Performance Enhancement Initiative in Chemical Recovery Complex of Seshasayee Paper

Sundara Raman.T.G., Shenoy.R.V., Karthik. S. Selvam.N. & Sudarsana Srinivasan.A.

Seshasayee Paper & Boards Limited, Erode-638 007 (T.N.)

ABSTRACT

The paper dwells in select performance enhancement initiatives successfully implemented in the Chemical Recovery Complex encompassing Evaporator section, Chemical Recovery High pressure Cogeneration plant, Recausticizing and Rotary Lime Kiln bay of Seshasayee Paper mill. Thrust is given on schemes for maximizing Green energy generation from the High pressure Chemical Recovery Cogeneration plant for process use, thus relating to minimal grid power drawl. This apart, water conservation schemes in the style of Mist cooling and process condensate polishing for reuse as boiler feed water are being discussed. From the point of view of economy ,fuel switch scheme from furnace oil replacement to producer gas derived from high moisture lignitic coal gasified in the gasifier had been outlined

Introduction

The highly energy intensive Pulp and Paper industry gets respite through Green energy generation in the style of Chemical Recovery Complex. Maximizing Green energy generation -through innovative schemes as also available from practicing pulp industries - for paper and pulp use would be the focal point of this paper . Emphasis is given for such of those initiatives which realize increased energy produced from the available input from the Fiberline in the form of weak liquor. The dilute liquor is the waste filtrate with 85 to 88% water and balance 12 to 15 % dissolved solids (constituting organic lignin (46%) and inorganic chemicals (54%)). The liquor is concentrated in multi-effect evaporator to Black liquor solids (BLS) of 70 % concentration. BLS is a Carbon Neutral fuel and hence heat and power from the Chemical Recovery Cogeneration unit would be one of green energy.

Chemical Recovery Complex constitutes as under the following major sections-

- Multi-effect Evaporator
- Chemical Recovery Boiler integrated with Steam turbo-generator
- Rotary Lime Kiln integrated with Recausticizing

Select schemes in all of these areas , worthy of mention shall be discussed in this paper, in the order as stated above..

Multi-effect Evaporator

The seven effect evaporator supplied by M/s Alfa-Laval India Ltd. during 2007 is primarily aimed at increasing the concentration of weak liquor obtained from the fiberline at around 13 to 15 % concentration to ~over 70 % . Low pressure mildly superheated steam at 4 kscg is used as the heating medium . Steam economy of over 6.0 had been obtained on a continued scale.

Efforts had been made to obtain the liquor at higher concentration (15 % -as against the design value of 11.5 %). Through improvement of Condenser vacuum at 650 mmWC , effective utilization of post plate type condenser and maintaining cleaner evaporator & condenser surface, the heat transfer efficacy had been increased all of these related to lowered specific steam consumption. As against the initial period figures for steam consumption at 1.10 T/ T BLS, it is now reduced to 0.98 T/T BLS generated.

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 are drawn from both the 21MW & 16 MW steam turbines. With CPP-1(Coal fired high pressure Cogeneration unit) and CPP-2 (Recovery H.P. Cogeneration unit) in operation alongside, steam has to be apportioned at two pressure levels(for process use ,utilities & Deaerator).

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) & medium pressure (29 bar)

