Chapter - III
Case studies:

This chapter includes 16 actual case studies, which have been implemented successfully in the Indian sugar Mills.

Each of the individual case studies presented in this chapter includes.

- A brief description of the equipment / section, where the project is implemented.

- Description of energy saving project.

- Implementation, methodology, time frame and problems faced during implementation (if any)

- Benefits of energy saving project

A diagram of the project is also included, wherever applicable.

The data collected from the plant is presented in its entirety. However the name of plant is not revealed to protect the identity of plant. Other units also to achieve the benefits can implement similar projects.
Installation of 30 MW commercial co-generation plant

Background

The Indian sugar Industry by its inherent nature can generate surplus power, in contrast to the other industries, which are only consumers of energy. This is mainly because of the 30% fibre content in the sugar cane used by the sugar mills. This fibre, referred to as bagasse, has good fuel value and is used for generation of the energy required for the operation of sugar mill.

The bagasse is fired in the boiler for producing steam at high pressure, which is extracted through various backpressure turbines and used in the process. The simultaneous generation of steam and power commonly referred to as Co-generation. Conventionally, the co-generation system was designed to cater to the in house requirements of the sugar mill only. The excess bagasse generated was sold to the outside market.

In the recent years, with the increasing power ‘Demand Supply’ gap the generation of power from excess bagasse was found to be attractive. This also offers an excellent opportunity for the sugar mills to generate additional revenue. Co-generation option has been adopted in many of the sugar mills, which substantial additional revenue for the mills. This also contributes to serve the national cause in a small way, by bridging the ‘Demand supply’ gap.

Previous status

A 5000 TCD sugar mill in Tamilnadu operating for about 200 days a year had the following equipments:

- Boilers
  - 2 numbers of 18 TPH, 12 ATA
  - 2 numbers of 29 TPH, 15 ATA
  - 1 number of 50 TPH, 15 ATA

- Turbines
  - 1 number 2.5 MW
  - 1 number 2.0 MW
  - 1 number 1.5 MW

- Mill drives
  - 6 numbers 1000kW steam turbines
  - 1 number 1200kW shredder turbine
The plant had an average steam consumption of 52%. The power requirement of the plant during the sugar-season was met by the internal generation and during the non-season from grid.

Energy saving project:

The plant went in for a commercial co-generation plant. The old boilers and turbine were replaced with high-pressure boilers and a single high capacity turbine.
A provision was also made, for exporting the excess power generated, to the state grid. The mill steam turbines, were replaced with DC drives. The details of the new boilers, turbines and the steam distribution are as indicated below:

- **Boilers**
  - 2 numbers of 70 TPH, 67 ATA
  - Multi fuel fired boilers.

- **Turbines**
  - 1 number of 30 MW turbo-alternator set
  - (Extraction cum condensing type)

- **Mill drives**
  - 4 numbers of 1200 kW DC motors for mills
  - 2 numbers of 1000 kW DC motors for mills
  - 2 numbers of 1100 kW AC motors for fibrizer

**Implementation methodology, problems faced and time frame**

Two high capacities, high-pressure boilers and a 30MW turbine were installed in place of the old boilers and smaller turbine.

While selecting the turbo generator, it was decided to have the provision for operation of the co-generation plant, during the off-season also. This could be achieved by utilizing the surplus bagasse generated during the season, as well as by purchasing surplus bagasse from other sugar mills and biomass fuels such as groundnut, shell, paddy husk, cane trash etc.

The shortfall of bagasse during off-season was a problem initially. The purchase of biomass fuels from the nearby areas and the use of lignite solved this problem.

The entire project was completed and commissioned in 30 months time.

**Benefits**

The installation of high-pressure boilers and high-pressure turbo-generators has enhanced the power generation from 9 MW to 23 MW. Thus, surplus power of 14 MW is available for exporting to the grid.

The following operating parameters were achieved:

- Typical (average) crushing rate $= 5003$ TCD

- Typical power generation
  - During season $= 5,18,231$ units/day
- During off season = 2,49,929 units/day
- Typical power exported to the grid
- During season = 3,18,892 units/day (13.29 MW/day)
- During off season = 1,97,625 units/day (8.23 MW/day)
- Typical no. Of days of operation = 219 days (season)
  = 52 days (off season)

The summary of the benefits achieved (expressed as value addition per ton of bagasse fired) is as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Previous status (low pressure boiler system)</th>
<th>Present status (high pressure boiler system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagasse quantity</td>
<td>TPH</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Steam quantity</td>
<td>TPH</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>ATA</td>
<td>14</td>
<td>67</td>
</tr>
<tr>
<td>Power generation</td>
<td>kW</td>
<td>158</td>
<td>382</td>
</tr>
<tr>
<td>Extra power generated</td>
<td>kW</td>
<td>-</td>
<td>224</td>
</tr>
<tr>
<td>Steam quantity available for process</td>
<td>TPH</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Steam pressure available for process</td>
<td>ATA</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Steam on cane</td>
<td>%</td>
<td>52</td>
<td>45</td>
</tr>
</tbody>
</table>

Financial analysis

The annual monetary benefits achieved are Rs. 204.13 million (based on cost of power sold to the grid @ Rs 2.548 / unit, sugar season of 219 days and off season of 52 days). This required an investment of Rs 820.6 million. The investment had an attractive simple payback period of 48 months.

Note:

Critical factors affecting power generation

The efficient operation of a co-generation system depends on various factors. This has a direct bearing loss in power generation had the power exported to the grid.
Some of these critical factors affecting the power generation (quantified as loss in generation per day) are as follows:

- 1% drop in bagasse % in cane: 18300 units
- 1% increase in moisture content in bagasse: 6800 – 10200 units
- 1% increase in process steam consumption: 4200 units
- 1% drop in crushing rate: 5000 – 7400 units
- 1-hour downtime: 20600 units

The above figures are based on the following operational parameters:

- Crushing rate: 5000 TCD
- Steam – bagasse ratio: 1:2.2
- NCV of bagasse (50% moisture): 1804 kCal / kg
- Bagasse content in % cane: 27%

![Commercial co-generation plant](image-url)
Case Study – 2

Replacement of steam driven mill drives with electric DC motors

Background

Conventionally, steam turbines are used as the prime movers for the mills in a sugar industry. These steam turbines are typically single impulse type turbines having about 25 – 30% efficiency.

The recent installation of commercial co-generation system with provision for selling the excess power to the grid has made the generation of excess power in a sugar mill very attractive. One of the methods of increasing the co-generation power in a sugar mill is to replace the smaller efficiency drives such as DC motors or hydraulic drives.

