CRYSTALLIZATION WITH FOURTH EFFECT FALLING FILM EVAPORATOR TO ENHANCE POWER GENERATION

Verma Vivek

ABSTRACT
Cogeneration is known to be thermodynamically efficient utilisation of fuel where its thermal energy is used to generate electricity as well as use part of remaining heat energy to meet the process requirements. The author through this paper explained how to enhance power generation by crystallization with fourth effect falling film evaporator using innovative approach & efficient technologies and gives true example through Dhanalakshmi Srinivasan Sugars, Tamil Nadu which is one of its kinds of plant that was designed much efficient that; it is exporting electric power at the rate of 100 kW/Ton of cane.

Keywords: Cogeneration, Evaporation, Continuous Crystallization, Refined Sugar, Colour Value, Massesuite Boiling, Flashing System.

INTRODUCTION
In the last two decades many sugar mills started practicing co-generation and contributing in reducing the energy deficit that India is currently facing. But many mills are unable realise the benefits of co-generation for which it is intended for. There are several factors contributing to the issue. However apart from the non-technical factors there exist several technical factors which need to be addressed. The time has come for the implementation.

KEY FACTORS
The key areas which have major impact on enhancing power export are:
1. Reduction in use of process thermal energy with optimized vapour bleeding scheme.
2. Reduction in in-house electrical power consumption.
3. Recovery of waste heat from all streams for use in process or power generation.
4. The installation of more efficient cogeneration systems.
5. Installation of energy efficient equipment in the process house.
6. Optimization of process layout and operational parameters.

So one’s thrust should be on minimization of the steam requirement for sugar processing through efficient vapour bleeding by most suitable selection of evaporator type and size.

SYSTEM CONFIGURATION AND ACHIEVEMENTS
A live example on embracing various technologies which are implemented in Dhanalakshmi Srinivasan Sugars Pvt. Ltd., Tamilnadu are reflected next, that led this
plant much efficient. The current steam demand of the plant is 31-34% on cane and achieved highest exporting power range i.e.100-105kW/Ton of cane.

Steam is consumed directly or indirectly mainly in two areas of the sugar processing i.e. evaporation and crystallization. This paper presented different techniques to enhance cogeneration with minimum steam consumption in sugar factories in order to make the sugar factory more profitable by increasing the power export.

This plant operates at 110 ata, 540°C cycle with one 110 TPH boiler and 23 MW Power Generation capacity with Sulphur-Free Refined Sugar production. Apart from the steam economy and power generation milestones of this plant has few more special features.

- A modern 2 roller 4-mill tandem plant with electrical drives and an inline shredder.
- The clarification is Sulphur free with only defecation followed.
- A modern boiling house with a combination of Falling Film Evaporators (FFE$s$), Direct Contact Heaters, Vertical Continues Pan for A, B, C, R1 and R2 Massecuite boiling with Melt Clarification system.
- CIP system with full automation in line FFE$s$.
- Steam and vapour balance done to achieve 31% process steam consumption on cane.

- 40% savings on power consumption by the advanced AC-VFD Motors in the process plant over the conventional systems.
- Fully automated Sugar and Co-Generation units with DCS controls.
- State of art cooling and condensing system with gravity inflow cooling towers.

The achievement of the plant lies in the process house especially the evaporation and crystallization, in this plant the systems were designed and implemented to ensure its supremacy in achieving the performance.

A. Evaporator Station

Concentration of cane juice to saturation point alone consumes major portion of total energy demand. The quantum of steam used for this purpose is very significant for co-gen. Optimized selection of total temperature difference and number of effects reduces a lot the sinking of the energy in this section.

Making availability of more numbers of streams for process heating and that too at required temperature & pressure, do phenomenal improvements in the sugar process.

Typically, more is the number of evaporator effects; greater will be the steam economy. The evaporator station in this plant was designed to deliver 0.65-0.70 absolute bar pressure to pans and that too from 4th effect vapours. The whole thing that lies behind all this happening is by crystallization
with fourth effect of Falling Film Evaporators (FFEs). Falling Film Evaporator contrary to Rising Film and Robert type evaporator can be easily operated with very low ΔT i.e. as low as 3-4°C. FFEs as acting as the backbone for the efficiency levels that plant is achieved.

