Experience of Chemical Recovery Operations with Wheat Straw as Main Raw Material

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ABSTRACT

Recovery operations consist of concentrating the weak Black Liquor for firing in the Recovery Boiler & to produce white liquor which is returned to the Pulp Mill for cooking. Overall purpose is to have maximum caustic recovery with minimum wastages, minimum conversion cost & meeting all the environmental norms.

The present study describes the recovery of caustic from black liquor generated out of wheat straw cooking and the challenges/problems associated with the use of wheat straw WBL as raw material for the Chemical recovery plant. The practical difficulties faced on account of high silica along with a host of non process elements(NPEs) & low GCV of straw WBL as compared to the wood WBL in the entire recovery cycle (Starting from WBL storage to Causticizing) are covered herein. The paper chronicles all the significant events and decisions taken by Trident which went into setting up the first conventional Agro based Soda recovery plant. The learnings from the operation of the old Recovery plant and how they paved way for the system modifications in the new plant is covered in the paper. There were some firsts which are to the credit of Trident viz the first Agro based falling film evaporator generating 65% solids leading to the elimination of cascade evaporator in the boiler resulting in overall steam generation efficiency. Another significant step was the setting up of a state of the art Causticizing plant coupled with the first lime kiln operating at high silica. The same are discussed in detail.

Paper describes the counter measures taken to efficiently run the recovery plant to meet the Pulp Mill requirement with minimum make up & conversion cost & unique practices being followed in the Recovery Operations. This covers the process modifications and best practices adopted. Be it utilization of boiler flash steam recovery or supplying evaporator lime steam condensate directly to boiler deaerator, process modifications and reengineering are described. Best Practices involve the counter measures for the initial quality control which are needed due to constraints in the raw material or the upstream process. Some of these are dosing of white liquor in the WBL feed and the adherence to time bound hydro jetting cleaning schedules in Evaporator.

The concluding part includes the future plans that the organization has envisaged viz capacity augmentation of both the Evaporators and boilers, ESP modifications for a greener environment

Introduction

Current paper production at Trident Ltd is 425 MT/day. The raw material used for making paper is a mixture of wheat straw and wood in ratio of approximately 70:30. At Trident there are 2 pulp mills, SFL and WFL. Straw Fiber Line (SFL) processes wheat straw and produces pulp, with present production around 225 TPD of bleached pulp. Wood Fiber Line (WFL) processes wood chips and produces pulp, with present production around 110 TPD of bleached pulp. There are 2 Recovery Units, Recovery 1 and Recovery 2.

Brief Description of Recovery Plant Technology & Capacity
Recovery-1 commissioned in 1998
Recovery-2 commissioned in 2008

SECTION	RECOVERY-1		RECOVERY-2	
	Supplier	Capacity	Supplier	Capacity
Evaporator	PAS-Axero	Six Effect FFFF Plant Water Evaporation-75 TPH Steam Economy - 5.2 O/L Concentration - 47.5 %	Enmas Andritz	Seven Effect FFFF Plant Water Evaporation-170 TPH Steam Economy - 6.2 O/L Concentration - 65 %
Boiler	Enmas Andritz	165 TdsPD firing capacity Firing Conc. - 62 % with Cascade Evaporator	Enmas Andritz	400 TdsPD firing capacity
Causticising	Swetha	34 TPD (TAA as NaOH)	GL&V/DOE	Total capacity of both Causticizing plants - 110 TPD as Na2O Rakes & Slakers Supplied by GL&V, LMCD supplied by DOE-USA

Various aspects of running Recovery on Agro based liquor

Operating conventional recovery plants with agro based liquor as compared to wood or bamboo based liquor involves big challenges. The composition of straw based liquor is severely mutated due to the presence of certain NPEs (non process elements). This difference in composition is translated not only in operational and design challenges but economical stiffness as well.

- The major NPEs are Silica, Chlorides and Potassium. Silica is present as such, while Potassium in the form of K_2S, K_2CO_3 etc and Chlorides as NaCl and Kcl.
- The main sources of these NPEs are Raw material, Process water and make up chemicals.
- Wheat straw is the prime source of silica and chlorides and they keep on building up in the system and enriching to a level which adversely affects the plant operation in all the stages of Recovery process.

The immensely high proportions of silica, chlorides and calcium cause build up of thick hard scale which is a major deterrent for heat transfer and plant throughput.

The residual active alkali (RAA) in the wheat straw based liquor is in the range 5-4-5.7 gpl. The low RAA directly influences the rate of scaling in the evaporator and the efficient burning in the boiler. The direct indicator of the low RAA is the viscosity of the final concentrated liquor (HBL). The liquor generated at 65% solids is highly viscous and the values lie in the range of 1000-1500 cp.