The power turbines (multi-stage steam turbines) can operate at efficiencies of about 65 – 70%. Hence, the equivalent quantity of steam saved by installation of DC motors or hydraulic drives, can be passed through the power turbine to generate additional power.

This replacement can aid in increase of net saleable power to the grid resulting in additional revenue for the sugar plant. This case study highlights the details of one such project implemented in a 5000 TCD sugar plant.

Previous status

A 5000 TCD sugar mill had six numbers of 750 HP mill turbines and one number of 900 HP shredder turbine.

The average steam consumption per mill (average load of 300 kW) was about 7.5 TPH steam @ 15 ATA. The steam driven mill drives had an efficiency of about 35%, in the case of single stage turbine and about 50% in the case of two stage turbines.

The plant team was planning to commission a commercial co-generation plant. This offered an excellent opportunity for the plant team to replace the low efficiency turbine driven mills with DC motors or hydraulic drives and maximize the co-generation potential.

Energy saving project

The plant team contemplated the replacement of the steam driven mills with electric DC motors along with the commissioning of the co-generation plant.
**Concept of the project**

The conventional single stage impulse type steam turbines have very low efficiencies of 35%. Hence, the steam consumption per unit of power output is very high.

A single high capacity steam turbine is more efficient as compared to multiple numbers of smaller capacity steam turbines. Hence, the steam can be passed through the larger capacity steam turbine to generate more saleable power.

The latest drives such as DC drives and hydraulic drives have very high efficiencies of about 90%. The steam saved by the installation of DC drives can be passed through the larger capacity power turbines of higher efficiency (about 65-70%) to generate additional saleable power.

**Implementation methodology, problems faced and time frame**

The steam turbine mill drives were replaced with DC drives once the co-generation plant was commissioned. The modifications carried were as follows:

- Four numbers of 1200kW and two numbers of 1000kW DC motors were installed in place of the six numbers of 1000kW mill turbines.
- Two numbers of 1100 kW AC motors were installed for the fibrizer in place of the single 1200kW shredder turbine.

There were no major problems faced during the implementation of this project. The implementation of the project was completed in 24 months.

**Benefits achieved**

The comparative analysis of the operational parameters before and after the modification is as follows:
<table>
<thead>
<tr>
<th>S1.No</th>
<th>Parameters</th>
<th>Steam turbine</th>
<th>DC drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Man drive efficiency %</td>
<td>35.0</td>
<td>90.0</td>
</tr>
<tr>
<td>2</td>
<td>Overall system efficiency %</td>
<td>26.6</td>
<td>39.5</td>
</tr>
<tr>
<td>3</td>
<td>Steam input / kWh of power delivered to the mill in kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• At 15 ATA</td>
<td>25</td>
<td>16.83*</td>
</tr>
<tr>
<td></td>
<td>• At 66 ATA</td>
<td></td>
<td>7.97*</td>
</tr>
<tr>
<td>4</td>
<td>Steam consumption per mill (average load of 300 kW) in TPH</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• At 15 ATA</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• At 66 ATA</td>
<td></td>
<td>2.39*</td>
</tr>
<tr>
<td>5</td>
<td>Saving in steam in TPH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Equivalent saving in power in kW</td>
<td></td>
<td>850</td>
</tr>
</tbody>
</table>

* The steam consumption indicated is the equivalent steam consumption in a power turbine for generation of additional power.

The equivalent power saved (850 kW / mill) by the implementation of this project could be exported to the grid to realize maximum savings.

Financial analysis

The annual energy saving achieved was **Rs 62.37 million** this required an investment of **Rs 42.00 million**, which had an attractive simple payback period of **9 months**.
Installation of an extensive vapour bleeding system at the evaporators

Background

The sugar industry is a major consumer of thermal energy in the form of steam for the process. The steam consumers in the process are - evaporators and juice heaters (mixed juice, sulphited juice and clear juice).

Out of the consumers, the evaporation which concentrate the juice typically from a brix content of 10 - 11 to about 55 - 60 brix consume the maximum steam. The evaporators are multiple effect evaporators, with the vapour of one stage used as the heating medium in the subsequent stages.

Multiple effect evaporators

In the older mills the evaporators are triple quadruple effect and the vapour from the first effect is used for the vacuum pans and from the second effect for juice heating. The other requirements were met through usage of exhaust steam.

In the modern sugar mills efforts have been taken to reduce the steam consumption. The following approach has been adopted in the boiling house for reducing the steam consumption.
Increasing the number of evaporator effects the higher the number of effects the greater will be the steam economy (i.e. kilograms of solvent evaporated per tonne of steam).

Additionally, the following aspects were also considered in the cane preparation section:

- Installation of heavy-duty shredders, to achieve better preparatory index (> 92+ as compared to the conventional 85+) for cane
- Installation of Grooved Roller Pressure Feeder (GRPF) for pressure feed to the mills. This allows for better juice extraction from the cane.
- Lesser imbibition water addition, on account of the better juice extraction by the GRPF, resulting in reduction of boiling house steam consumption

Conventional System
This case study pertains to a sugar mill of 2500 TCD, where the above approach has been adopted at the design stage itself, resulting in lower steam consumption.

In a typical sugar mill, the most commonly used evaporators are the quintuple effect evaporators. The typical vapour utilisation system in the evaporators comprises of:

- Vapour bleeding from 11- or 111- effect for heating (from 35°C to 70°C) in the raw (or dynamic) juice heaters
- Vapour bleeding from 1- effect for heating (from 65°C to 90°C) in the first stage of the sulphited juice heater
- Exhaust steam for heating (from 90°C to 105°C) in the second stage of the sulphited Juice heater
- Exhaust steam for heating (from 94°C to 105°C) in the clear juice heaters
- Exhaust steam for heating in the vacuum pans (C - pans)

Extensive vapour bleeding – the extensive use of vapour coming out of different effects of the evaporators are used for juice heaters and vacuum pans. The later the effect the better is the steam economy in the system.

The specific steam consumption with such a system for a 2500 TCD sugar mill is about 45 - 53 % on cane, depending on the crushing rate. However, maximum steam economy is achieved, if the vapour from the last two effects can be effectively utilised in the
process, as the vapour would be otherwise lost. Also, the load on the evaporator condenser will reduce drastically.