Extensive vapours coming out of the different effects of the evaporators are used for juice heaters and vacuum pans. FFEs making whole evaporation station as amalgam of efficient bleeding system along with flashing system with enhancing flash recovery are making the plant high energy efficient & reduced steam demand. The efficient distribution of liquid for constant wetting of heating tubes with juice is well taken care for a trouble-free operation of a Falling Film Evaporator. The FFE with hi-tech cascade distributor design forms a thin and even film of feed solution at inner surface of the tube maintaining positive juice circulation. The competent design modification of falling film evaporators and its distributor design helped in achieving marvelous consequences in this plant. The evaporator station setup at this plant is as under:

- Quintuple Evaporator station with all identical Falling Film bodies (7 Nos. x 1500 m²).
- Condensate Flash Vessel System with flashing off vapours from hot condensate to be further utilised for juice evaporation. Parallelly it eliminated the condensate pumps of individual steam/vapours consumers. Direct Contact Juice Heaters (DCH) for Raw, Defecated and Clear Juice & Syrup heating in vary close approach.
- Single Floating Evaporator for cleaning all effects.
- Working temperature range of the evaporator is 125°C to 75°C.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Evaporator Effects</th>
<th>Operating Pressure</th>
<th>Operating Temp. (°C) (bar A)</th>
<th>Operating Temp. Difference (ΔT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st Effect</td>
<td>1.8-1.9</td>
<td>118-120</td>
<td>6-8°C</td>
</tr>
<tr>
<td>2</td>
<td>2nd Effect</td>
<td>1.3-1.4</td>
<td>110-112</td>
<td>8.9°C</td>
</tr>
<tr>
<td>3</td>
<td>3rd Effect</td>
<td>0.9-1.0</td>
<td>98-102</td>
<td>7-10°C</td>
</tr>
<tr>
<td>4</td>
<td>4th Effect</td>
<td>0.6-0.65</td>
<td>93-96</td>
<td>5-7°C</td>
</tr>
<tr>
<td>5</td>
<td>5th Effect</td>
<td>0.35-0.40</td>
<td>75-78</td>
<td>12-15°C</td>
</tr>
</tbody>
</table>

Table 1: Present operating parameters of evaporator station.
The bleeding scheme is the heart of evaporator station where lot of energy can be saved for enhance power generation capacity specifically by operating crystallization part using fourth effect vapours of falling film evaporator.

Dhanalakshmi Srinivasan Sugars Pvt. Ltd. entire juice heating was only with direct contact heaters (DCH) (no tubular, no PHE).

a. Mixed Juice is two stages heating, first with Pan Vapors followed by 5th effect
vapour. These two stages heating raise the juice temperature at 70-74°C.

b. Limed Juice is in three stages all through DCH using 4th, 3rd & 2nd effect vapour.

c. Clear juice is single stage using 2nd effect vapour.

d. All crystallization part is taken by Vertical Continuous Vacuum Pan (SCP®) which is operating with 4th effect vapour of falling film evaporator.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Configuration</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MJ 1st Heating</td>
<td>Pan Vapour</td>
<td>54-57 0C</td>
</tr>
<tr>
<td>2</td>
<td>MJ 2nd Heating</td>
<td>5th Effect Vapour</td>
<td>74-77 0C</td>
</tr>
<tr>
<td>3</td>
<td>DJ 1st Heating</td>
<td>4th Effect Vapour</td>
<td>86-89 0C</td>
</tr>
<tr>
<td>4</td>
<td>DJ 2nd Heating</td>
<td>3rd Effect Vapour</td>
<td>96-99 0C</td>
</tr>
<tr>
<td>5</td>
<td>DJ 3rd Heating</td>
<td>2nd Effect Vapour</td>
<td>107-110 0C</td>
</tr>
<tr>
<td>6</td>
<td>CJ 1st Heating</td>
<td>2nd Effect Vapour</td>
<td>107-110 0C</td>
</tr>
<tr>
<td>7</td>
<td>All Pans (A, B, C &amp; R)</td>
<td>4th Effect Vapour</td>
<td>86-89 0C</td>
</tr>
</tbody>
</table>

Table 2: Vapour bleeding arrangement

The said bleeding scheme has reduced the steam consumption at 31.0-34.0% on cane and enhanced the power generation capacity.

