

Enhanced Green Power Generation through Chemical Recovery High Pressure Cogeneration at Seshasayee Paper

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ABSTRACT

Energy Conservation in pulp and paper mills, is not restricted to one form of energy management. Power and Steam Management go hand in hand, with Climate Change Development, adding as the third dimension. The paper aims at bringing out select innovative climate friendly combined heat and power (CHP) schemes relating to Chemical Recovery high pressure Cogeneration plant being successfully implemented in Seshasayee Paper.

Black liquor is a Carbon Neutral fuel and hence CHP from the Chemical Recovery Cogeneration unit would be one of green energy. The 900 TPD BLS Chemical Recovery Boiler is designed with the highest operating steaming conditions in the sub-continent with high efficacy in both the phases (600 & 900 TPD BLS) of operation. In order to gain increased mileage of Carbon Neutral power, low pressure steam extraction flow is maximised with minimal steam extraction at medium pressure in the 16 MW Extraction Back pressure steam turbo-generator. The added benefit is one of increased power conversion because of reduction in desuperheating of low pressure steam after turbine nozzle, as also lowering the turbine extraction pressure by another 0.5 bar. With all of the above in place, the energy conversion to electrical power achieved is of the highest order.

Since this carbon neutral power produced to the tune of around 8.5 MW-replaces grid power (derived from fossil fuel), emission reduction is estimated at ~ 4000 tCO₂(equiv)/month, which certainly is of a tall order for the boiler firing 600TPD BLS. Added to the above, is the contribution to Climate Change Development by way of minimal N₂O emission in stack gas, which had been made possible through multi-air staging and high combustion temperature of Recovery Boiler. Hence Carbon Foot Print associated with the final product (paper) is greatly reduced through maximizing usage of green energy from the Recovery Cogeneration plant.

Chemical Recovery High Pressure Cogeneration plant

In line with the contemporary paper mills, SPB had gone in for high pressure Chemical recovery boiler (CRB) to replace the existing low pressure (11 bar & 29 bar) boilers. The new boiler shall be firing black liquor of high concentration (~ 70 % solids) for generating steam at 65 kscg and 465°C with feed water temperature from Deaerator at 135°C. Since the feed water is pumped by High Pressure Boiler Feed Pump to a pressure of over 85 to 90 kscg, the feed water temperature entering the Economiser would be around 137°C, because of heat of compression. Steam generation capacity is estimated at 140TPD with liquor firing at 900Te solids/day (Refer Annexure -1). The boiler is designed to operate at 65% turndown (with liquor firing at 580 Te solids/day), during the initial phase and yet ensuring main steaming conditions. This would mean generous sizing and extra precaution in superheater design & steam

temperature control scheme.

The quantity of 586 TPD (dry solids) at a heating value of 2900-3000 kcal/kg (dry basis) is being fired to generate at main steam boiler outlet, high pressure steam of 68 to 75 TPH after taking into account 3 to 4 TPH for soot blowing operation.

Steam is generated at a pressure of 65 kg/cm² & 460°C at main steam outlet has a small pressure drop of 1 kg/cm² and temperature drop of 5°C. High pressure steam enters at 63 kg/cm² & 455°C the Double extraction Back pressure steam turbo-generator- having extraction at 11 kg/cm² (MP) and

ANNEXURE -1

A. H.P. Chemical Recovery Boiler Input Specifications

STEAMING CONDITIONS	VALUE	UNIT
Steam evaporation rate (MCR)	140	TPH
Steam Evaporation Rate (1 st Phase)	83	TPH
Steam outlet pressure	66	ATA
Steam outlet temperature	465±5	°C
Steam temperature control	55 to 100	%
Feed water inlet temperature to Feed Pump	135	°C
Fuel	Black Liquor	
BLS firing rate (1 st Phase)	580	TPD
BLS firing rate (2 nd Phase)	900	TPD
BLS Concentration	70	%
Design GCV [Dry basis]	3250	Kcal/kg
Flue Gas exit temperature	175 to 177	°C
SPM in flue gas leaving Boiler	50	mg/Nm ³

Seshasayee Paper & Boards Limited
Erode - 638007 (T.N.)