Many of the energy efficient sugar mills, especially those having commercial cogeneration system, have adopted this practice and achieved tremendous benefits. The reduced steam consumption in the process can result in additional power generation, which can be exported to the grid.

**Present System**

In a 2500 TCD sugar mill, the extensive use of vapour bleeding at evaporators was adopted at the design stage itself. The plant has a quintuple-effect evaporator system. This system comprises of:

- Vapour bleeding from the V-effect, for heating (from 30°C to 45°C) in the first stage of the raw juice heater
- Vapour bleeding from the IV-effect, for heating (from 45°C to 70°C) in the second stage of the raw juice heater
- Vapour bleeding from the II-effect, for heating in the A-pans, B-pans and first stage sulphited juice heater
- Vapour bleeding from the I-effect, for heating in the C-pans, graining pan and second stage of sulphited juice heater
- Exhaust steam for heating in the clear Juice heater

However, to ensure the efficient and stable operation of such a system the exhaust steam pressure has to be maintained uniformly at an average of 1.2 – 1.4 ksc.

In this particular plant, this was being achieved, through an electronic governor control system for the turbo-alternator sets, in closed loop with the exhaust steam pressure. Whenever, the exhaust steam pressure decreases, the control system will send a signal to the alternator, to reduce the speed. This will reduce the power export to the grid and help achieve steady exhaust pressure and vice-versa.
Benefits achieved

The installation of the extensive vapour utilisation system at the evaporators has resulted in improved steam economy. The specific steam consumption achieved (as % cane crushed) at various crushing rates are as follows:

- At 2500 - 2700 TCD: 41% on cane
- At 2700 - 2800 TCD: 40% on cane
- At 2800 - 3000 TCD: 39% on cane
- At 3000 TCD and above: 38% on cane

Thus, the specific steam consumption (% on cane) is lower by at least 7%. This means a saving of 3.5% of bagasse percent cane (or 35 kg of bagasse per tonne of cane crushed).

Financial analysis

The annual benefits on account of sale of Bagasse (@ Rs.350/- per ton of Bagasse and 120 days of operation works out to Rs 4.50 million. This project was installed at the design stage itself. The actual incremental investment, over the conventional system, was not available.

Note:
In another sugar mill of 5000 TCD, the same project was implemented. The annual saving achieved was Rs.11.00 million. This required an investment of Rs.6.50 million, which had an attractive simple payback period of 8 months.
Case study – 4

Installation of Variable Speed Drive (VSD) for the weighed juice pump

Background

The sugarcane is crushed in the mill house, to separate the juice and the bagasse. The juice obtained from the mill house is known as raw juice. The raw juice is screened; to remove all suspended matter and any entrained fibers. The juice is at this stage, known as strained juice.

The strained juice is then sent to a weigh scale, from where it gets transferred to a weighed juice tank. This weighed juice is passed through the primary/raw juice heaters to the sulphiters, with the help of weighed juice pumps. In the sulphiter, S02 is injected continuously for colour removal.

The flow of the weighed juice to the sulphiters through the juice heaters has to be maintained at a steady flow rate, to achieve uniform heating and quality.

Previous status

In a 2600 TCD sugar mill, there was a weighed juice pump operating continuously to meet the process requirements.
The pump had the following specifications:

- Capacity : 27.77 lps
- Head : 45 m
- Power consumed : 23kW

The flow from the weighed juice tank was not uniform. On one hand, the tank was getting emptied, whenever the time between the tips of the weigh scale was more. On the other hand, whenever the time between the tips was less, the level of juice in the tank builds-up. The tip of the weigh scale is governed by, the cane crushing rate and also the quality (juice content) of cane.
Moreover, the pump was designed for handling the maximum cane-crushing rate. The maximum head requirement is only 25 m (equivalent to 2.5 ksc), while the pump had a design head of 45 m. This also contributed to the excess margins in the pump, leading to operation with recirculation control.

Hence, to keep the juice flow smooth and avoid the tank from getting emptied, the pump was operated with recirculation control. The pressure in the juice heater supply header, is maintained by periodically 'throttling and adjusting the control. Valve in the recirculation line.

The operations of a centrifugal pump with valve control or recirculation are energy inefficient methods of capacity control, as energy is wasted in pumping more quantity, than is actually desired.

In the above context, it is advisable to have a uniform flow of juice and also avoid wastage of energy through re-circulation. This can be achieved in an energy efficient manner, by varying the RPM of the pump.

Energy saving project

The plant team decided to conduct trials with a suitable variable speed mechanism for the weighed juice pumps. A variable speed system will help achieve the RPM variation of the pump and exactly match the varying capacity requirements.

Concept of the project

The installation of a variable speed system, will not only ensure a consistent flow, resulting in improved quality of the product, but also, offer substantial energy savings.

Among the different variable speed systems, the installation of a variable frequency drive (VFD) can result in maximum energy savings. The VFD can be put in a closed loop with the discharge pressure. This will enable constant flow of juice to the juice heater and sulphiter, irrespective of the level in the juice tank. The discharge pressure set point can be adjusted periodically, depending on the crushing rate or number of tips manually.

In the new sugar mills, the number of tips and time interval between the tips is measured. This can be used by the VFD, for automatically varying the juice flow through the system, according to the rate of crushing.
Implementation methodology, problems faced and time frame

The plant team decided to install a Dyno-drive initially (as it was readily available) and install VFD at a later stage.

The dyno-drive also, like the VFD, helps in achieving speed variation, to match the varying capacity requirements. The installation of dyno-drive resulted in the elimination of the recirculation control totally, thereby reducing the pressure (or head) losses.

There were no major problems faced during the implementation of the dyno-drive, as it was readily available in the plant and its operation was familiar to the plant personnel. The implementation of this project was completed in 1 month.

Benefits achieved

The installation of a dyno-drive for the weighed juice pump, resulted in the following benefits:

- Consistent and steady flow to the Juice heaters
- Improved quality of sulphitation, as the juice flow was steady
- Reduced power consumption by an average of 11 kW (a reduction of about 30 - 40%).

However, the installation of a VFD at a later stage can result in maximum energy savings. The installation of a VFD can result in the reduction of the average power consumption by at least another 40 - 50%.

Financial analysis

The annual energy saving achieved (with the installation of a dyno-drive) was Rs.0.236 million. No investment was made, as a dyno-drive was readily available in the plant.
Variable Frequency Drive Panel
Utilisation of Exhaust Steam for Sugar Drier and Sugar Melter

Background

The sugar manufacturing process needs substantial amount of thermal energy, in the form of steam. The majority of steam requirement is at low pressures (0.6 to 1.5 ksc), while a small percentage of the steam consumption is at medium pressure of about 7.0 ksc.