Composition Of Straw BL

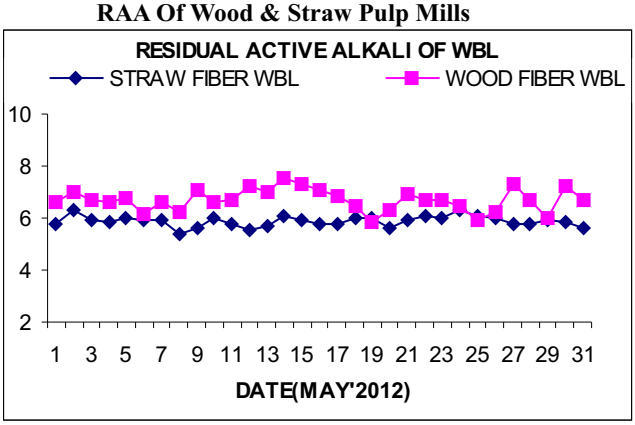
S. No	Parameters	W. Straw B.L
1.	Total Solids, % w/w.	10.8
2.	Swelling Volume Ratio, ml/gm.	10
3.	Gross Calorific Value, Cal/gm.	2890
4.	Silica as SiO_2, % w/w.	2.87
5.	Acid insoluble as SiO_2 %w/w.	3.0
6.	Chloride as Cl, % w/w.	4.3
7.	Potassium as K, % w/w.	6.0
8.	Sodium as Na, % w/w.	15.0
9.	Calcium as Ca, % w/w.	0.08
10.	Inorganic as NaOH, % w/w.	35.01
11.	Organic, % w/w. (by difference)	64.99

Steps Taken to counter the high Silica content in the WBL in Evaporator

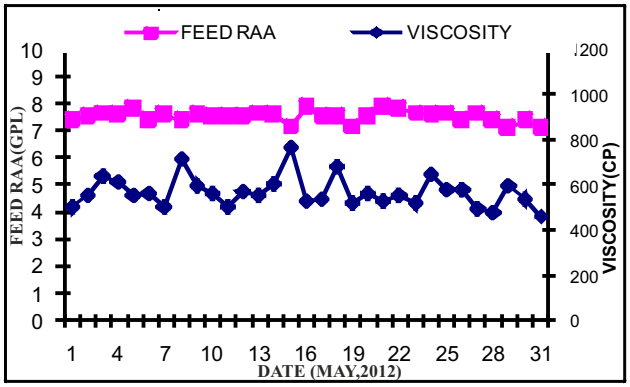
- **Controlling the final HBL viscosity by addition of White liquor in the evaporator feed -**

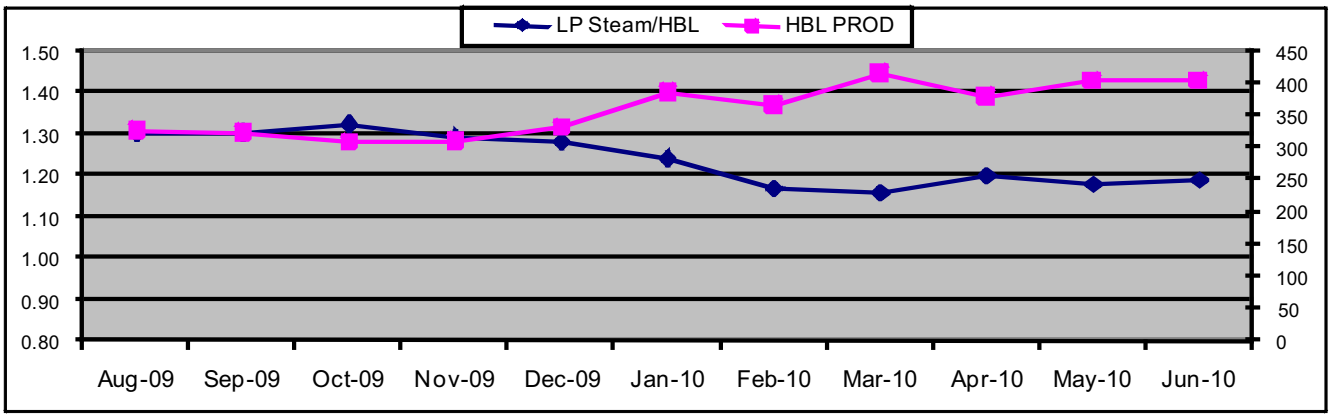
RAA of the feed liquor in the WBL is being maintained in the range of 7.0-7.5 gpl by auto controlled dosing of a solution with TTA of 75-80 gpl. The same has yielded

RAA Of Wood & Straw Pulp Mills



Viscosity Control With Feed RAA Enhancement





We are planning to install the online viscosity meter to further reduce the fluctuations in the HBL viscosity

great benefits along with online boiling of the finishers effect has resulted into maintain the production rate & steam economy > 6.0 by reducing the viscosity of HBL to 500-600 cp. System is inline from Jan-10 onwards

- **Strictly Adhering to the HP Hydro jetting cleaning Schedules -**

  Cleaning Schedule is followed based on both the time & drop across each effect to keep the plant in healthy condition. Approximately 12-14 bodies in Rec-2 & 7-8 in Recovery-1 are cleaned every month to meet the pulp requirement.