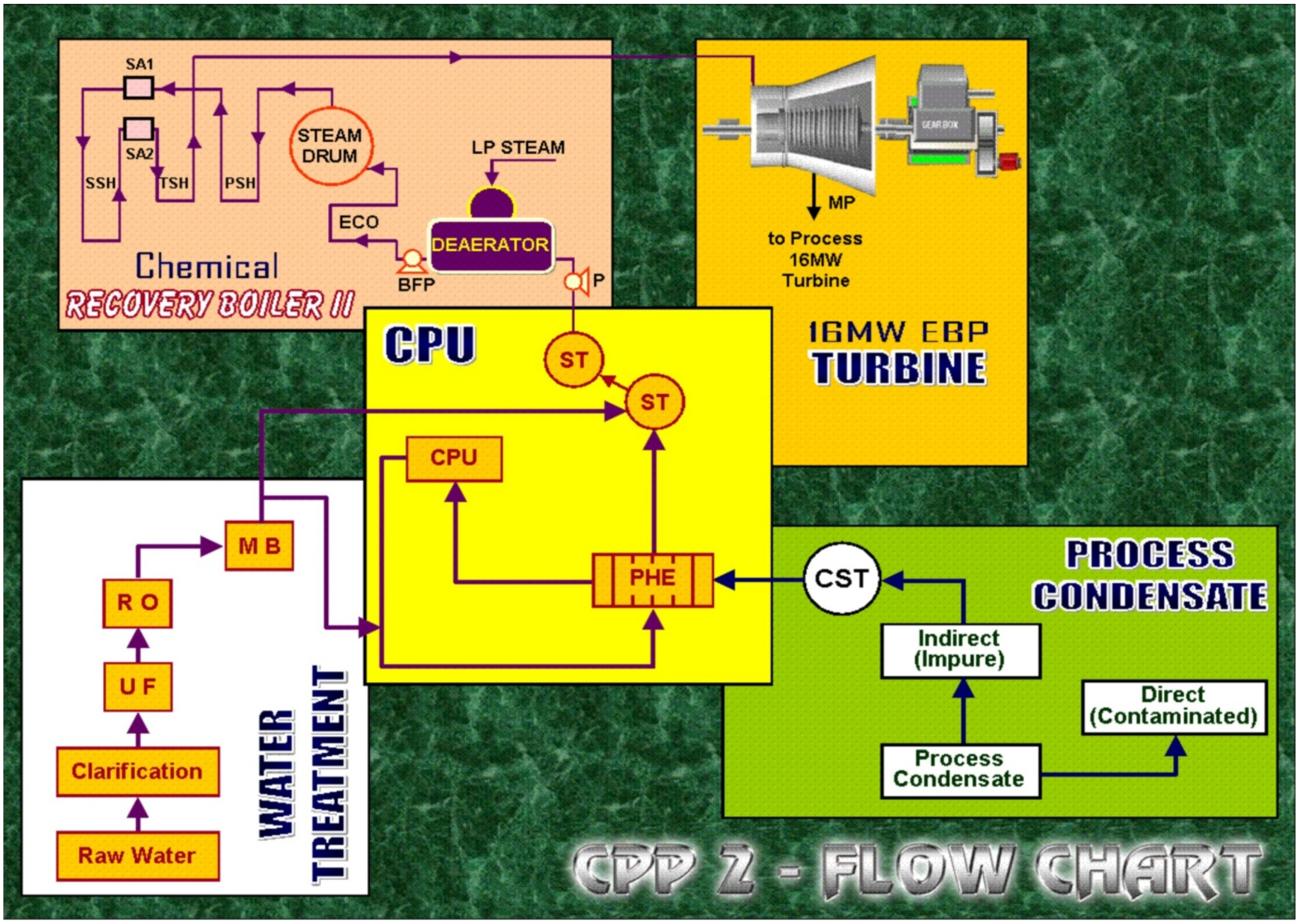


Fig. 1. Chemical Recovery Cogeneration Plant Flow Chart

boilers. The new boiler designed and supplied by Enmas Andritz was commissioned during the latter half of 2008 and had been firing Black liquor of high concentration (~ 70 % solids) for generating high pressure steam of over 80 TPH at 65 kscg and 465°C with feed water temperature from Deaerator at 135°C (Fig.1). The Recovery boiler is designed for Steam generation capacity estimated at 140TPD with liquor firing at 900Te dry solids/day (Table-1). However the boiler is also designed to operate at 65% turndown (with liquor firing at 600 to670 Te solids/day), during the first phase and yet ensuring rated main steaming conditions with steam generation at 80 to 85 TPH.. This would mean generous sizing of superheater heating surface and extra features in superheater design & steam temperature control scheme. The quantity of 630 -670 TPD (dry solids) at a Gross heating value of 2900-3300 kcal/kg