In the sugar mills, the requirement of steam at lower pressures is met from the exhaust of the turbine; while the medium pressure (MP) steam, in most of the plants, is generated by passing the live steam generated from the boiler, through a pressure-reducing valve. This is schematically indicated below:

With the installation of commercial cogeneration systems, the projects for additional cogeneration have become attractive, as additional power can be sold to the grid.

One of the methods of improving cogeneration is the replacement of high-pressure steam with low-pressure steam, wherever feasible. In a sugar mill, there is a good possibility of replacing some quantity of MP steam users with exhaust steam, resulting in increased power generation.

This case study describes one such project implemented in a 2500 TCD sugar mill.
In one of the 2500 TCD sugar mills, medium pressure steam at 7.0 ksc, generated by passing live steam at 42 ksc, through a pressure reducing valve (PRV), was being used in the following process users:

- Hot water superheating for use in the centrifuges
- Sugar drier blower
- Sugar melter

The temperature requirements for the sugar drier blower and sugar melter are about 80°C and 90°C respectively. The centrifuge hot water was to be heated to a temperature of about 115 – 125°C exhaust steam generated by passing live steam through a turbine was available at around 1.2 ksc

Energy saving project

The exhaust steam was utilised in place of live steam for sugar melting (blow-up) and sugar drying.

Concept of the project

The sugar melting requires a temperature of 90°C and sugar drying needs about 80°C. The heat required for these two process users, can be easily achieved by exhaust steam.

Replacement of live steam with exhaust steam in these two users can increase the cogeneration every ton of medium pressure steam replaced with exhaust steam can aid in generation of additional 120 units of power.

Implementation methodology, problems faced and time frame

The steam distribution network was modified, to install steam line from the exhaust header to sugar melter and sugar drier blower.

There were no problems faced during the implementation of this project, as the modification involved only the laying of new steam pipelines and hooking it to the main steam distribution system. The entire modification was carried out in 15 days time

Benefits

The live steam consumption, amounting to about 0.3 TPH, in the sugar melter and sugar drier blowers, was replaced with exhaust steam.

This resulted in additional power generation of about 35 units, which could be sold to the grid.
Financial Analysis

The annual energy saving achieved was Rs. 0.2 million. This required an investment of Rs. 0.02 million, which had a very attractive simple payback period of 2 months.

Note:
Similarly, exhaust steam can partly substitute the use of live steam for hot water heating in centrifuges. The centrifuge hot water heater requires a temperature of about 115 - 125°C. Exhaust steam can be used for heating the centrifuge wash water to at least 105°C. The heating, from 105°C to 125°C can be carried out by live steam. This will partly substitute the use of live steam and will increase the cogeneration power.
Avoiding or Minimisation Of Continuous Recirculation in Boiler Feed Water Pump by Provision Of Automatic Recirculation Control Valve (ARC Valve)

Background

The boiler feed water pump (multi-stage high-pressure pumps), is normally designed for 25% excess capacity, of the maximum continuous rating (MCR) of the boiler. This is done to take care of safety aspects and any exigencies.

Hence, the boiler feed water pump operates at lower capacity utilisation, even at full load operation of the boiler. This gets reflected as recirculation or valve throttling, during pump operation.

At low boiler loads the feed water flow requirements further reduces. During such conditions of low flow through the pump, the discharge pressure increases, affecting the pump glands and impeller. The continuous operation of the feed water pump at these low flow conditions, therefore, affects the operating characteristics and damages the pump.

To avoid this damage, the boiler feed water pumps are provided with a by-pass arrangement, to recirculate/bypass part of the discharge. This bypass helps maintain a minimum flow through the pump. The by pass arrangement could be a continuous by pass ‘ON – OFF’ by pass or a regulated by pass.
The operation of a pump with continuous by-pass is energy inefficient, as on a continuous basis, excess energy is spent for pumping the recirculation water. The continuous by-pass can be replaced with a regulated by-pass system, where the by-pass valve opens only during times of actual requirement.

This case study deals with one such example implemented in one of the 2500 TCD sugar mills.

Previous status

One of the major sugar mills, operating with commercial co-generation system, had a boiler feed water pump of the following specifications:

- Capacity : 29.5 m³/h
- Head : 600 m
- Power consumption : 110 kW

The boiler feed water pump was operating to cater to the boiler-operating load of about 18 TPH, whereas it is designed for meeting the maximum boiler-operating load. Thus, there is always a continuous excess capacity built into the system. The pump had a by-pass line, which was kept open continuously.

Energy saving project

The re-circulation in the boiler feed water pump was reduced/avoided by the provision of an automatic re-circulation control (ARC) valve.

Concept of the project

The operation of a centrifugal pump with continuous re-circulation is an energy inefficient practice, as energy is wasted in pumping more water, without doing any useful work.

However, a certain minimum flow has to be maintained, to take care of the pump at low load conditions. The automatic recirculation valve (ARC valve) can help meet both the above requirements effectively. The ARC valve opens the by-pass, when the pressure builds-up at the discharge, during times of low flow. However, during normal flow, the by-pass valve will be kept closed.
Implementation methodology, problems faced and time frame

The implementation of this project was taken up in stages as follows:

- The re-circulation was kept to the bare minimum, by keeping the re-circulation valve only crack open manually.
- Consequently, the maximum pressure set point was ascertained and an auto recirculation valve (ARC valve) was installed, at the delivery of the boiler feed water pump.
- This ARC valve will open or close, depending on the flow requirements to the boiler.

The implementation of this project was completed in 12 months - time and no major problems were faced during the implementation of the project.

Benefits

The following benefits were achieved by the implementation of the above project:

- By reduction of recirculation to a bare minimum (achieved through valve control), 10 kW equivalent reductions in power consumption was achieved.
- With the installation of an ARC valve, there was an additional 10 kW reduction in power consumption, of the boiler feed water pump.

Thus, an overall reduction in power consumption of about 20 kW was achieved with this modification.

Financial Analysis

The annual energy saving achieved was Rs.0.43 million. This required an investment of Rs.0.25 million (for ARC valve) and had an attractive simple payback period of 8 months.
Boiler feed water pump
Installation of Rotary Blower In Place Of Compressor For Syrup Sulphur Burner

Background

The sulphur burner requires air for combustion. Low-pressure air compressors supply this air conventionally. However, compressed air is highly energy intensive, as the power consumption of the compressor is directly proportional to the average operating pressure.