- **Maintaining the Vacuum in the Surface condenser > 625 mmHG**

  Vacuum plays a very important role in evaporation & scaling of the heat transfer area. Vacuum is maintained in the range of 630-660 mmHG by efficient operation of cooling tower & regular cleaning of condensers

- **Online WWL/WL boiling of the finisher & Second effects**

  Daily boiling of one of the 1st effects & regular boiling of 2nd effects are taken to keep the HT surfaces in healthy condition in between the HP cleaning to take care of the high fouling rate at higher concentrations.

In the downstream process viz the boiler; NPEs acquire a higher level of importance as they are present with the concentrated liquor. The presence of NPEs influences the thermal properties of the ash or deposit on the pressure part of the boiler. The salient parameters which are affected for the worse are Sticky temperature and the ash melting temperature. All of these are lowered by the presence of chlorides in the liquor. Lowering of the temperature triggers the onset of melting of the deposit and enhances the sticky nature which will nurture the build up of hard deposit on the boiler tubes, which will eventually reduce the thermal efficiency and cause operational issues while boiler is operating.

The presence of aluminium, calcium and silica adversely affect the steam economy of the boiler and lime mud unsuitable and hard to reburn. Potassium and chlorides cause accelerated deposition on the pressure part and choking of flue gas passage.

Steps Taken to counter high Silica/NPE's content & Low GCV of the WBL in the Boilers

- **Strict adherence to the Effective Soot blowing operation**

  SB operation is based on both time & pressure drop across different zones. Points taken care for effective soot blowing to minimize the HP Steam Consumption as well as to maximize the steam generation are:

  - ESP Inlet temperature should not cross 180 ^{0}C
  - Maximum time between operation of any particular SB should not exceed 24 hrs
  - Certain SB's are operated timely in every shift based on criticality of the particular zone & experience of likely areas where deposition is more
  - SB are operated based on the pressure drop across Super heaters, Boiler bank, Economisers

RB-2 ΔP across B.B < 30 mmWC ΔP across Eco < 75 mmWC
RB-1 ΔP across B.B < 25 mmWC ΔP across Eco < 25 mmWC

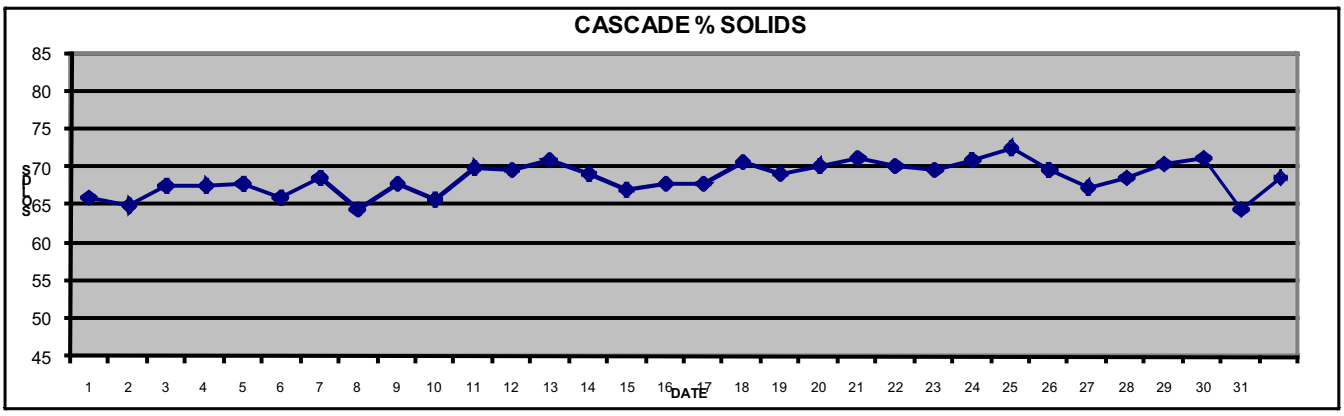
- **Maintaining the Furnace stability/flame**

  - Liquor temperature is maintained in the range of 122-128 ^{0}C
  - Oxygen is maintained in the range of 2-3 % to ensure uniform & complete combustion
  - Positive draft is being maintained in the range of 10-25 mmWC as per the liquor concentration, calorific value, ratio of straw: wood mix
  - Viscosity of the liquor is maintained from Evaporator- mentioned earlier

- **Firing of liquor at Solids > 66 %**

  In the Recovery-1 street, although certain limitations/disadvantages are their due to presence of cascade evaporator which result into reduction in steam generation as well as higher moisture content in the flue gas. But after the installation of the new plant, partial stream of concentrated black liquor from evaporator-2 (after meeting the requirements of RB-2) is being diverted into the SCBL tank that has led to increase in concentration

CASCADE Outlet Solids In %



of the liquor after the cascade up to 68-70 % against the design of 62 %. This step has added to furnace stability, more steam generation by operating at furnace draft of 10 mmWC. Flue gas temperature has also increased considerably to meet the ESP inlet conditions.