Table -1

A. H.P. Chemical Recovery Boiler Performance Summary

Steaming Conditions	**Design**	**Present**	**Units**
Steam evaporation rate (MCR)	140	-	TPH
Steam Evaporation Rate	83	80 -87	TPH
Steam outlet pressure	66	63-66	ATA
Steam outlet temperature	460 to 470	455 to 470	°C
Steam temperature control	55 to100	-	%
Feed water inlet temperature to Boiler Feed Pump	135	132 to 135	°C
Fuel	Black Liquor Solids		
BLS firing rate (1st Phase)	580-630	650-670	TPD
BLS firing rate (2nd Phase)	900	-	TPD
BLS Concentration	70	68-71	%
GCV [Dry basis]	3250	2900-3050	Kcal/kg
Oil Support (1st Phase)	2	<1	Kl/day
Flue Gas exit temperature	175 to 177	158 to 162	°C
HP steam for Primary air heating	0.8	Nil	TPH
Auxiliary Power Consumption(1st Phase)	1.2-1.4	1.25	MW

B. Extraction Back Pressure Steam Turbo-Generator Performance

Steaming Conditions	**Design**	**Present**	**Units**
Design Steam input	130	-	TPH
Steam input -1st Phase	78 to 88	77 to 87	TPH
Steam inlet pressure	64	62 -65	ATA
Steam inlet temperature	455	450 to 465	°C
1st Extraction Flow	0-40	3-8	TPH
1st Extraction Pressure	11.5	11.5	ATA
1st Extraction temperature	200	200	°C
Exhaust Steam Flow	30-130	74-82	TPH
Exhaust Steam Pressure	5.5	5	ATA
Exhaust Steam temperature	160	160	°C
Power Generation Capacity	16		MW
Power Generation (Phase-1)	8.5	9 to 10	MW

(dry basis) is being fired to generate at main steam boiler outlet ,high pressure steam of 73 to 83 TPH after taking into account 4 to 5 TPH high pressure for soot blowing operation.

Combustion Air Optimization

Both Primary as well as Secondary air for combustion are preheated using low and medium pressure steam. Tertiary air is unheated. Excess air had been trimmed with the result that primary as well as secondary air flows are reduced leading to lowered steam consumption. Stack heat loss is reduced because of lowering in flue gas quantity. In effect, excess air optimization would result in marginal HP steam reduction as also lowered steam requirement and excess air.

Excess air (O_2) is controlled for combustion air optimization. Optimizing excess air flows through reducing primary air flow and its temperature would aid in lowering low pressure steam; this in turn would relate to increased net available steam for process use, as can be seen from the recent experimental study depicted in Table- 2.

Table -2
Energy Management through Combustion Air Optimization
Experimental Study [Year: 2012]

Parameter	Unit	Before	After	Result
O2 in flue gas	%	5.5 to 6.5	3.5 to 4	2 % point reduction
Total Air flow	TPH	120	114 to 115	5 to 6TPH reduction
Primary Air temperature	° C	180 to 185	165 to 170	15 ° C drop
Steam required for heating	TPH	6	5	1 TPH reduction
Boiler Steam generation	TPH	83	83	-
Steam to Process	TPH	29	30	1 TPH increase

High pressure steam enters at 63 kg/cm^{2}g and 455°C the Double extraction Back pressure steam turbo-generator designed by BHEL - having extraction at 11 kg/cm^2 (MP) and exhaust at 4.5 kg/cm^2 (LP) steam . Steam is being used for utilities and balance for process use. Energy available in fuel (BLS) is converted to High pressure steam-as thermal energy. 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) realizing thermal efficiency of ~ 58 to 61%.

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. 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 boiler thermal efficiency [60 %], the electrical power would be hardly 9 to10 %.

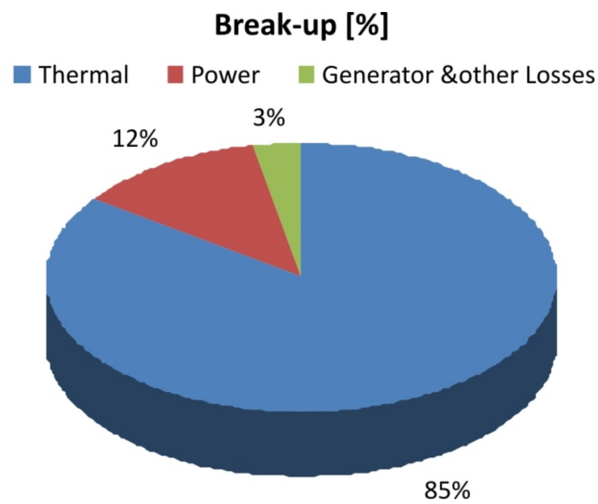


Fig. 2. Energy Distribution across Turbo-generator

Performance Enhancement Initiatives in Recovery Cogeneration Plant

Performance enhancement related to energy management and increased productivity had been made possible on a sustained basis through adoption of best practices **.**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. It therefore is highly necessary to work towards maximizing the power generation in the extraction back pressure turbine. In high pressure cogeneration plants, power generation is maximized once the process steam requirements (at the desired pressure levels) have been satisfied.