B. 16MW Extraction Back Pressure steam turbine specifications

STEAMING CONDITIONS	VALUE	UNIT
Design Steam input	130	TPH
Steam input (MCR)	70 to 80	TPH
Steam inlet pressure	64	ATA
Steam inlet temperature	455	°C
1 st Extraction Flow	0-40	TPH
1 st Extraction Pressure	11.5	ATA
1 st Extraction temperature	200	°C
Exhaust Steam Flow	0-130	TPH
Exhaust Steam Pressure	5	ATA
Exhaust Steam temperature	160	°C
Power Generation Capacity	16	MW
Power Generation (Phase-1)	8 to 9	MW

exhaust at 4.5 kg/cm² (LP) steam .
Steam is being used for utilities and

balance for process use. Energy
available in fuel (BLS) is converted to

Fig.1. CPP –II [Recovery] COGEN LADDER CHART

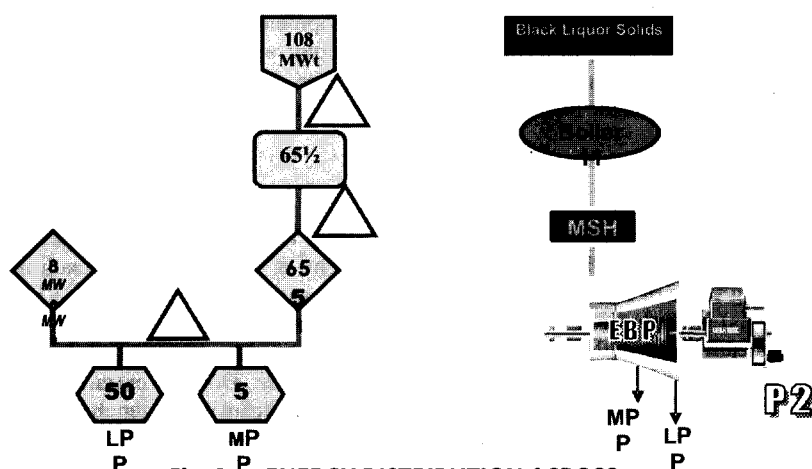
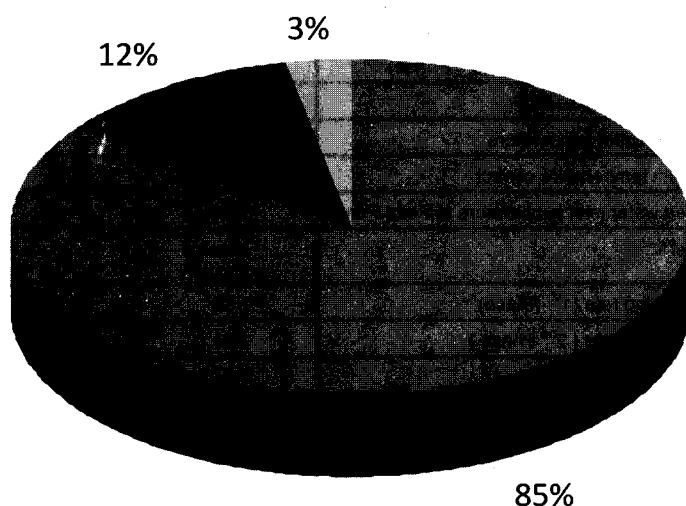


Fig. 2. ENERGY DISTRIBUTION ACROSS Break-up [%]

■ Thermal ■ Power ■ Generator & other Losses



High pressure steam-as thermal energy. Boiler efficiency is 100% Heat losses(%). It should be noted unlike in a conventional biomass fired boiler, there is heat of reduction (endothermic), smelt heat losses and so on, which are additional to the conventional heat losses (which are mainly stack heat losses which are high because of high moisture and hydrogen content in black liquor).

Energy Distribution in Recovery H.P. Cogeneration

In the present case of study with extraction back pressure [EBP] steam turbo-generator, being a cogeneration plant without any condensation with the steam extracted totally , the thermal energy in the form of low pressure steam is high and the electrical power generated is hence lower as compared to extraction condensing steam turbine. Heat in steam drives the turbine and electrical Power is generated and at both points of extraction , the MP steam & LP steam at the desired steam pressures contain the heat energy in the form of steam and the heat is fully made use of in utilities and process. The energy figure is stated in terms of MWt (thermal/heat) upto and including extraction and exhaust steam and only at generator outlet it would be referred as MW(electrical/ Power) (Fig.1). As it can be seen from the turbine alone, energy in the form of steam is at a high of 80 to 85 % and power in the form of electrical energy is at a low of 12 to 13 %. Steam turbine generator and stage losses would be around 3 %.(Fig.2). Starting from the fuel as input including the boiler thermal efficiency [60 %], the electrical power would be hardly 9 to 10%.

One can see that thermal energy is favored over electrical energy by a ratio of no less than 7:1.