On Back page is graph of the Cascade outlet solids being maintained in the RB-1

Steps Taken for efficient operation in the Causticizing

Green liquor contain very high silica content in the range of 7-9 GPL that leads to problems in the downstream operation of settling & poor filterability of the mud & scaling of the GL Lines

- **Online Swapping of the GL/WWL lines to reduce the fouling of GL lines**

  - On-off valves are provided in both the Causticizing & RB Section for swapping the GL & WWL lines.
  - Lines are interchanged after 3 days to avoid any build up of scale in GL transfer line
  - Lines are being cleaned with HP once in 2 years
  - Spare lines are provided for the processing lines to facilitate the cleaning with HP pump by isolating the line

- **Online Density measurement for controlling the GL Concentration at both Boiler & Causticizing**

  - Online density measurements are provided to maintain the concentration of the GL right from MDT to Processing system.
  - Avoid processing of high GPL green liquor & hence scaling in the lines
  - This also helps in maintaining the downstream operation like lime addition, temp & WL conc.

- **Continuous withdrawal of lime mud from clarifiers**

  - Lime Mud withdrawal is based on flow & density measurement through the VFD controlled pumps
  - Density of the lime mud is being maintained at 1350 kg/m3 which helps in controlling the alkali loss by avoiding/eliminating the withdrawal of low concentration mud
  - It results into more consistent, smooth operation
  - Same is being operated based on the rake arm load & twaddle of the lime mud in the older unit.

- **Efficient Operation of the Lime Mud Filters**

  - Fully automated LMCD (Lime mud clari-disc) filter has been installed to reduce the moisture content & alkali loss through the filter. Even with high silica content of 6-8 % in the lime mud, we are able to get the final discharge concentration in the range of 58-60 % with residual alkali content of < 0.5 %.
  - Vacuum pumps & condensers system are regularly cleaned to maintain the vacuum in the filters
  - Pre-condensers are installed to reduce the loading on vacuum pump & Temp at the outlet is maintained at 40 ^{0}C

Automation of the Causticizing plant has helped us to maintain the ORE in the range of 95 % with recovery efficiency of 98.5 % even with the high silica content in the system & we are striving to achieve the 96% ORE.

Evolution- Learning from Old Plant and Applying on New Plant

The Soda Recovery plant of Trident Ltd hold the distinction of being the first conventional recovery plant based on agro residues. The plant was commissioned in 1998 which is now operating efficiently. The problems in the initial stages of the plant commissioning were far more in magnitude with respect to operation that the phrase "teething problems" cannot suffice.

Following are the parameters/targets being maintained in both the units to effectively meet the pulp requirements keeping the minimum cost of conversion

PARTICULARS	UOM	RECOVERY-1	RECOVERY-2	
WFL Solids	%	15.0		
SFL Solids	%	11.5		
Steam Economy	RATIO	5.0	6.0	
Steam Gen/MT of Solids	MT/MT	2.60	2.90	
Steam Cons/Gen Ratio	RATIO	1.00	0.70	
Power Consumption	KWH/MT	750	570	
WL TTA AS NA2O	GPL	85	92	
WL TAA AS NA2O	GPL	73	79	
WL TSS	PPM	<25	<20	
ORE	%	95.5		
Variable Cost	**Rs/ MT of WL**	**8000**	**1500**	

The biggest challenge was to sustain the furnace, running the boiler without oil support was a far fetched goal. The various issues faced are summarized as follows

- Changes made in the air distribution as need of enhancement in the primary air was felt and interconnecting ducts with dampers were provided between the secondary and primary wind boxes for enhancement in the air flows at the primary level. Unlike all other recovery boilers we maintain a bare minimum height of the char bed as it has a tendency of accumulating as a hard mass.
- Secondary wind box pressure was increased by throttling the air ports to sustain the heat at the hearth level and support the furnace in absence of oil support
- Initially there were four firing doors at the operating floor. After observations it was decided to run only two guns which were directly positioned above the secondary ports(which are on two sides of the boiler)
- The cascade evaporator which raises the solids from 47.5 to 62.0 %, eats up a lot of heat that could have gone into the generation of steam and ensure efficient ESP operation
- ESP ash contains high level of chlorides & same was purged intermittently out of the system and significant gain was attained in terms of efficient combustion and reduced flue gas path blockage.
- The scaling in the evaporator is onset when the liquor is concentrated in the 3rd and 2nd effects; a stand by 2nd body was installed in 2006 to maintain the steam economy during bypass of 2nd/3rd effect.
- The ESP body is made of MS and high moisture & low inlet flue gas temperature accelerated the corrosion of the body and the subsequent ingress of moisture and cool air.
- Frequent problems were faced in the clarifiers on account of manual operation, fluctuations in the settling rates of the lime mud which can not be timely corrected on account of the absence of any measurement.