Power Generation Enhancement

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 between 0.3 to 0.5 MW.

The concept first of its kind for achieving enhanced Green Power generation- had been successfully demonstrated in the existing HP Cogeneration plant. 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. 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 16 MW STG in operation, specific steam consumption (SSC) could be reduced from an average of 9.2 TPH/MW (2009-11) to 8.7 Te/MWh (2012-13) through increased loading of steam through LP exhaust and reduced loading of steam through MP extraction of the 16 MW STG (

Table 3
Recovery Cogeneration Performance Summary- Operation-Month Record

Parameter	2009/May	2010/May	2012/Jun	Units
BLS	625	645	657	TPD
BLS Concentration	68-70	68-70	70-71	%
HFO Consumption	67	40	27	Kl/m
Steam Generation	70	70	80	TPH
Power Generation	7.65	7.7	9.2	MW
Specific Steam Consumption	9.2	9.1	8.7	TPH/MW
Cogen Power consumption	1.15	1.25	1.25	MW
Net Power to Process	6.5	6.45	7.95	MW
Steam for Process	25	25	27	TPH
Emission Reduction Certified	35	35	42	"00 tCO2

Refer Table-3). The figure could be further improved to < 8.4 TPH/MW through minimizing steam to the practicable extent through LP exhaust.

Generator Efficiency

The Generator supplied by BHEL designed for as high of 97.9 % had exceeded the figure during guarantee run by 0.2 (98.1%). With power factor at over 0.95 , the generator power loss is extremely low.

Avoidance of HP steam through PRDS

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

Other schemes for Energy enhancement

- HP steam avoidance for Sootblowing
- FO consumption reduction even at 70% load (though design calls for increased fossil fuel usage)
- Rated main steam temperature maintenance at all loads

Appreciating the importance of maintaining rated steam temperature even at lower boiler operating loads (60 % to 70%) , as desired by the client, the boiler designer had generously designed superheater heating surface. This special design had yielded encouraging results in the form of rated steam temperature of over 460°C being achieved at all periods of boiler operation. In turn , this had led to reduced specific steam consumption through increased power generation in the Extraction Back-pressure steam turbo-generator.

Electrical Power Conservation

To start with, by going in for energy efficient feed pump(BFP) specifically tuned for the 1st phase of operation (boiler operating at 70 % load), instead of the boiler designer's recommendation of going in for large BFP to cater to design evaporation (140 TPH), there had been power saving to the tune of 150 kW , as can be noted from Table- 4.

Table 4 Power Saving with Energy efficient BFP

Feed water flow	Energy efficient BFP	Standard larger capacity BFP	Power saving
TPH	%	%	kW
83 -85	70	45-47	150

The fans PA, SA as well as ID fans are of high efficiency units. Coupled with VFD integrated, the auxiliary power consumption could be maintained at a low figure.

Station power consumption of the cogeneration plant at 1.2 MW , as a matter of fact , is even lower than the design guaranteed figure by 15 %. (Refer Table -5).

The 4 field Electro-static precipitator designed and supplied by BHEL with AVC controls is energy efficient, but the power saving is marginal. SPM of the flue gas discharged to stack is within 100 ppm.

Table 5
Achieved APC achieved in Recovery Boiler

BLS ,TPD	Auxiliary Power Consumption [APC] , MW	
	Design Data	Operating Data
580	1.2	
660	1.4	1.25
740	1.55	
820	1.75	
900	1.9	

Energy Productivity

The Barometer of Productivity is termed as Energy Productivity Index. It integrates unit Availability factor(A), Net Power generation(Pn) , Steam for process(Sn) with BLS feed as input.