B. Crystallization

Crystallization is another major energy intensive area. This section, further have significant effect on the efficiency of the plant.

But in Dhanalakshmi Srinivasan Sugars all are Vertical Continuous Vacuum Pan (SCP®) so the demands are of minimum possible steam pressure for massecuite boiling. Lower pressure requisite for this plant for pan bleeding have made higher impact on the co-gen.

Continuous pans are characterized by constant boiling point and constant heating surface to volume ratio in contrast to batch boiling where temperature increases with boiling. In low pressure operation pans tube temperature does not increase much and also improves sugar quality beside thermal energy benefits there are quality benefits as well.

The effect of low pressure boiling on sugar quality of Dhanalakshmi Srinivasan Sugars is that their refined sugar colour is only 33-34IU. The SCP® configurations of pans are efficiently making optimizing evaporative crystallization of sugar solutions. SCP® has shown high efficiency without any compromise on the process parameters.
Vertical continuous pan is easily operated at very low AT i.e. as low as 20-25°C. Vertical continuous vacuum pan played a significant role in the reduction of energy consumption and to enhance power generation that plant is achieved.

The installed vacuum pan for various massecuite boiling is as under:
- All three Vertical Continuous Vacuum Pan (SCP®) for A, B, C, R1 & R2 massecuite boiling with complete automation.
- Molasses Conditioner for AH, BH, CL and R1 molasses of direct contact heating type.
- 2 nos. of Seed Crystallizer of 20T for A and B Seeds.
- 2 nos. of Grain Crystallizer of 30T for B and C Grain.
- 5 nos. of supply tanks of 2 for syrup & melt and 3 for molasses storage.

Figure 2: Pan Station
The process engineering design of the plant have made significant impact on various aspects of factory operation and equipment usage and finally to power generation and export. This design together depresses the utility requirements to a greater level in the sugar process house. Middle pressure steam requirement is eliminated. Furthermore, all these together alter the co-gen in an encouraging way such that the total electricity generation of the plant gets increased by 9-12% if compared with other factories operating in the vicinity.

Other remarkable parameters of this plant are as under:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Unit</th>
<th>SEASON WISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plant Crushing Rate</td>
<td>MT</td>
<td>3200</td>
</tr>
<tr>
<td>2</td>
<td>Power Consumption per ton of Cane</td>
<td>kWh/T</td>
<td>29.40</td>
</tr>
<tr>
<td>3</td>
<td>Sugar Colour (Season average)</td>
<td>IU</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Season wise parameters

Figure 3: Cogeneration Unit
RESULT AND DISCUSSIONS

A lot of opportunities for energy saving exist in the sugar industry and there is need to exploit these for better performance. It is imperative for cogeneration to be adopted in the industry to increase electricity output and to make better use of process steam through optimised bleeding arrangement supported by efficient evaporators and continuous pans. The deployment of energy efficient equipment and technology for the improvement of co-generation can entirely change the present scenario of sugar factory.

Increasing power export beyond present level of 70-80 kWh/Ton to 100-110 kWh/Tons, it becomes very important for profitability of this industry.

This concludes that 12% of total electricity generation can be enriched by correction in energy management system as a ultimate measure in the efficiency improvement of sugar plant. Adopting such technology and idea, the sugar infrastructure will have enough power to cater the energy demand of themselves and their vicinity.

FURTHER SCOPE

There is further scope of improvement in power co-generation with addition & balancing of energy efficient equipment & technology like bagasse dryer, flue gas heat recovery, exhaust condensate heating.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>UOM</th>
<th>Jan-2016</th>
<th>Feb-16</th>
<th>Mar-16</th>
<th>Apr-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Generation per Ton of Cane</td>
<td>kWh/T</td>
<td>135.96</td>
<td>128.11</td>
<td>135.85</td>
<td>135.35</td>
</tr>
<tr>
<td>Power Consumption per Ton of Cane</td>
<td>kWh/T</td>
<td>32.5</td>
<td>29.81</td>
<td>31.86</td>
<td>30.14</td>
</tr>
<tr>
<td>Power Export per Ton of Cane</td>
<td>kWh/T</td>
<td>103.46</td>
<td>99.3</td>
<td>103.99</td>
<td>105.21</td>
</tr>
</tbody>
</table>

Table 4: Month wise cogeneration details