Although the countermeasures took care of the problems at hand but were not enough to eliminate the issues, however they did reduce to a significant level. Development management, early management or Initial Flow Control as they call in TPM jargon was adopted for the development plan for the new recovery plant. The new plant was installed with the capacity of 400TDS and commissioned in 2007-2008.

- The evaporator was installed with seven effects with an economy of 6.2 generating concentrated black liquor at 65 % solids. This was the first ever evaporator operating on Straw liquor generating such high concentrations.
- Above decision has changed the overall costing of the Recovery plant as it has resulted into elimination of cascade from boiler & resulted into huge steam saving. Lot of study has gone into the same with the help of Andritz to study the impact of silica & viscosity on the concentration, Scaling & heat transfer coefficient.
- The evaporator bodies from 7th till the 2nd are LTV and the final finisher effect split into three bodies is Lamella type. The finishers raise the concentration from 35 to 65 % solids
- Bypassing arrangements were provided in 2nd, 3rd & 4th body as a part of design. The 2nd bodies can be bypassed without shutting the plant with the help of modern automation online isolating valves.
- The secondary air ports are provided at two levels one at the level of the oil burners and at a slightly higher level, having a better coverage in the furnace and maintaining appropriate bed profile
- The boiler utilizes the total available heat from burning black liquor for the generation of steam, as there is no Cascade evaporator. This has resulted into making the Recovery Section a net generator of steam
- The ESP casing is fully made up of concrete eliminating the possibility of corrosion induced ingress of moisture which may severely damage the collecting and emitting electrodes.
- Causticizing plant has been provided with equipments that can be used for two stage Causticizing process. Two stages were planned to purge out the silica in the system which cause numerous problems in lime re burning
- The clarifier underflow rates are controlled with variable speed drives after getting feedback from flow tubes, the old plant clarifier underflows are operated as per the rake arm load and intermittent pump operation. This automation has paved rich dividends as we have not faced any problem of unnecessary loading on clarifiers due to less mud withdrawal from the start itself.
- Lime mud clari-disc filter installed for the dewatering of lime mud and reducing the moisture content to as low as 40% with opposing factors such as high silica.
- Strict adherence to scheduled high pressure jet cleaning of the evaporator bodies which involves the cleaning of each of 2nd /3rd bodies twice a month,1st bodies once in a month and 4th and 5th bodies at an interval of 40-50 days

Best Practices Being Followed/Adopted By Trident

1.White liquor dosing to maintain the RAA of WBL & Viscosity of the HBL in place of the Weak white liquor -

Trident adopted for the procedure of monitoring/ controlling the HBL viscosity at the Evaporator by controlling the WBL feed RAA. HBL viscosity is being checked twice in a shift & kept below < 500 cP by addition of white liquor. Rest of time, operator adjusts the setting by monitoring the pump load & density of the product. Following correlation has developed over the years between pump load, viscosity & density of Product

Earlier WWL dosing was used to increase the RAA of WBL feed from 5-6 gpl to 7-8 gpl & that was putting the extra loading on the evaporator & less production. Replacement of the WWL with white liquor resulted into significant improvement in production & Steam Saving (approximately 35 MT/day)

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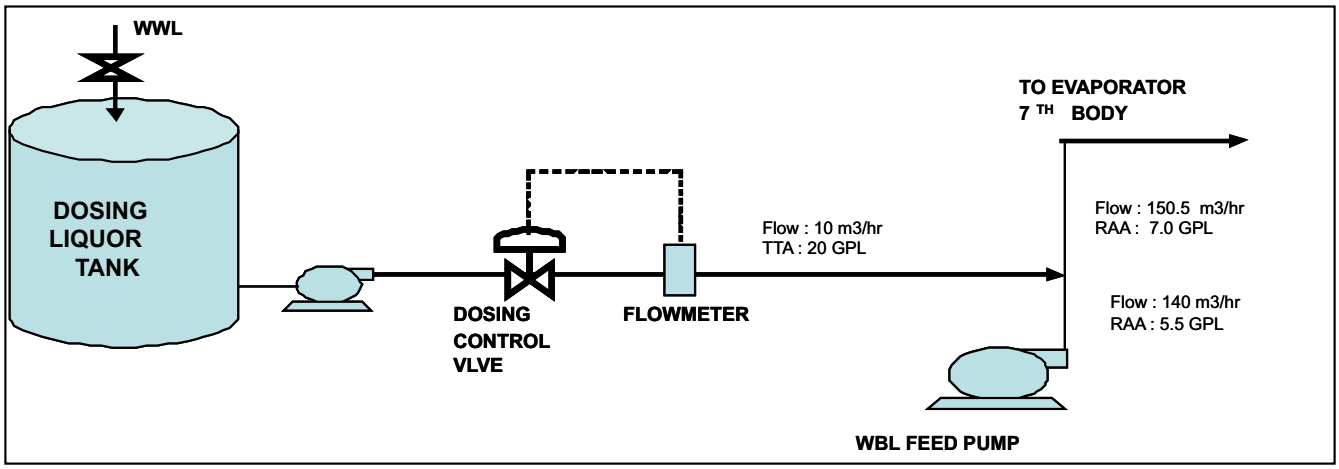