As power generation is 10% to 15% at best, any small improvement in the extraction centres will have a significant enhancement on power generation in a cogeneration plant, as is the case of our mill, wherein the benefits of further enhanced power generation are realized because of operating at lower solids firing in the first phase of operation , as can be seen from Fig. 2. It therefore is prudent to work towards maximizing the power generation in E1 and E2 (turbine extraction nozzles). This concept is summarized in the proceeding sections. In high pressure cogeneration plants, power generation is maximized once the process steam requirements (at the desired pressure levels) have been

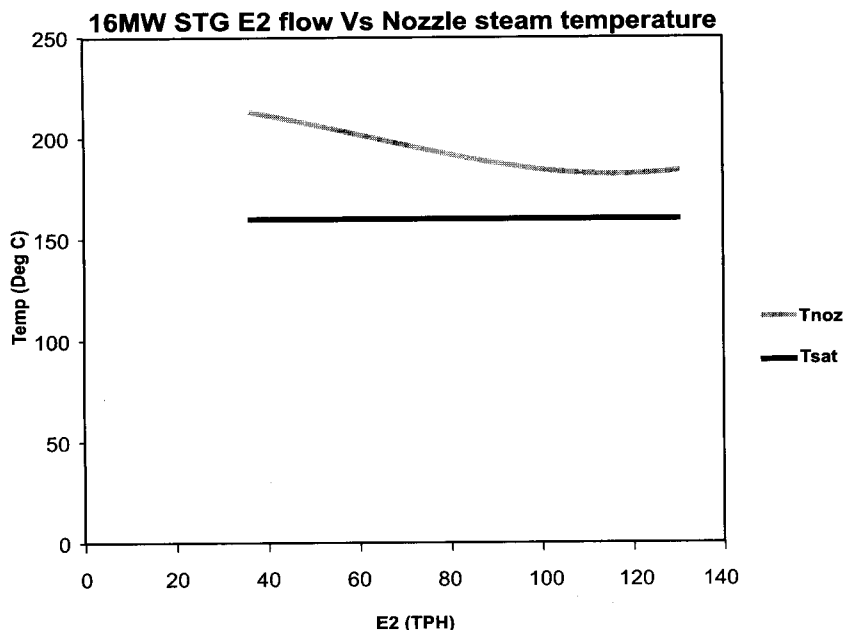
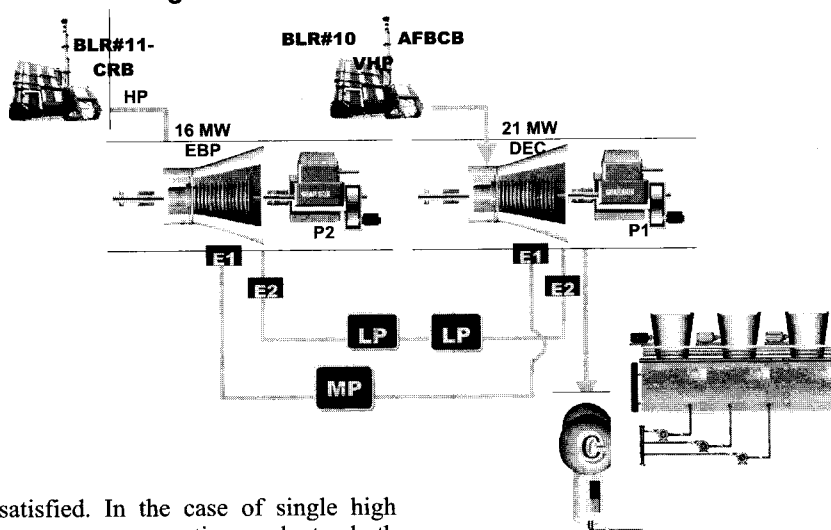


Fig.3. Steam Flow Path & Power Distribution



satisfied. In the case of single high pressure cogeneration plants, both medium pressure (MP) & low pressure (LP) steam draws shall be related to process & station steam demands. However, in case of a battery of cogeneration plants, there is the opportunity to maximize the power generation potential, even after meeting the steam demands of the mill.

Integrated Steam & Power Energy Balance

In order to meet the steam and power requirements of the paper mill we have both a 105 bar and a 65 bar high pressure cogeneration units. LP and MP steam is drawn from both the 21MW & 16 MW steam turbines.

With CPP-1 (Coal fired high pressure Cogeneration unit) & CPP-2 (Recovery H.P. Cogeneration unit) in operation alongside, steam has to be apportioned at 2 pressure levels (for

process use & Deaerator). Refer Fig.3 for steam flow path & power distribution.

