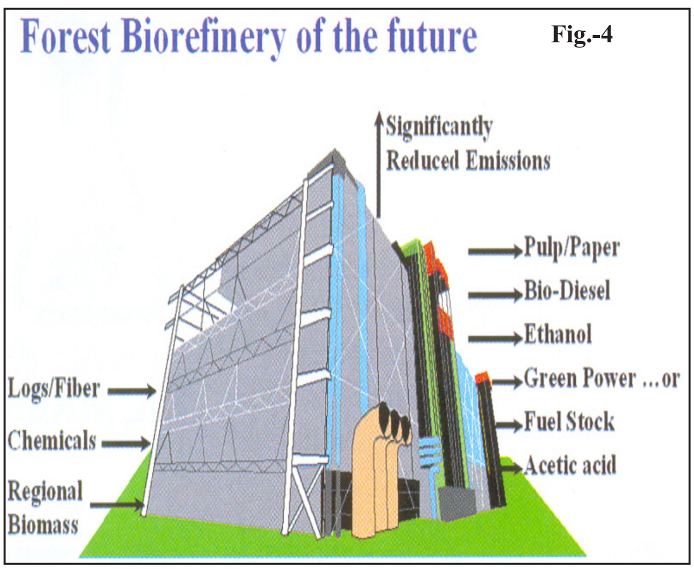

Fig.-4

motor fuels. Motor fuels could be methanol, di methyl ether, or diesel fuel--substitute fuel via the Fischer-Tropsch process. If future mills are large bio refineries, then the skill sets and process technology for making pulp and paper will be secondary. Engineering projects will be similar to those of petrochemical refineries.(8).

Conclusion

Chemical recovery is an essential part of kraft pulp production. In addition to recovering cooking chemicals, the chemical recovery process generates heat and power. The combination of high dry solids of the black liquor (through the evaporation process) and high steam values in the recovery boiler are the determining factors in turning the pulp mill into obtaining a net energy surplus from the pulp mill. A recovery boiler capable of maximizing the production of green energy and at the same time efficiently recovering the chemicals is need of the hour.

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