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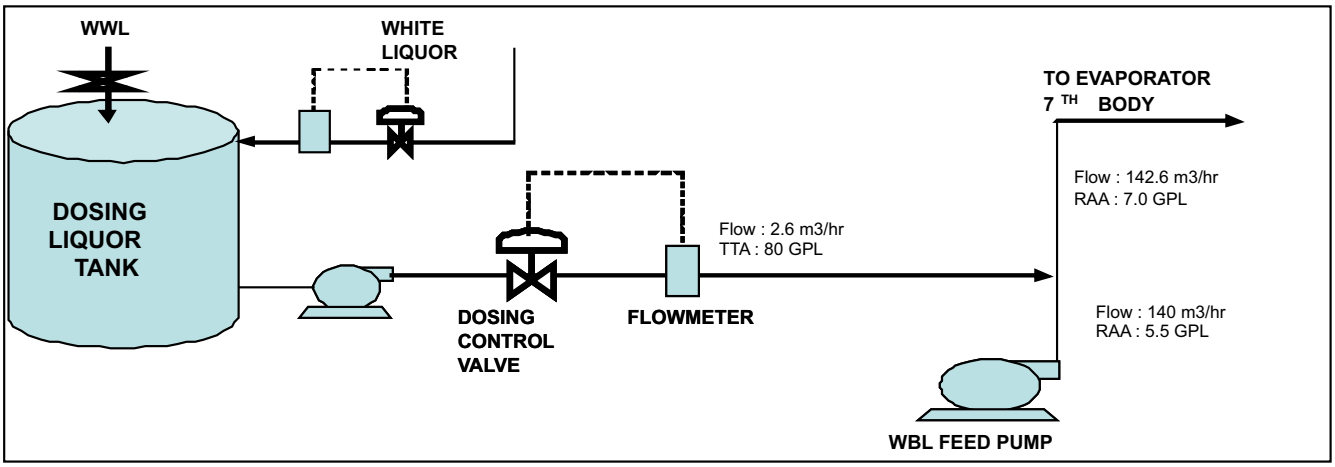
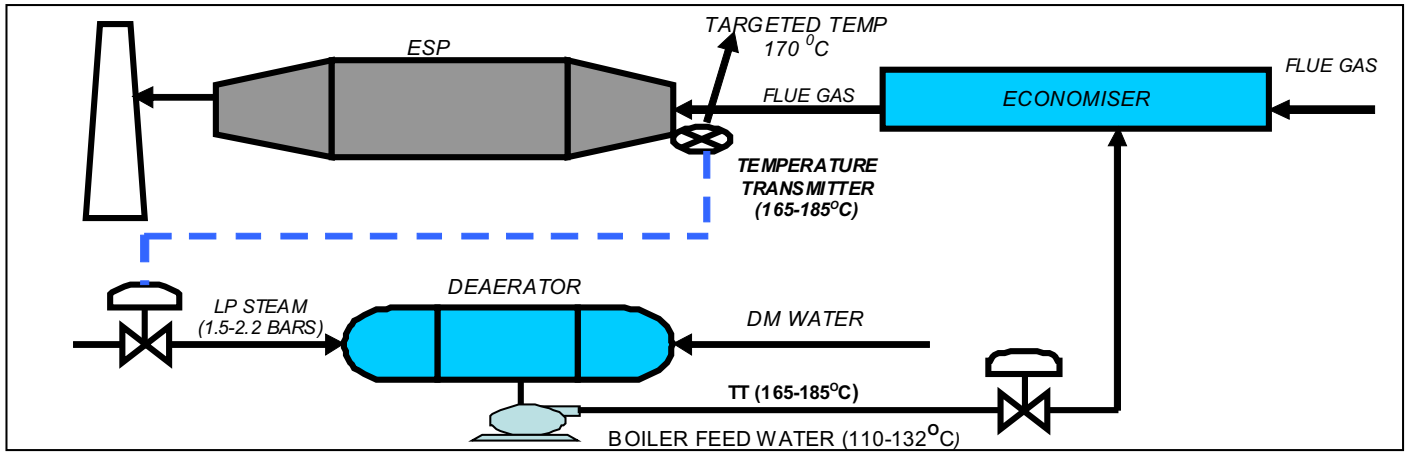


2. Auto Controlling of the ESP inlet temperature with the Deaerator temperature thru the DCS:

Variable cost of the Rec-2 unit is very less as compared to Rec-1 as discussed earlier. To take the advantage of the same we are keeping the processing through the Rec-2 at maximum. One of the limitations we are facing at the high ESP inlet temp of flue gas at loading more than design. Disadvantages of the same are poor ESP performance & heat loss through the flue gas. To counter the same, we have linked the same with deaerator temperature i.e. high FG temp will give low temp/pressure set point in the deaerator, so that extra heat can be transferred to low temp feed water in the economizer zone. System is running successfully with proper interlocks from last 3 years & we are able to control the ESP inlet temp in the range of 160-175 ^{0}C which was earlier going up to 190 ^{0}C.