The actual pressure requirements of the air are much lower. Positive displacement rotary blowers can effectively supply the same quantity of air at much lower power consumption.

Hence, the recent trend among the major sugar mills is to replace the sulphur burner among the major sugar mills is to replace the sulphur burner compressors with rotary blowers

Previous status

In one of the 2500 TCD sugar mills, the air requirements of the sulphur burner were being met through a 750 m$^3$/h compressor operating at 5.0 ksc.

The actual maximum air pressure requirement is only 0.5 ksc. A rotary blower, at much lower power consumption, as compared to an air compressor, can easily supply this.

Energy saving project

The air compressor utilised for supplying combustion air required for combustion of sulphur in the sulphur burner was, replaced with a positive-displacement rotary blower.

Concept of the project

A rotary blower, for supplying the same quantity of air (750 m$^3$/h), at the desired maximum process pressure of 0.5 ksc consumes at least 30 – 40% less power as compared to the compressors

Implementation methodology, problems faced and time frame

The air compressor in the sulphur burner was replaced with a positive displacement rotary blower, during the off-season.
Implementation methodology, problems faced and time frame

The air compressor in the sulphur burner was replaced with a positive displacement rotary blower, during the off-season.

There was a general apprehension that, the desired combustion was not being achieved in the sulphur burner, on account of the lower pressure operation. However, once the plant team got familiarized with the operation and satisfactory results were achieved, these problems were solved.

The entire project was implemented in 20 days and was taken up during the off-season.

Benefits

The power consumption with air compressor and rotary blower are as highlighted below:

- With air compressor : 7.35 kW
- With rotary blower : 4.50 kW

Thus, a net reduction in power consumption by 2.85 kW was achieved with this modification.

Financial Analysis

The annual energy saving achieved was Rs. 0.06 million. This required an investment of Rs. 0.10 million which had a simple payback period of 20 months.
Rotary blower
Installation of Thermo-compressor for use of Low Pressure Steam

Background

The sugar industry has many steam users - both "live" medium pressure (MP) steam and exhaust steam. Some of these live steam users can be totally replaced with exhaust steam, while in some other users, the live steam consumption can be partially replaced with exhaust steam.

One such live steam user in a sugar mill is the adjoining distillery. A typical distillery requires steam at about 0.7 - 0.9 ksc for the distillation column and about 1.0 - 1.2 ksc for the ENA column. The exhaust steam pressure of 0.4 ksc available from the sugar mill will not be able to cater to this requirement. Hence, live steam is drawn from the 8.0-ksc header and dropped to 1.5 ksc, through a pressure-reducing valve, for use in the distillery.

Any conservation measures, which can replace/ minimize the live MP steam consumption, can result in maximising the cogeneration in a sugar mill. One such method of minimising the MP steam consumption is by the installation of a thermo compressor.

The thermo-compressor, by passing a very small quantity of MP steam can "compress" the waste exhaust steam (typically about 0.4 ksc) available in the sugar mill. The resultant LP steam (typically about 1.5 ksc) can be utilised for any process steam requirement, such as the distillation column and ENA column in a distillery.

This modification can result in minimising the usage of MP steam consumption, effectively utilise the heat value of exhaust steam and maximise the cogeneration potential.

Previous status

In a typical 4000 TCD sugar mill in Maharashtra, the turbine exhaust steam at 0.40 ksc was continuously vented out. The quantity of the steam vented, amounted to about 6300 kg h. There were no process users in the sugar mill or the distillery, which could utilise this exhaust: steam of 0.40 ksc.

The distillery required 10 TPH of steam at 1.5 ksc. A separate boiler was meeting the steam requirements of the distillery. The sugar mill boiler met any additional requirement of steam. In both the cases, steam was generated at 8 ksc and reduced to 1.5 ksc through a pressure-reducing valve.
The expansion of steam through a pressure-reducing valve is not a good system, as no power is generated with pressure reduction.

The turbine exhausts steam, instead of being venting out, could be converted to medium high-pressure steam through thermo-compression and used to meet the steam.

**Energy saving project**

A thermo-compressor system was installed, for reusing the turbine exhaust steam, in the distillery. The resultant MP steam saved in the distillery, was passed through the power generating turbines for generation of additional power.

**Concept of the project**

In the thermo-compressor body, high or medium pressure motive steam accelerates through the nozzle. As it enters the suction chamber at supersonic speeds, it entrains and mixes with low-pressure exhaust steam, entering from the suction inlet.

The resultant steam mixture then enters the convergent-divergent diffuser. In this section, the velocity reduces and its kinetic energy is converted to pressure energy. The steam discharged by the thermo-compressor is then recycled to a localised process.

The resultant discharge steam is available at a pressure, suiting the particular process application. Varying the velocity and quantity of the motive steam and fine-tuning the configuration of the thermo-compressor can design the outlet steam pressure and quantity, requirements of the distillery.

**Implementation methodology, problems faced & time frame**

A thermo-compressor system along with the associated mechanical hardware including traps, strainers, safety valves etc., and flow control instrumentation on the motive steam, was installed. The thermo-compressor operating parameters are as follows:

- **Motive steam**: 3700 kg/h at 20 ksc
- **Suction steam**: 6300 kg/h at 0.4 ksc
- **Discharge steam**: 10000 kg/h at 1.5 ksc

There were no problems faced during the implementation of this project. Moreover, the thermo-compressor operation is maintenance free. The system was installed in 6 months' time.
Benefits

The resultant 1.5 ksc steam obtained by thermo-compression of exhaust steam, was directly used in the distillery. This reduced the passing of high/medium-pressure steam through the pressure-reducing valve.

Financial analysis

The annual energy saving achieved was Rs. 6.00 million. This required an investment of Rs. 2.00 million, which had a very attractive simple payback period of 4 months.

Schematic of thermo compressor system
Thermo compressor
Installation of Hydraulic Drives for Mill Prime Movers

Background
The mill prime movers in sugar mills are typically steam turbines. The use of steam turbines as prime movers gained popularity over the earlier steam engines, on account of its simple design and operational flexibility, even though it has very high specific steam consumption.

These steam turbines are single stage impulse type turbines. They are characterised by very low efficiencies of 35 - 40%. The efficiency of the steam turbines remains at optimum levels, only when the input steam parameters and speed are kept at the rated level. Even with moderate steady steam parameters and speed, the steam turbine driven mills require about 25 - 30% more running power over that actually required.

