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EXPERIENCES OF REDUCING STEAM CONSUMPTION IN A SUGAR PLANT

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Abstract

In the Indian sugar industry steam consumption is a vital parameter as the steam saving will be converted into either power for export or a saving in bagasse which will be sold at a high price. Steam conservation therefore plays a vital role in the Indian sugar industry. Since the cane price is rising continuously, the margin from sugar is narrow and power export is inevitable to run the sugar industry profitably.

The paper deals with innovative ways to reduce the steam consumption by utilising low vapour heat for pan boiling, waste heat recovery for juice heating, molasses conditioning and condensate flash steam recovery.

Keywords: waste heat recovery, molasses conditioning, low vapour heating, condensate flash steam recovery

Introduction

Normally in India, the factories are operating at a steam % cane in the range of 40 - 50 %. It is vital to reduce the steam % cane to the absolute minimum which will lead to increased power for export or savings in bagasse consumption. At present, steam reduction is a must to improve the bottom line. Various energy efficient heat loops were introduced at the Shree Tatyasaheb Kore Sahakari Sakhar Karkhana Ltd in Warananagar, Maharashtra, India, and the steam consumption was reduced from 460 kg of steam per ton of cane to 360 kg of steam per ton of cane crushed.

Plant Operating Conditions Prior to Steam Economy Measures and Modifications

The Shree Tatyasaheb Kore Warana Sahakari Sakhar Karkhana Ltd. (Warana Sugar Co-Operative) is a renowned co-operative sugar factory in India promoted by the late Tatyasaheb Kore. There are two co-generation boilers with the capacity of generating 120 tons of steam per hour (TPH) and one small bagasse fired boiler of 40 TPH capacity (to make up steam required) to run the sugar plant at 8 500 tons cane per day (TPD) capacity along with a 60 kilolitres per day (KLPD) distillery, and refinery at a lower capacity of 150-200 tons sugar per day due to lower steam availability. The evaporator configuration is a quintuple effect with the vapour bleeding arrangement shown in Table 1. The existing heat and mass balance is shown in Figure 1.

Table 1. Existing heat loop

S. No.	DESCRIPTION	HEATING MEDIA	TYPE	TEMP. RANGE
I	**Raw Juice Heating**			
1	1st Stage	5th Effect	Vapour Line Juice Heater	30 °C to 38 °C
2	2nd Stage	Condensate	PHE	38 °C to 40.8 °C
3	3rd Stage	2nd Vapour	Tubular heater	40.8 °C to 71 °C
II	**Sulphited Juice Heating**			
1	1st Stage	2nd Vapour	Tubular Heater	70 °C to 85 °C
2	2nd Stage	1st Vapour	Tubular Heater	85 °C to 102 °C
III	**Clear Juice Heating**			
1	1st Stage	1st Vapour	Tubular Heater	Up to 104 °C
IV	**Pan Boiling**			
1	A-Massecuite	2nd Vapour	Batch Pan	
2	B- Massecuite	2nd Vapour	Continuous Pan	
3	B1 – Massecuite	2nd Vapour	Continuous Pan	
4	C- Massecuite	1st Vapour	Continuous Pan	
V	**Others**			
1	Molasses Conditioning	2nd Vapour	Direct Contact	
2	Pan Body washing	Exhaust Steam		
3	B & C Melter	Clear Juice		
4	Super Heated Wash water (SHWW)	Medium Pressure		
5	Hot air Blower for sugar drying	Medium Pressure		
6	Sulphur Furnace			