Turbine extraction steam drawl Strategy

As a starting point analysis has been carried out in detail to evaluate the impact of varying extraction steam flows from the 16 MW STG, as well as evaluate any changes in power generation potential.

E1 steam drawl

With gradual reduction in MP steam extraction load, both the steam pressure and temperature at the exit of the nozzle are high, resulting in reduced power conversion (with attendant higher steam enthalpy). The drop in power generation potential is as high as 0.2 to 0.3 MW and gets drastically reduced at minimum load, as can be seen from the illustration in Table 1. This analysis has been done with the full load operation as the design basis. The potential could be greater, but is limited by the existing design of the steam turbine. The estimated power generation potentials are summarized in Table-1.

E2 steam drawl

With increasing LP steam extraction loads, the steam temperature at the exit of the nozzle is marginally lower, resulting in reduced power loss (with slightly lower steam enthalpy). The increase in power generation potential varies with extraction load from as high as 0.7 MW, but nominally 0.5 MW, as can be seen from the summary in Table 2. This analysis has been done with the

TABLE-1
Impact of Varied MP steam extraction on Power Generation -(E1)

Steam gen (TPH)	E1 (TPH)	P _{E1} (ksc)	T _{E1} (°C)	h _{E1} (kcal/kg)	Δh (kcal/kg)	Power redn (MW)
88	16	19.5	320	734	17	0.32
88	25	-	-	725	8	0.23
88	40	13.25	283	717	-	-
88 & 78	0	-	-	-	-	0
78	16	16.85	308	727	10	0.19
78	25	-	-	720	3	0.09

TABLE-2
Impact of Varied LP steam extraction on Power Generation -(E2)

E2 (TPH)	P _{E2} (ata)	T _{E2} (°C)	H _{E2} (kcal/kg)	Δh (kcal/kg)	Power reduction (MW)
48	6.1	207	684.2	12.5	0.64
62	6.1	200	680.4	8.7	0.57
72	6.1	194	677.5	5.8	0.45
82	6.1	190	675.3	3.6	0.31
105	6.1	183	671.7	0	0
130	6.1	183	671.7	Base	Base

full load operation as the design basis.

Recommendation

It is recommended to integrate the extraction flows and draw the same from one source (16 MW STG or 21 MW STG), instead of splitting the extraction steam flows between the two steam turbines. This methodology shall be followed to the extent possible with E2 flows. Also by lowering the exhaust steam pressure even by a small amount, marginal increase in Power generation is to be expected.

From the performance record of the 16 MW STG in operation, the specific steam consumption (SSC) could be reduced from an average of 9.8 Te/MWh (First quarter of 2010) to 8.3 Te/MWh through increased loading of steam through LP exhaust and reduced loading of steam through MP extraction of the 16 MW STG (Refer Table-3). The figure could be further improved to < 8 Te/MW through minimizing steam to the practicable extent through E1.

reduction in a big way. Of the six GHG identified as the prime contributors to Global warming, the 2 gases which contribute in Stationary Combustion are CO₂ and N₂O.

Whereas the former is a well known GHG emitter , the latter though normally considered to be innocuous in Pulp and Paper industries, need to be discussed because of its high GWP of 310 , with CO₂ as base at GWP of unity.

CO₂, the prime GHG , is of major concern in Stationary Combustion units. Black Liquor solids being fired in Chemical Recovery Boiler for High Pressure Cogeneration is a Carbon Neutral fuel and hence there is no question of accounting for CO₂ emitted.

By selecting higher pressure and temperature of steam generation, the carbon intensity reduction is significant in that power generation is enhanced through selection of suitable Extraction Back pressure steam turbo-generator.

contributed to substantial Carbon Emission reduction , as can be seen from Table -4.

N₂O Reduction

Nitrous oxide emission is normally not given importance in Industrial Boilers as invariably the quantum is in traces , since the combustion temperature is of a high order. N₂O in High Pressure Chemical recovery CHP is of the order of a few ppm in flue gas leaving stack , because of the following factors viz.,

- High Combustion temperature (1100-1200 °C);
- Vertical Air System with Multi-level combustion air (3 Tier) staging;
- High Cycle efficiency, enhanced further through adoption of Back Pressure turbo-generator & absence of Condensing system;

Carbon Foot Print [CFP]

For the Paper Manufacturing industry, CFP of paper is the amount of GHG released into the environment during the full cycle of papermaking. The major contributor to this CFP is CO₂ emission from fossil fuels used to generate heat and power, including purchased electricity from grid. CO₂ emissions from transportation of raw materials ,chemicals and paper, as well as methane emissions do contribute to CFP.