With the normally prevalent steam pressure fluctuations in the sugar mills, its consequent effect on efficiency of the steam turbines and the increasing trend towards commercial cogeneration systems, the trend of late, is to replace these steam turbines with either DC drives or hydraulic drives.

The benefits of installing DC drives have. Already been discussed in Case Study - 2 of this thesis. This case study highlights the benefits of installing hydraulic drives in place of steam turbines for the mill prime movers.

Previous status
One of the sugar mills had the following mill drive configuration:

- For 6 mill system – 800 kW rating steam turbine x 3 nos. (2 mills driven by single turbine)
- For 4 mill system – 800 kW rating steam turbine x 2 nos. (2 mills driven by a single turbine)

This configuration was designed to cater to the initial installed capacity of 2500 TCD.

The following operational parameters were observed:

- The specific steam consumption of these steam turbine were 24 kg/kW as compared to the specific steam consumption of 13 kg/kW in the power turbines.
- Speed range and speed accuracy were very poor.
• Adaptability to complex system is difficult
• Monitoring of power consumption is not possible
• The overall efficiency is only of the order of 27 – 30%
• Maintenance and lubrication requirements are very high
• Space requirements are large

The plant teams had plans to increase the cane crushing capacity to 4000 TCD. The inherent disadvantages of the steam turbines can be overcome especially after the proposed increase in cane crushing rate by the installation of hydraulic drives.

**Energy saving project**

The steam turbines used as mill drives were partially replaced by hydraulic drive, during the capacity up gradation activity.

**Concept of the project**

The hydraulic drives are a combination of two components - the pump normally driven by an electric motor and the hydraulic motor, which runs by the displacement of oil. The speed of the motor depends on the rate at which the displacement of oil takes place.

The hydraulic drive works on the principle of high torque delivery at low speeds. The torque delivered is directly proportional to the system pressure and the speed is directly proportional to the oil flow.

The advantages of hydraulic drives are as follows:

• High transmission efficiency - the overall efficiency of converting steam power into shaft power for a hydraulic system is about 58%. This results in substantial power savings
• Very low inertia enabling the system operation on load
• Upgradeable modular design
• Easy adaptability on existing mills
• Simple to operate
• Instantaneous and unlimited reversal of rotation, enabling quick response to load changes
• Compact unit, resulting in space savings
• Reliable and rugged design
• Minimal foundation work

• Alignment problems eliminated, thereby minimising maintenance

Due to the above-mentioned advantages, hydraulic drives are increasingly replacing the conventional steam turbine mill drives.

Implementation status, problems faced and time frame

The mill configuration was altered, to cater to the capacity upgradation of 4000 TCD, as per the following:

• The second mill drive of the 6-mill system was removed and added as the fifth mill drive of the 4-mill system, thus, making two 5-mill systems.

• The last four mill steam turbine drives (of the old 6-mill system) were replaced with hydraulic drives of 300 kW each.

• The new fifth mill drive (of the modified 4-mill system) was provided with a hydraulic drive of 600 kW rating.

There were initial technical problems related to the oil-pumping unit, which was rectified by the supplier. Apart from this, there were no particular problems faced during the implementation of this project.

The entire implementation was taken up during the off-season and was completed in 6 months time.

Benefits achieved

The net installed power consumption reduced from 0.895 kW/TCD (for average crushing of 2500 TCD) to 0.509 kW/TCD (for average crushing of 4800 TCD). In addition very stable operating conditions are being achieved at almost negligible maintenance cost.

Financial analysis

This project was implemented as a technology upgradation measure. The installation of hydraulic drives helps in achieving mechanical, electrical and process benefits. Hence, the saving achieved could not be exactly quantified. The entire modification required an investment of Rs 25.00 million.
Hydraulic drive for mill prime mover.
Installation of Fully Automated Continuous Vacuum Pans for Curing

Background

The vacuum pan is vital equipment, used in the manufacture of sugar. The concentrated syrup coming out of the evaporator at around 60-65 Brix is further concentrated in these pans. This is a critical process for the production of good quality sugar and involves removal of water and deposition of sugar molecules on the nuclei.

Massecuite boiling is conventionally carried out by batch process in the Indian sugar industry. These pans are characterised by the following:

- The hydrostatic head requirement is high
- Higher hydrostatic heads necessitate higher massecuite boiling temperatures, which aid colour formation
- Massecuite looses its fluidity, especially towards the end of the batch cycle
- Higher boiling point elevation results in lower heat flux for a given steam condition
- Consumes very high steam, by design - due to the non-uniform loading cycle, unloading cycle and pan washing cycle times

Of late, the continuous vacuum pans have been developed and installed in many sugar plants with substantial benefits. This case study highlights the benefits of installing a continuous vacuum pan for curing.

Previous status

One of the sugar mills had the following pan configuration for the massecuite curing:

- Batch vacuum pans of 40 tons holding capacity (11 nos.) : 5/6 nos. for A-massecuite
  4 nos. for B-massecuite
  2/3 nos. for C-massecuite

- Batch vacuum pans of 80 tons holding capacity (3 nos.) : 2 nos. for A-massecuite
  1 nos. for B-massecuite

- Continuous vacuum pan of 135 tonnes holding capacity : 1 nos. for C-massecuite
The above configuration was designed for 6000 TCD capacity. The following operational parameters were observed:

- The steam consumption was erratic, as it was dependent on various factors, such as, loading time, unloading time, pan washing and cleaning.
- The evaporation rates are erratic - they are high during start-up and progressively reduce towards the end of the batch cycle
  - The S/V ratio is low (~ 6)
  - Hydrostatic head requirement is high (about 3.0 - 3.5 m)
  - Average retention time is very high
  - Requires very frequent cleaning of the pan body
  - Less adaptable to automation

To overcome these inherent shortcomings and to cater to their capacity upgradation plans to 8000 TCD, continuous vacuum pans were installed for all three types of massecuite curing. were observed:

**Energy saving project**

Consequent to the capacity upgradation to 8000 TCD, continuous vacuum pans were installed for A- massecuite, B- massecuite and C- massecuite curing.

**Concept of the project**

A continuous operation of a vacuum pan means, a complete integrated system comprising of the sub-systems, covering total control of the inputs and outputs. The operation of the pan in a continuous manner makes it easy for automation and installing control systems.