3. Utilizing the RB condensate flash vapor for Preheating the Secondary Air:

Earlier the flash steam from the flash tank was getting vented into atmosphere. That was leading to the energy loss



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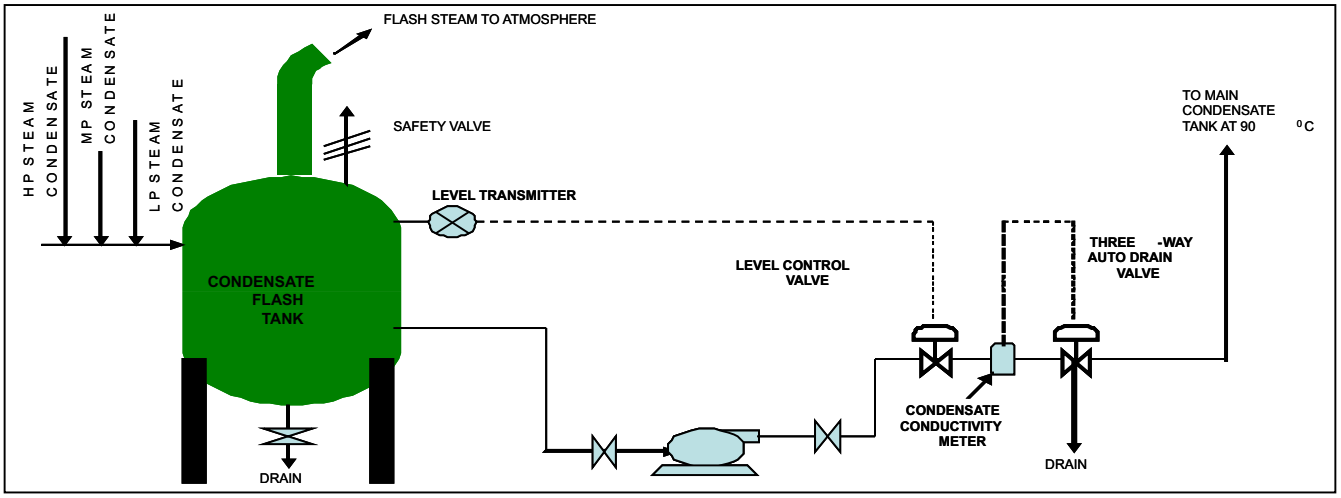

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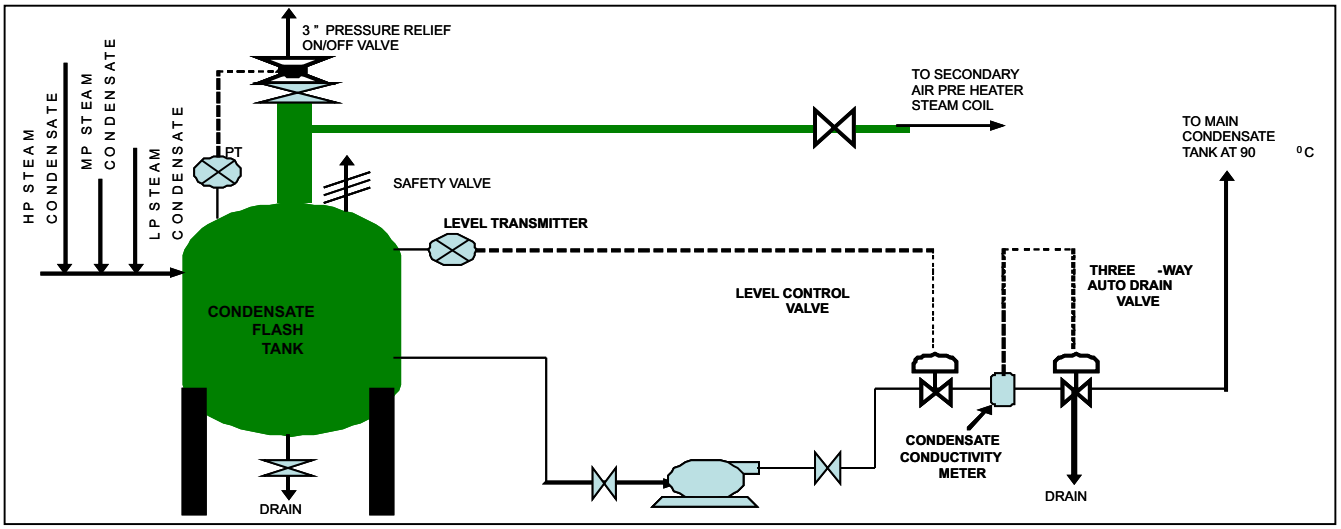

into atmosphere & also causing problem of the corrosion of the RB structures. Team took the challenge to use the energy in the flash vapor being escaped into atmosphere. After studying the system & with proper safety/interlocks, the flash tank was pressurized & vapor was used in the SA SCAPH in place of LP steam. The same resulted into significant saving of the steam (approximately 24 MT/day of LP steam) in addition to reduction in the corrosion of the boiler structural material. System is running in the auto mode from the DCS requiring no manual intervention & same is running successfully for last three years.