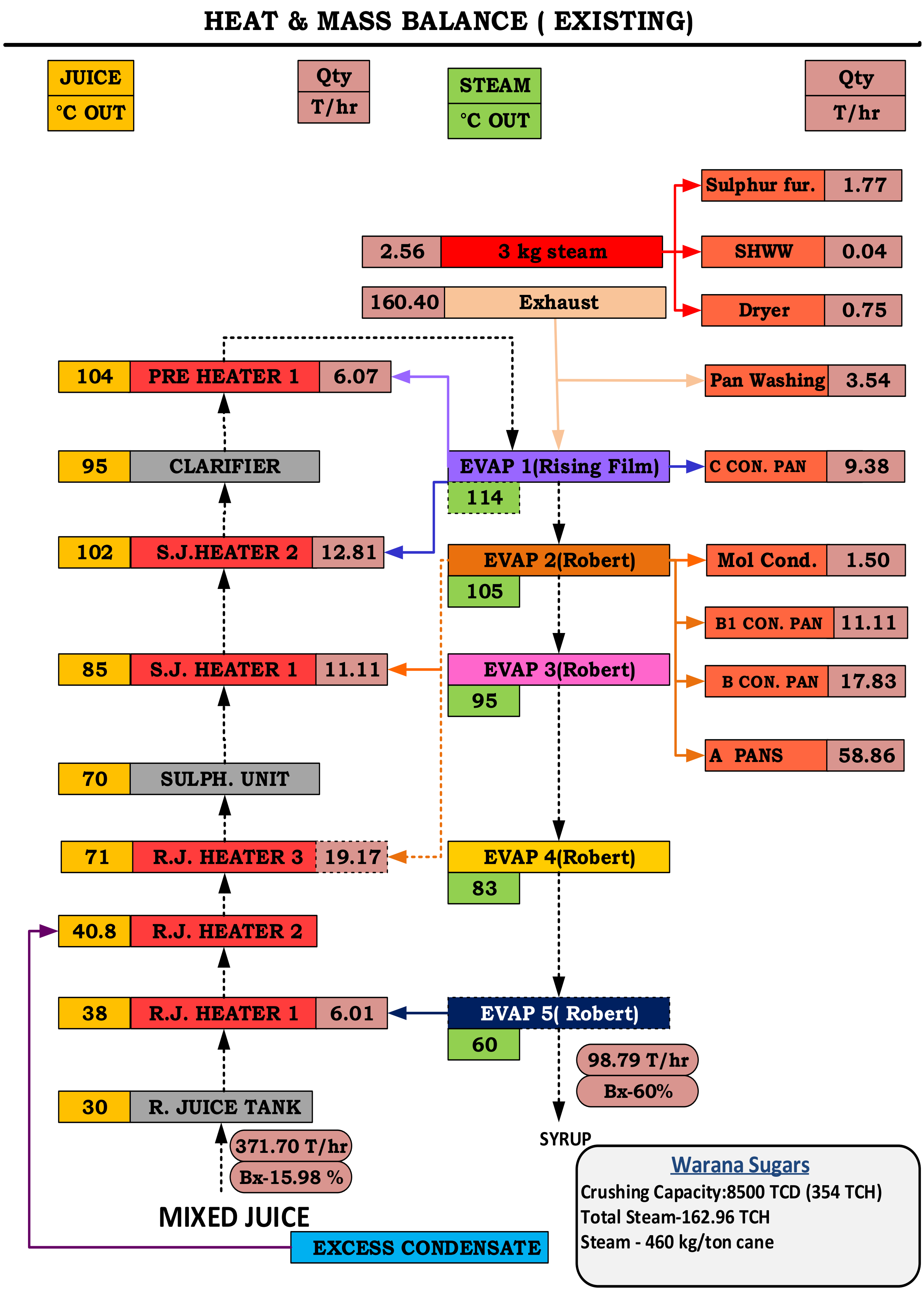


Figure 1. Existing heat and mass balance

The plant operating data are shown in Table 2.

Table 2. Plant Operating Data

S.NO	DESCRIPTION	DETAILS
1	Crushing Rate in TCD	8 500
2	Juice % Cane	105
3	Steam consumption in Kgs/ton of Cane Crushed	460
4	Total steam consumption (Sugar plant + Distillery+ Refinery) in Tons	163+31=194
5	Power Export in Kwhr	28 000
6	Distillery Production in KLPD	60
7	Refined Sugar Production per day in Tons	150-250
8	Bagasse Saving in Tons	Nil
9	Bagasse Saving in % Cane	Nil

Various Challenges Experienced by the Factory

Some of the challenges experienced with the evaporators and pans are mentioned below:

Evaporators:

1. Lower exhaust pressure due to higher steam demand;
2. There is no condensate flash steam recovery system in the plant;
3. Higher rate of evaporation in first two effects since there is no bleeding from 3rd and 4th effect;
4. Poor performance of first effect due to low Clear Juice temperature, i.e. 102 ºC to 104 ºC.
5. Higher vapours consumption for juice heating from initial effects leads to lower vapour availability for later effects;
6. Improper juice distribution in the inlets to the 2nd, 3rd, 4th and 5th effects. Due to improper juice distribution, the vapours are short circuited to the next effect along with juice. Juice coils are near the outlet and the sizes are incorrect. The cross sectional area of the juice distributors are 300 % more than required when compared to the juice inlet pipes. Due to this, juice is not distributing to the entire heating surface of the evaporator body. It is covering only a 28 to 30 % area which causes the fast fouling, hard scales and low rate of evaporation;
7. Improper non-condensable gas (NCG) withdrawal from 2nd, 3rd, 4th and 5th effects leads to poor evaporation; and
8. Improper steam and vapours piping connections lead to higher radiation and condensation losses. There are two rising film evaporators with a 2 000 m^2 heating surface used as the 1st effect of the quintuple set. The exhaust steam line from the Power Turbine to mills is 900 mm and it is connected to a 2 000 mm header. From the 2 000 mm header it is distributed into two branches of 1 300 mm to each evaporator 1st effect. The approximate length of pipe is 90 m. In addition, a 600 mm line is drawn from this header to the pans. Exhaust steam is used in the pans continuously.

Pans:

1. Grain pans are at a lower floor level and vacuum crystallisers of continuous pans are at a higher floor level. Complete transfer of grain is not possible in the present set up and any left-over grain was dropped in massecuite crystallisers which causes an imbalance of molasses purities;

2. The C-pan capacity is higher than the B-pan capacity. C-pan capacity is higher than the requirement whereas the B-pan capacity is lower than the requirement;
3. The massecuite gutters from the crystallisers to the centrifugal machines do not have a proper slope. Due to poor layout, massecuite crystallisers are far from the centrifugal machines. The flow of massecuite from crystalliser to feed mixer is difficult. Hence, water is added in the massecuite gutter to improve the fluidity of massecuite;
4. The venturi of the condenser and tail pipe sizing is incorrect and leads to lower vacuum in pans. Pans are boiled at +70 °C, causing high colour formation and lower exhaustion;
5. The injection water pump suctions are inefficient and unable to pump the desired quantity of water resulting in hot water overflowing from the channel as effluent, which leads to the addition of more makeup water; and
6. Continuous centrifugal machines are operating at lower load resulting in high stock levels, higher recirculation and higher molasses purity thereby resulting in a reduction in crushing rate. There is no automation in the continuous centrifugal machines for the massecuite feeding. Massecuite feeding is done in manual mode. Due to manual feeding, the continuous centrifugal machines are always operated at 60 % maximum load whilst the water addition is at maximum which is equivalent to the full capacity of machines, causing more crystal dissolution and higher molasses re-circulation.

Various Modifications and Installation of New Equipment for Steam Reduction and Higher Crushing Rate

Various modifications were carried out in order to improve the steam economy. Where required, new equipment was installed.

New Installations

1. Flash steam recovery system installed for High Pressure (HP) condensate and Low Pressure (LP) condensate;
2. Two stage direct contact heater installed for clear juice heating and clear juice temperature increased to 112 °C which improved the 1st effect evaporation rate;
3. Condensate heater battery installed for raw juice heating in the 2nd stage with LP and HP condensate water;
4. Direct contact heater installed for filtrate juice heating with clarifier flash vapour to utilise the waste heat which in turn reduces the steam required for sulphited juice heating in 1st stage;
5. A new 300-tons vertical crystalliser installed for C-massecuite cooling and the existing 70-tons air cooled crystalliser utilised for grain storage for B1 massecuite application; and
6. Auto feed control system installed in continuous centrifugal machine which improved the curing rate in centrifugals and reduced the molasses purity, factory stock and sugar recirculation. After this modification machines are operating at 98 % (+/- 2 %) capacity. As a result, two centrifugal machines were stopped completely and the molasses re-circulation reduced drastically. The overall impact on final molasses came to 0.12 % reduction. The purities remained constant.