In this context, the Chemical Recovery Island is certainly a Climate Friendly unit contributing to high levels of Carbon Emission reduction . Paper, the final product being produced from the Paper machines, derive the carbon from the source raw material , chemicals as well as the type of energies (Combined Heat and Power) being used. The Raw material for Paper manufacture is wood and bagasse and is hence Carbon neutral. The source of energy is the Cogeneration plants and the imported grid Power.

Through maximum power generation alongwith steam for process from the

TABLE 3
Power Generation Enhancement in 16 MW STG in the last quarter of 2010

2010	Power Generation [MW]	SSC [Te/MW]	SSC reduction, %
1 st Quarter	7.4	9.8	Base
2 nd Quarter	7.8	9.2	6
3 rd Quarter	8.15	8.85	10
4 th Quarter	8.5	8.5	13
Dec.2010	9.0	8.3	15

Performance enhancement through effective main steam pipe insulation

Through effective thermal insulation of the main steam pipeline, valves, flanges etc connecting Boiler #11 and the existing 16 MW steam turbine, the energy would be conserved by way of maintaining higher steam temperature to ensure enhanced Power generation.

Avoidance of steam through PRDS

The HP steam generated from the recovery Boiler is led totally to the 16MW STG, avoiding steam passing through PRDS for process use. This had ensured increased power conversion in the steam turbine.

Carbon Emission Reduction

With the alarming increase in Global warming, a stage had been reached, wherein all available options have to be explored in effecting GHG

Maximising the power generated from the CHP unit of Recovery Cogeneration unit, the imported grid power (predominantly fossil fuel based) is displaced. This apart the power generated from the Coal based Cogeneration boilers are also lowered. The auxiliary station power consumption is lowered through adoption of Energy efficient Boiler Feed pump and high efficiency fans attached with Variable Frequency drives. All of the above factors have

TABLE 4
GHG emission reduction with CHP enhancement in 2010

2010	Power Generation [MW]	Emission Reduction, Te CO ₂
1 st Quarter	7.4	3600
2 nd Quarter	7.8	3900
3 rd Quarter	8.15	4400
4 th Quarter	8.5	4600
Dec.2010	9.0	5100

Carbon neutral BLS and with minimal usage of fossil fuel powered units and barest drawl of grid power, the carbon contribution to the final product (paper) is of a low order. Hence CFP in Paper produced is quite low and is being lowered further through enhancement of net power available from the High Pressure Chemical recovery Cogeneration unit.

With increased power generation of Carbon neutral power based on BLS as fuel, displacing the fossil dominated grid power (CEF of 0.90), the CEF had dropped substantially by as much as 20% from 1.2 to 1.05. As regards steam for process use, there had hardly been any change , since the steam generated from BLS as fuel had been more or less same as before. In a nut-shell, the CFP going into the final product (paper) had been lowered by $\sim 0.5 \text{ TeCO}_2/\text{Te}$ finished product, all because of significant increase in Green power generation.

Conclusions

It had now been conclusively been proved that

- The extraction steam temperature increases with reduction in extraction flow (E 1).
- The Operational data more or less are in line with the design figures.
- Through transfer of E1 steam flow from 16 MW STG to that of 21 MW STG, the exhaust steam temperature of E2 dropped, in line with our prediction.
- Through maximising E2 steam in Recovery Cogeneration turbine, significant increase in power generation had been achieved.

The proposed power enhancement scheme advocated with the two High

pressure cogeneration units in operation most certainly ensures power savings /enhancement on a continuous basis. This shall, of course, be related to slight dent in equivalent steam generation (via desuperheating of extraction steam), which aids in improved quality of steam to process. The Carbon Foot Print addition to the final product (Paper) had been greatly reduced with the increased Green Power generation from the energy efficient High Pressure Chemical Recovery Cogeneration plant.

This successful exercise could be readily replicated in all other mills in any part of the world having battery of cogeneration units as can be seen from Table - 5

TABLE 5
CFP REDUCTION DURING 2010

2010	Power Genern. [MW]	Steam For Process, TPH	CFP Reduction, $\text{TeCO}_2/\text{Te Paper}$
1 st Quarter	7.4	25	0.35
2 nd Quarter	7.8	26	0.38
3 rd Quarter	8.15	25	0.42
4 th Quarter	8.5	25	0.45
Dec.2010	9.0	25	0.50