Energy Productivity Index (EPI): $[P_n * S_n]*A/BLS_f$

Higher Energy Productivity Index [EPI] relates to enhanced Productivity as can be appreciated from the illustration extracted from Recovery cogeneration plant in operation .

With hourly average Power generation of 9.3 MW from the Steam turbo-generator connected to the Chemical Recovery Boiler and making available power and steam to process (Pulp and Paper plant) at an hourly average of 8 MW and 26 TPH respectively, Energy Productivity Index is certainly of a high order, as can be seen from the worksheet in Table-6 .

Table 6 Energy Productivity Index Case Study Month: June 2012

Parameter	Index Basis	Actual	Index Normalisation	Index Normalised Factor	Nomenclature
Availability	720h	703 h	703/720	0.976	A
BLS Flow	586TPD	19242 ton	19242/586/24/703	1.121	BLS_f
Gross Power	8.3 MW	6410000			
Station Power	1.3 MW	878000			
Net Power	7.0 MW	5563000	5563000/7000*703	1.126	P_n
Process Steam	25 TPH	18980 ton	18980/25*703	1.075	S_n
Energy Productivity Index	**1.00**	**1.054**			**EPI**

Availability of the boiler here refers to non-functioning of the boiler because of operational issues. It includes time taken for washing of pressure part exterior, pressure part failure and combustion instability.

Schemes on the anvil

Plans are under way to switch over to 30ata superheated steam drawn from the existing boiler in operation for soot blowing in Recovery Boiler. This would mean that the entire HP steam generated from the Recovery Boiler be passed through the 16 MW Steam turbo-generator , thereby contributing to significant increase in Green Power generation.

Efforts are on to maximize exhaust (LP) steam with minimal (MP) steam extraction, thereby increasing further Green Power from the steam turbo-generator. .

Boiler Water Management

The boiler feed water encompasses condensate from process and utilities and treated high quality demineralised water. The feed water quality is maintained at the purity as called for 105 kscg unit (in line with CPP). The hot process condensate is being passed through Condensate polishing unit (CPU) preceded by heat recovery unit (Refer Fig.3).

Mist Cooling system for water conservation

Clarified water was used as sealing water in the vacuum pumps in the Evaporation plant and in the Lime Mud Clari Disc Filter and in the White Liquor Clari Disc filter compressor. The rotor of the vacuum pumps and compressor used to get scaled due to the hardness in the mill water and the efficiency / availability of the equipment was coming down. Descaling Chemicals in these equipment were being used regularly which was adding to the cost of production.

The process condensate generated in the evaporation plant is let out at 60°C. The same has to be cooled to a temperature below 32 / 33°C before using as sealing water for the vacuum pumps

Fig.4 Mist Cooling Unit in Operation

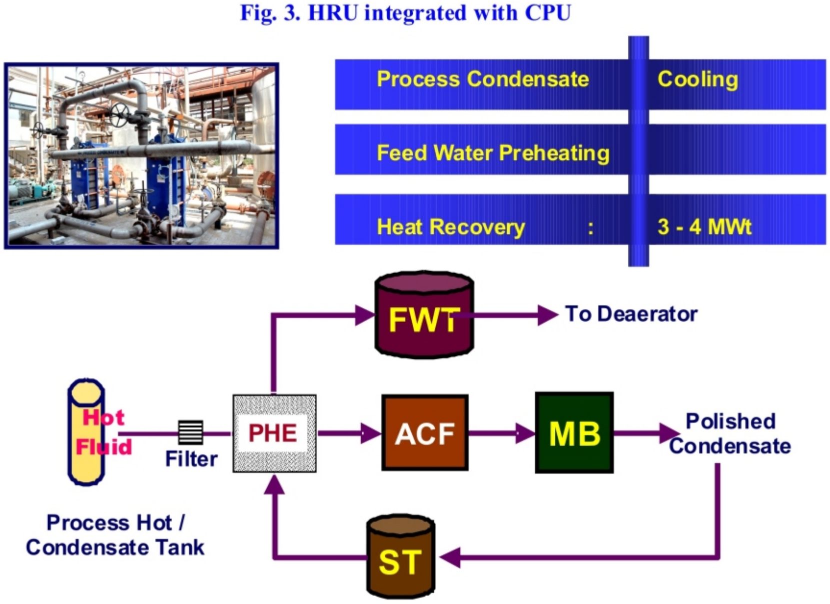
& compressors. For bringing down the temperature of the process condensate, a Mist Cooling System had been installed (Fig. 4). In the new unit, the process condensate at 60 °C is sprayed in the form of a mist and collected in a sump and pumped as sealing water at 33 °C .