Various Modifications

1. Entire exhaust piping re-designed to avoid pressure drop, condensation and radiation losses. Present exhaust header of 2 000 mm diameter, along with the 1 300 mm diameter section, was removed completely. The existing exhaust 900 mm pipe was connected to new 1 100 mm single pipe up to both the 1st effect evaporators. At the end of the 900 mm header, a 400 mm diameter pipe with an isolation valve which was connected to the pan vapour line. As and when evaporators are stopped, exhaust steam will be used for

pans from this line. After this modification, the exhaust condensate return was improved drastically, i.e. from 85 % to 95 % on steam quantity;

2. The entire juice coil was removed and redesigned with appropriate cross section area for proper distribution of juice. By doing these modifications, the evaporation rate improved which increased the operational duration of the evaporator set to 12 to 14 days whereas the earlier operational duration was five to six days between cleans. Due to the even juice distribution, there is no hard scale resulting in increased heat transfer coefficient in evaporators. There is no caramelised sugar observed in the tubes;
3. Air cooled crystallisers utilised for storing the grain for C-continuous pan;
4. Load on the first and second effect evaporator reduced by rearranging vapour bleeding for raw juice and sulphited juice heating from 3rd and 4th effect which improves the evaporation rate in 3rd and 4th effect;
5. Improper connection of NCG was fixed by re-designing of evaporators' NCG connections which improved the performance of the evaporator;
6. Redesigned and replaced all steam and vapours piping with proper sizes which balances the juice heating and pan boiling;
7. Existing C-continuous pan utilised for B massecuite application and the existing B-continuous pan utilised for C massecuite application according to their capacity requirement by rearranging molasses/massecuite discharge line;
8. Crystallisers and feed mixer are interconnected with proper slope pipe which improved the massecuite fluidity and totally avoids the addition of water in the massecuite gutter;
9. Condensers venturi and tail pipe sizing were redesigned which improved the pan boiling and the temperature maintained at 58 to 60 ^{0}C; and
10. Eliminated makeup water requirement for cooling tower by redesigning of cooling system spray pond pump suction line and channel.

Table 3 shows the modified heat loop and Figure 2 shows the energy and mass balance after the modifications.

Table 3: Modified Heat Loop

S. No.	DESCRIPTION	HEATING MEDIA	TYPE	TEMP. RANGE
I	**Raw Juice Heating**			
1	1st Stage	5th Effect	Vapour Line Juice Heater	30 °C to 45 °C
2	2nd Stage	Condensate	Specially designed Liquid Liquid Heat Exchanger by using HP & LP condensates	45 °C to 70 °C
3	3rd Stage	4th Vapour	Tubular heater Dynamic arrangement	70 °C to 73 °C
II	**Sulphited Juice Heating**			
1	1st Stage	3rd Vapour	Tubular Heater Dynamic arrangement	70 °C to 85 °C
2	2nd Stage	3rd Vapour	Direct Contact Type Heater	85 °C to 92 °C
3	3rd Stage	2nd Vapour	Direct Contact Type Heaters	92 °C to 102 °C
III	**Clear Juice Heating**			
1	1st Stage	2nd Vapour	Direct Contact Heater	95 °C to 102 °C
2	2nd Stage	1st Vapour	Direct Contact Heater	102 °C to 112 °C
IV	**Pan Boiling**			
1	A-Massecuite	2nd Vapour	Batch Pan	
2	B- Massecuite	2nd Vapour	Continuous Pan	
3	B1 – Massecuite	2nd Vapour	Continuous Pan	
4	C- Massecuite	2nd Vapour	Continuous Pan	
V	**Others**			
1	Molasses Conditioning	4th Vapour	Direct Contact	
2	Pan Body washing	1st Vapour		
3	B & C Melter	Clear Juice		
4	Super Heated Wash water (SHWW)	Liquid Liquid Heat exchanger	PHE	115 °C
5	Hot air Blower for sugar drying	1st Vapour		
6	Sulphur Furnace	Electrical Heating		