4.Utilization of the Evaporator primary condensate into the deaerator directly resulted into steam/power saving

The Evaporator primary condensate or live steam condensate is directly pumped to the boiler Deaerator. This enables the recovery of condensate at a higher temperature without the loss of flash steam that was being incurred in the main condensate tank. Normal temperature of the feed DM water was 80-90°C before implementation. Now the condensate which is attained at a temperature of about 100-105 °C goes directly to the Deaerator. However there are protections in the form of three way auto drain valve which may open at higher conductivity.

5.Increasing reliability of Boiler through self reliance in MP steam

One of the most vital utilities required to run the Recovery boiler is the medium pressure (MP) steam at a pressure of 9-10 bars. MP steam is needed for heating Black liquor, combustion air and furnace oil besides atomizing needs of liquor firing guns and oil burners. A pipeline tapping was taken from the line which branches out of the main steam line for supplying HP steam to soot blowers and the primary fan air heater. The tapping was provided with a Pressure reducing and de-superheating station (PRDS), to reduce the pressure of HP steam to 10bars and de-superheat to the appropriate temperature. Whenever there is a sharp fall in the MP steam pressure or ingress of high quantities of condensate with steam, the PRDS is utilized. The same is however not used frequently, but at occasions when the supplied MP steam cannot sustain the boiler at bare minimum rates of operation.

Future Action Plan for meeting the Environment challenges

1. ESP Modification

We are working on upgrading the ESPs of the RB's to meet the new emission norms set by CCPB. For the same, Trident has conducted the study of the same in collaboration with Ionization Filtration ltd for the RB-2 ESP. Purpose of the same was to meet the environment norms of < 75 mg/Nm3 at increased firing capacity of 450 TdsPD.

2. Up-gradation of the existing evaporator capacities to reduce the steam consumption & gear up for increased Pulp Production:

The same is being taken in two steps

- **Increasing the capacity of more efficient Evaporator-2**

  i. Increasing the Heat transfer area of the individual bodies by addition of tubes (Provision kept during design phase for adding 10 % extra area) - Completed
  ii. Installation of the one more finisher body to increase the production rate will be completed by Sept-12
  iii. Installation of the on-off valves for 2nd effect for weak white liquor online washing will be completed by July-12

The above steps will lead to increased feeding of the Recovery Boiler-1 through the Evaporator-2 to reduce the overall cost of White Liquor production

- **Up gradation of the Evap-1 street for higher steam economy & higher outlet concentration by addition of one more effect**

  The same will lead to drastically reduction into steam consumption in the evaporator. The same will also help in consistent firing of the more concentrated liquor in the RB-1 (> 70 % conc.) that will further improve the boiler performance & ESP performance by reduction in the moisture content of flue gas.

Conclusion

Although there is big challenge involved in handling the straw based liquor & problems associated due to presence of high silica & high NPE's but with the systematic & disciplined approach we can counter/overcome these challenges. Major challenge is to maintain the right quality & quantity at evaporator stage which smoothen the things to a great extent in the downstream process. As evaporator is major energy consumer, the efficient running of this section can hugely cut down the cost factor.

We can summarize to below points that requires focused attention for meeting the challenges

1. Residual Active Alkali should be constantly monitored/controlled in the incoming WBL & Feed to Evaporator
2. Viscosity should be constantly monitored/controlled in addition to the density of the concentrated product to take care of any changes in the WBL characteristics
3. Strict adherence to the cleaning of the HP Cleaning of the Evaporator Section & cross checking/full proof examination of the cleaned surfaces
4. Vacuum should be maintained around 660 mmHG & any leakages/drop in vacuum should be immediately addressed. Efficient operation of the Cooling water circuit (Cooling tower & Condensers) should be ensured
5. Firing liquor solids should be consistently marinated above 66 % & parameters to be adjusted to maintain the furnace stability
6. Strict adherence to the efficient Soot blowing operation & ESP inlet temp to be controlled to maintain ESP performance & reduce heat losses through Flue gas.
7. Consistent & automated control of the lime mud withdrawal helps in great way in maintaining the right quality & production output with minimum alkali losses
8. Online green liquor density measurement & auto changeover of GL & weak white liquor lines helps the operative team to maintain the required WL quality & consistent product output.

In the end, we can say that with systematic approach coupled with automation/DCS operation to keep track of the critical parameters (to get timely feedback & to minimize the human error), straw based recovery can be operated efficiently & economically.

Acknowledgment

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