Present water evaporation in Evaporation plant is 175TPH. Of the 170 TPH of process condensate produced, 100TPH is used as hot water in Recausticizing plant for Lime mud washing and 50TPH is used in Mist cooling system. This meets the Sealing Water requirement of 45TPH.

Benefits

a) Mill water usage had got reduced by 1050 m^3 per day.
b) Usage of descaling chemicals is totally avoided resulting in cost reduction
c) Improved performance & minimal scaling of vacuum pumps & compressor had been ensured

Fig. 3. HRU integrated with CPU



Techno-economics

As against the Installation cost of the Mist Cooling system of Rs 15 Lakhs, the savings on account of avoidance of descaling chemicals to the tune of ~ Re 1 Lakh per month.To crown it all, is conservation through reduction of around 30,000 m^3/month of water consumption.

Water Conservation Summary

Water Management initiatives encompass 3 schemes of relevance , viz.,:

- Steam Condensate Polishing scheme
- Evaporator Condenser Cooling water circuit
- Mist Cooling Process Condensate reuse
- Reuse of the boiler feed water pumps sealing water , spout cooling heat exchanger cooling water and CBD, soot blower steam condensate in the Bagasse pulp mill as warm water which accounts to ~ 950 m^3/day.

Rotary Lime Kiln

The 200 TPD Rotary Lime Kiln is presently operating at 70% load using furnace oil as fuel. The rotary lime kiln supplied & engineered by M/s FL Smidth is having dual cone burner of M/s Singhania make. The burner is designed for fuel oil firing in isolation and upto 70% replacement with producer gas as admixture. The duel cone burner is designed to fire both HFO as well as producer gas mix. Lime Sludge with (40 to 45%) moisture is being fired along with small quantity of limestone as make up, for producing lime with 71 to 75% purity. The product is being discharged for use in recausticizing. With spiralling oil price, it was decided to go in for Gasifier using solid fuels such as coal or briquetted biomass.

Gasifier Unit:

Fig. 5 Gasifier unit at SPB

Table 7

Analysis of Fuels used in Rotary Lime Kiln & Gasifier

Parameter	Units	Design Fuel	Fuel Switch	
		Furnace Oil	Lignitic Coal	Bio-char (Charcoal)
Total Moisture	%	Traces	26 to 32 %	10%
Ash	%	< 1%	3 to 5 %	4 %
Sulphur	%	4.5 %	0.1 to 0.5 %	Traces
GCV	Kcal/kg	10,100	4500- 4950	6400

The gasifier unit is designed and supplied by M/S Ujjawal Bio-technologies Ltd. High moisture(~30%) imported sized coal (>25mm) is being fired in the specially designed gasifier (Fig.5) for say 40% fuel oil replacement in lime kiln. Coal is being fed from the top of the reactor with air steam mixture being admitted from the bottom in counter-current manner, for partial combustion to generate producer gas as support fuel to furnace oil in lime kiln. Fuels used as on date in lime kiln and gasifier are listed in Table -7. The installation cost of the gasifier unit with all the accessories was around Rs 2.5 crores. Fuel oil consumption had been reduced by 1500 Kl. Annual saving (for last 2 years) with fuel switch using coal is of the order of Rs 2 Crores. .

Issue:

Tar management is an issue being reckoned with and is being addressed to by plant executives.

Uniqueness

This unit is the first of its kind using producer gas derived from high moistorous solid fuel dovetailed to Rotary lime kiln. Economy of the product lime had greatly improved through fuel switch to low cost fuel in gasifier. Sulphur in imported coal being very low , as against high sulphur furnace oil, SOx liberation is expected to be lowered significantly.

Replication

SPB had replicated the gasifier , so as to further bring down the usage of fuel oil in Lime kiln. .

Recausticizing:

The 246 TPD white production capacity plant comprising of the White Liquor Clari Disc filter was installed in the year 2007 and is presently producing 148 TPD to meet the white liquor requirement in the pulp mill for the Phase 1 operation.