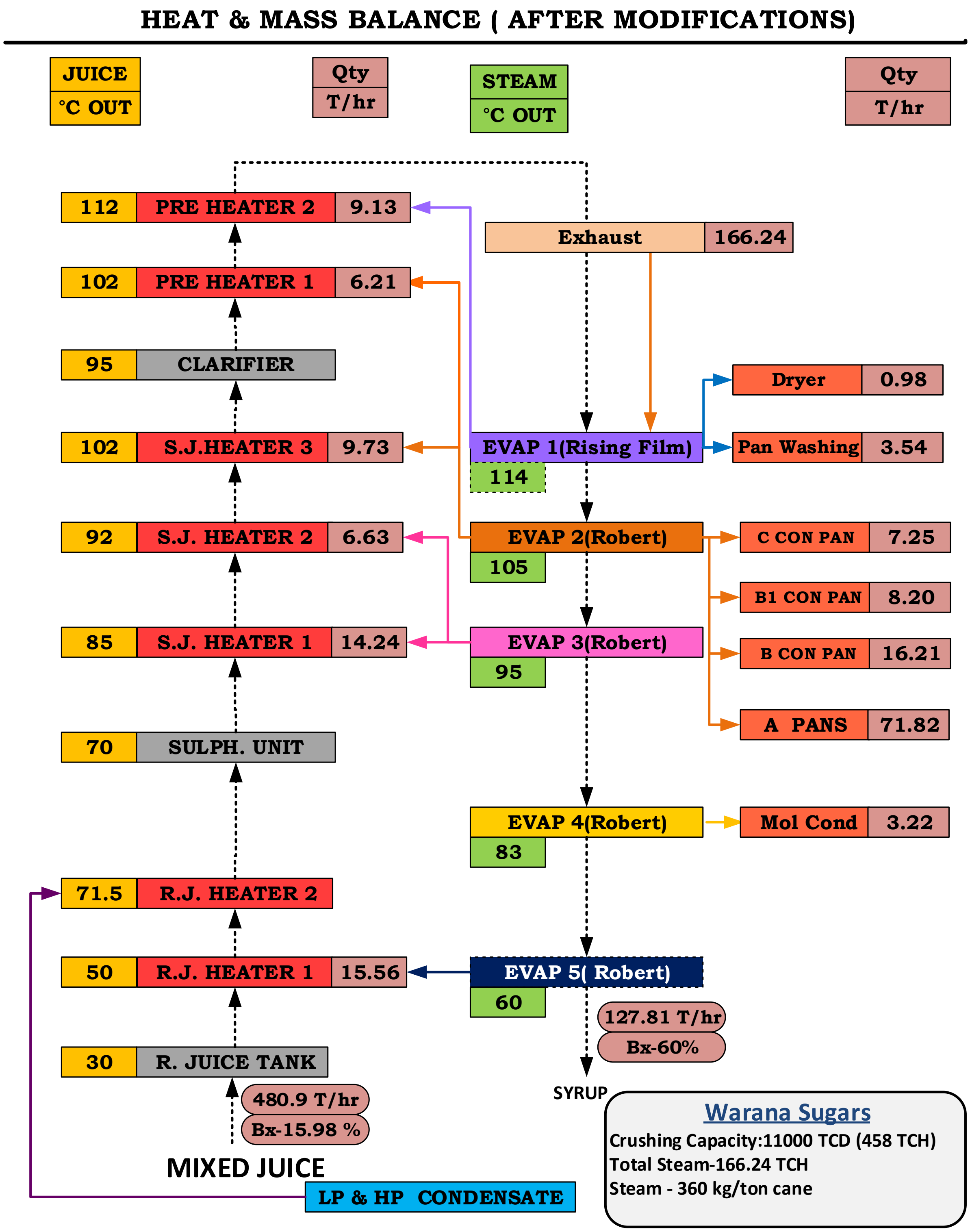
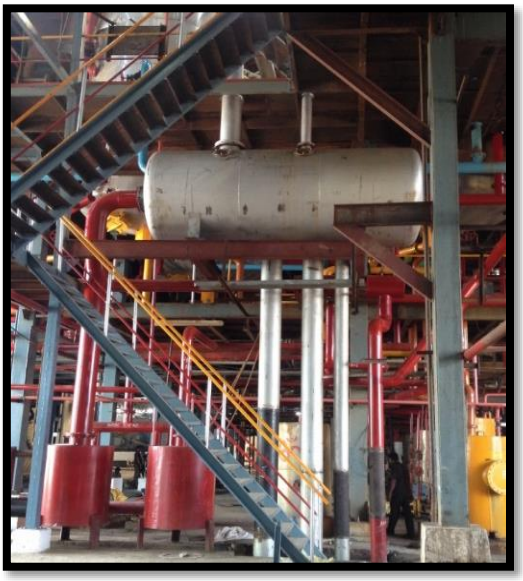