The latest continuous vacuum pans are being installed with predictive control systems, which ensure a steady and more consistent operation of the pan. Besides these automation facilities, the continuous vacuum pans have many advantages:

- There is no heat injury to the sugar crystal due to reduced hydrostatic head and lower boiling point elevation

- The use of smaller diameter tubes provides greater heating area per unit of calendria. This aspect gives more flexibility on thermal conditions of the steam that can be used

- This also allows maximum evaporation rates, commensurate with maximum possible crystallisation rates.
- Facilitates the use of low pressure steam on account of increased transmission coefficient brought about by higher circulation rate of massecuite.

- Reduction in steam consumption by 10 – 20% as compared to the batch pans.

- On account of reduction in steam consumption the condensing and cooling water power consumption also gets reduced.

- There is no draining, rinsing as in batch process which cause thermal losses and dilution.

- The coefficient of variation of crystal size is equivalent to or better than in batch pans on account of plug flow conditions and multi-compartment design.

- The continuous vacuum pan is automated resulting in simpler operation.

- They are compact and hence, the space requirement is much lower.

The continuous vacuum pans have gained immense popularity on account of the salient features mentioned above.

**Implementation status, problems faced and time frame**

During the expansion stage (8000 TCD) the batch pans were replaced in phases and the new configuration is as follows:

- Continuous vacuum pans of 80 tonnes holding capacity: 1 no. for A massecuite, 2 no. for B massecuite, 2 no. for C massecuite.

- Continuous vacuum pans of 80 tonnes holding capacity (2 nos.): 2 no. for A massecuite.

- Continuous vacuum pan of 135 tonnes holding capacity (4 nos.) : 2 no. for A massecuite, 1 no. for B massecuite, 1 no. for C massecuite.

The experience of having operated a continuous vacuum pan for the C- massecuite enabled the operators to gain first hand working knowledge and trouble-shooting skills.

Hence, there were no particular problems faced, during the phased replacement of the remaining batch vacuum pans, with continuous vacuum pans.

The replacement of all the batch vacuum pans with continuous vacuum pans was completed in two sugar seasons.
**Benefits achieved**

The following benefits were achieved by the installation of continuous vacuum pans:

- The continuous pans facilitate the use of low-pressure steam.
  - The vapour bleeding from the II - effect of evaporator, for heating in the A - pans and B - pans
  - The vapour bleeding from the I - effect of evaporator, for heating in the C- pans
- The continuous pans enable stabilised operation of the evaporators
- Reduction (10 - 20%) in steam consumption as mentioned below:

<table>
<thead>
<tr>
<th>Identity</th>
<th>Steam consumption (kg/ ton of massecuite)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With batch Vacuum pan</td>
</tr>
<tr>
<td>A - massecuite</td>
<td>Not available</td>
</tr>
<tr>
<td>B - massecuite</td>
<td>242</td>
</tr>
<tr>
<td>C - massecuite</td>
<td>354</td>
</tr>
</tbody>
</table>

- Improved grain size quality.
- Reduced sugar loss
- Heat balance optimisation

**Financial analysis**

The annual equivalent energy saving achieved was Rs 19.26 million (for 120 days sugar season and bagasse cost of Rs.250/MT). This required an investment of Rs.100.00 million, which had a simple payback period of 63 months.
Schematic arrangement of continuous vacuum pans

Typical continuous vacuum pan set up
**Installation of Free Flow Falling Film Evaporator (FFFFE)**

**Background**

Evaporators are a major consumer of steam in a sugar mill. The evaporator concentrates the juice from a level of 14 - 16 Brix to a level of 60 - 65 Brix. The exhaust steam is used for this purpose, as it offers the least steam consumption.

Several types of evaporators are used in sugar mills. Of the various types of evaporators available, the most commonly used type of evaporator in a sugar mill, are the short tube vertical evaporators.

Although commonly used and relatively inexpensive, the short tube vertical evaporators have several disadvantages, which are as follows:

- Large heating area is required, since the units are broad
- Heat transfer coefficients are sensitive to temperature difference and brix of juice

In one of the sugar mills, crushing about 6000 TCD, the evaporator was of the conventional short tube type, with the following configuration:

- There were two sets of evaporator comprising of a vapour cell and quadruple effect:
  - An old set of 6000 m² of main stream heating surface (4 bodies), with an additional 1800 m² parallel stream heating surface (4 bodies)
  - A new set of 4800 m² of mainstream heating surface (4 bodies), with an additional 1100 m² parallel stream-heating surface (4 bodies)
- The entire set of evaporator bodies was being utilised (total 8 bodies) for evaporation.
- The heating in pans was carried out by exhaust steam only.

The steam consumption with the above system was about 56 - 57% on cane crushed. With the increase in crushing capacity to 8000 TCD and the inherent disadvantages of conventional short tube vertical evaporators, the installation of FFFF evaporator was considered.
Energy saving project

The entire evaporator setup was revamped and a free flow falling film evaporator was installed instead of the vapour cell, in the old evaporator system.

Concept of the project

The free flow falling film evaporators have the following advantages:

- The feed liquor is introduced at the top tube sheet and flows down the tube wall as a thin film. Since, the film moves by gravity, a thinner and faster moving film form, resulting in higher heat transfer coefficients and reduced contact times.
- High temperature and pressure steam (1.5 ksc steam at a temperature of 120°C) can be used, as the contact time between juice and steam is about 30 seconds only.
- No elevation in boiling point, due to the absence of hydrostatic pressure.
- Satisfactory operation at low temperature driving forces.
- Heat transfer coefficients are sensitive to temperature difference and brix of juice
- Large contact time of 6 - 8 minutes, between the juice and steam
- Due to large liquid hold-up, these evaporators cannot be used with heat sensitive materials

Against these factors, the installation of free flow falling film evaporator (FFFF) is gaining increasing popularity in the sugar mills.

This type of configuration has possibilities for extensive vapour bleeding, with only marginal vapour going to the condenser. The exhaust steam used for heating in the pans can be replaced with vapour bleed. Such a system will offer the maximum steam savings in the evaporator.

Implementation status, problems faced and time frame

The entire evaporator system was revamped and the new configuration is as follows:

- The vapour cell of the old evaporator set was replaced with a FFFF evaporator
- The additional 1800 m² parallel stream heating surface (4 bodies) of the old evaporator set was removed
- The additional 1100 m² parallel stream heating surface (4 bodies) of the new evaporator set was removed
The vapour bleeding from the FFFFE/vapour cell was utilised for heating in the pans. There were no problems faced during the implementation of this project. The implementation of the entire project was completed in 6 months time.