Recausticing is done in two stages viz., Pre-slacking & Post slacking.

To reduce the silica levels in the circuit to 20 % of the lime requirement is added to the RGL pumped from the Recovery Boiler to the pre-slacker and then clarified in Green liquor clarifiers. The Clean Green Liquor (referred as CGL) is further processed in the post slacker. The lime sludge generated in this stage is disposed. In the post slacker, the CGL is processed with the remaining 80 % of lime and the slurry is filtered in the WLCD filter. The white liquor produced is pumped to pulp mll and the lime sludge generated is washed in a single mud washer and pumped to LMCD filter ; the Lime mud is reburned in the Rotary Lime Kiln.

Carbon Emission Reduction

By selecting higher pressure and temperature of steam generation, carbon emission reduction is significant in that power generation is enhanced through selection of suitable Extraction Back

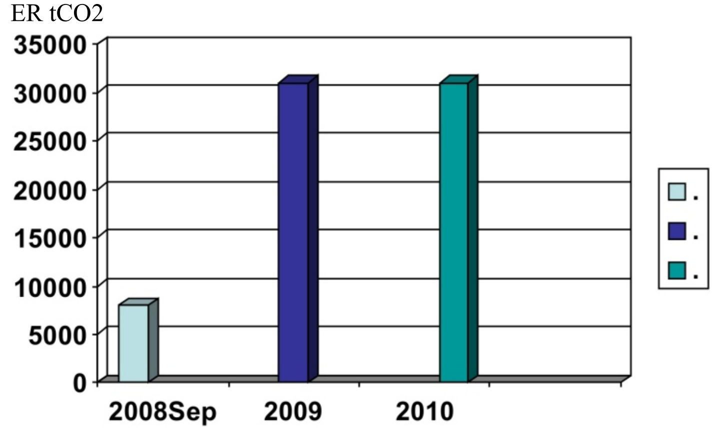


Fig.6. Annual Emission Reduction Credits related to Recovery Cogen

pressure steam turbo-generator. Maximising power generated from the Cogeneration unit to the tune of 9 to 10 MW, the imported grid power (predominantly fossil fuel based) is displaced. This apart, power generated from the Coal based Cogeneration boilers is also lowered. Auxiliary 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 contributed to substantial Carbon emission reduction , as is reflected from the ER generated to the tune of ~ 31000 VCU on an annual basis (Fig.6), which is expected to increase over the years with increased power generation from the Recovery Cogeneration plant..

Renewable Energy Certificate and PAT related gains

With BLS being classified by MNRE as Renewable energy, power generation from the Chemical Recovery plant can be traded as REC. On the PAT front, Specific Fossil energy consumption related to finished paper and export pulp is greatly reduced with enhanced performance of Recovery unit

Closure

This paper had laid emphasis on select schemes which are unique and had been successfully implemented in Seshasayee Paper Mill. Through adoption of the schemes listed, the gains which are continuing as on date can be summarised as under:

- Green Power replacing grid import fossil dominated power
- Green thermal energy for process enhanced
- Water management to a limited extent through reuse after course correction.,
- Alternate fuel usage in Rotary Lime Kiln
- CFP reduction effortlessly achieved contributing to Climate Change Development
- Contribution to SEC reduction & REC enhancement is of a high order.

Acknowledgment

The authors are thankful to SPB Management for permission to publish this paper.

References

1. Sundara Raman .T.G.[2011] "Advanced Green Power Generation through Chemical Recovery High Pressure Cogeneration at Seshasayee Paper", IPPTA J. Vol.23, No.1, Jan-March 2011,pp.151-155.
2. Sundara Raman.T.G. [2010]" Advances in Power Enhancement in Cogen Battery in Seshasayee Paper Mill " CII PAPERTECH 2010 Conference, Hyderabad, June 2010
3. Krishna Anand..S., Sundara Raman.T.G. and Subramanian.S.[2011] " Incorporating Supervisory Learning through Type 2 Fuzzy Expert System for Increasing Productivity of a Boiler " CIIT International Journal of Fuzzy Systems, ISSN 0974 9608, DOI: FS112011008, November 2011.