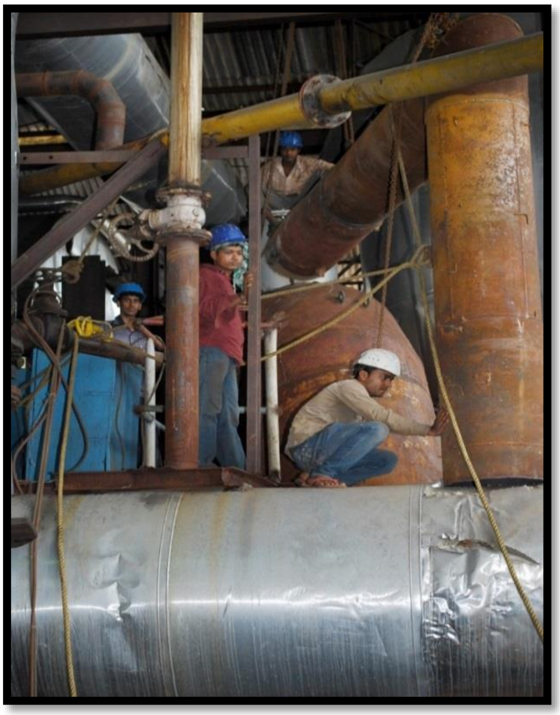
Figure 2. Energy and mass balance after the modifications

Figure 3 contains photographs of some of the project installations.

Condensate Heater Battery for Raw Juice heating 2nd stage



Condensate Flash Recovery System



Juice Heater Vapour Line Modifications

Condenser Venturi and Tail Pipe Modifications

Figure 3. Project Installation Photos

The changes in plant operating data is tabulated below:

Table 4. Comparison of Plant Operating Data before and after Modifications

S.NO	DESCRIPTION	BEFORE MODIFICATIONS	AFTER MODIFICATIONS
1	Crushing Rate in TCD	8 500	10 800
2	Juice % Cane	105	105
3	Steam consumption in Kgs/ton of Cane Crushed	460	360
4	Total steam consumption (Sugar plant + Distillery+ Refinery) in Tons	163+31=194	165+28=193
5	Power Export in Kwhr	28 000	28 000
6	Distillery Production in KLPD	60	60
7	Refined Sugar Production per day in Tons	150-250	350-400
8	Bagasse Saving in Tons	Nil	80 000
9	Bagasse Saving in % Cane	Nil	6.5

Other Benefits Achieved during this Crushing Season after the Modification.

1. Plant stable operation;
2. Higher cane crushed by 4 lakhs tons' of cane (in the previous year crushing was 9 lakhs tons and this year crushing was 13 lakhs tons).
3. Co-gen plant operated for more than two months extra after the crushing season stopped due to more bagasse saved as compared to zero savings in the earlier year; and
4. Reduction in molasses purity, improvement in crushing rate due to auto feed system for continuous centrifugal machine.

Disadvantages

1. Lower yield in distillery due to lower purity of final molasses.

Important Criteria for Steam Reduction

Criteria for steam reduction is not only the installation of steam saving devices but mainly depends upon:

1. Technical study of the plant;
2. Debottlenecking of existing plant equipment short falls;
3. Identification of waste heat;
4. Identification of required correct equipment and integration of the proposed devices into the existing system;
5. Improvements to evaporator station by optimising the heating surface;
6. Identifying and rectifying the deficiencies in the evaporator design/erection and improving the evaporation rate by optimising the operating temperature; and
7. Improvement in pan boiling with a reduction in the sugar and non-sugar recirculation.

The above factors are very important to achieve the targeted steam % cane.

Future Opportunities

There is further scope to reduce the steam % cane by installing the Falling Film Evaporator and modifying the vapour bleeding system. By operating the evaporator at elevated temperature even the condensate shall be effectively utilised for juice heating. With these arrangements the steam consumption could be reduced to 300 kg/ton of cane crushed.

Conclusions

Steam reduction in a phased manner will help to ease integration and operation to achieve the best results. In the present scenario, steam reduction is vital to operate the sugar business in a viable manner either by exporting power or selling bagasse. Apart from that steam reduction is the best tool to increase the crushing capacity without investing money in a boiler and power house, especially for a co-generation plant. In the expansion project, the major investment will be for the co-generation plant. If steam is saved with various energy efficient heat loops, the same plant can increase its capacity with minimum investment.

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We thank the management of Warana Sugars for providing the opportunity to install the various steam economy devices and cooperation for successful commissioning of the system.