Benefits achieved

The specific steam consumption achieved is as follows:

- With FFFF evaporator: 53 - 54% on cane crushed (for 8000 TCD installed capacity)
- With conventional short tube Vertical evaporator: 56 - 57% on cane crushed (for 6000 installed capacity)

Thus, there is a net reduction of specific steam consumption by about 3 - 4% on cane crushed.

Financial analysis

The net annual energy saving achieved was Rs 3.60 million (for 120 days sugar season and bagasse cost of Rs 250/MT). This required an investment of Rs 12.00 million, which had a simple payback period of 40 months.
Falling film evaporator
Installation of Belt Conveyors for cane carriers, Bagasse conveyors to Boilers and Sugar conveyor to the Hoppers

Background

The cane after passing through the levelers, cutters and shredders is conveyed to the mills by means of chain cane carriers. Similarly, bagasse from the mill house is conveyed through rake carriers to the individual boilers. The sugar coming out of the continuous centrifugal passes through vibratory conveyors to the hoppers for drying.

These conveyors are by design, very heavy and rugged. Hence, the prime mover power requirements are very high. Also because of their ruggedness, it calls for frequent maintenance.

The latest trend among the major sugar industries, is to install belt conveyors in place of the conventional material handling equipments, such as cane carriers, rake carriers and vibratory conveyors.

This case study highlights the benefits of installation of belt conveyors in a sugar industry for the above applications.

Previous status

In one of the 4000 TCD sugar mills, the material handling equipment for cane, bagasse and sugar conveying were as follows:

- Cane carrier : 50 kW motor x 1 no.
- Rake carrier for bagasse : 50 kW motor x 1 no.
- Sugar conveyors : 20 kW motor x 1 no.
- Mill-to-mill conveyor (last stage) : 30 kW motor x 1 no.
- Sugar conveyors (last stage) : 20 kW motor x 1 no.

These carriers had frequent maintenance problems and were characterised by very high power consumption.

Energy saving project

The cane carriers, rake carriers, vibratory conveyors and mill-to-mill conveyors were replaced with the belt conveyors.
Concept of the project

The belt conveyors are characterised by the following features:

- Simplicity of design
- Ease of installation
- Ease of operation and maintenance
- Lower prime mover power requirements

Implementation status, problems faced and time frame

Belt conveyors were installed in place of cane carriers for conveying shredded cane to the mills, rake carrier for bagasse conveying to the individual boilers, vibratory conveyors for sugar conveying to the hoppers and mill-to-mill conveyors (last stage of mill).

Initially, there was a general apprehension that the belt conveyors may not be able to perform the required duty conditions. Hence, the project was implemented in stages (one area taken up for replacement during each off-season). Once, the plant team was accustomed to the operation with belt conveyors, there were no particular problems faced during the implementation of this project.

Benefits Achieved

There was a net reduction in installed power as highlighted below:

<table>
<thead>
<tr>
<th>Identity of equipment</th>
<th>Conventional</th>
<th>Belt conveyor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane carrier</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>Rake carrier</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Sugar conveyor - 1</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Sugar conveyor - 2</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Mill - to - mill (last stage)</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>130</strong></td>
<td><strong>55</strong></td>
</tr>
</tbody>
</table>

The actual power consumption has come down by nearly 50%. In addition, the maintenance costs have also reduced tremendously.
Financial analysis

This project was implemented as a technology upgradation measure aimed at achieving easy & maintenance free operation and lower operating cost. Hence, the savings achieved could not be exactly quantified. The modification cost about Rs 3.00 million.

Bagasse conveyor
Installation of Conical Jet Nozzles for Mist Cooling System

Background

The spray pond is one of the most common type of cooling system in a sugar mill. In a spray pond, warm water is broken into a spray by means of nozzles. The evaporation and the contact of the ambient air with the fine drops of water produce the required degree of cooling.

There are many types of nozzle configurations available for different spraying applications. Most of them aim to give a water spray the form of a hollow cone. A good spray nozzle should be of simple design, high capacity and high efficiency. Of the various types of spray nozzles, the conical jet nozzles have been found far superior on all the above parameters.

Hence, the recent trend among the new sugar mills is to install the conical jet nozzles, to achieve maximum dispersion of water particles and cooling.

Previous status

In a 4000 TCD sugar mill, the cooling system consisted of a spray pond. There were 5 pumps of 100 kW rating operating continuously, to achieve the desired cooling parameters.

The materials of construction of the spray nozzles were Cast Iron (C.I). These nozzles the disadvantages of low capacity and high head requirements (of the order of 1.0 - 1.2 ksc or 10 -12 m of water column). The maximum cooling that could be achieved with the spray pond was about 34- 35°C.

To achieve better cooling, higher efficiency and energy savings, the conical jet nozzles were considered.

Energy saving project

The spray pond system was modified and conical jet nozzles were installed to achieve mist cooling.
Concept of the project

The water particle dispersion is so fine that, it gives a "mist" like appearance. The surface area of the water particles in contact with the ambient air is increased tremendously. Hence, better cooling is achieved with the mist cooling system.

The material of construction of the latest conical jet nozzles is PVC, which enables achieve better nozzle configuration. They will also help attain the same operating characteristics as the cast iron nozzles, but at a much lower pressure drop or head (0.5 - 0.8 ksc) requirement.

This reduces the cooling water pump power consumption substantially.

Implementation status, problems faced and time frame

The earlier CI nozzles of 40 mm diameter were replaced with PVC conical jet nozzles of 22 mm diameter, in phases. There were no problems faced during the implementation of this project. As the project was implemented in phases, it was implemented in total over 2 sugar seasons.

Benefits achieved

The cooling achieved with the mist cooling system was about 31 - 32 °c (i.e., a subcooling of 2 - 4 °c was achieved). This resulted in avoiding the operation of one 75 HP pump completely.

In addition, significant process benefits were achieved. The better cooling water temperatures, helped in maintaining steady vacuum conditions in the condensers. This minimised the frequent vacuum breaks, which occurred in the condensers (on account of the high cooling water temperatures) and also ensured better operating process parameters.

Financial analysis

The annual energy savings achieved were Rs.0.32 million (assuming a cogeneration system with 120 days of sugar season and saleable unit cost of Rs.2.50/kWh). This required an investment of Rs.0.50 million, which had a simple payback period of 19 months.
Mist cooling system
Installation of Regenerative Type Continuous Flat Bottom High Speed Centrifugal for A – Massecuite Curing

Background

The syrup after concentration to its maximum permissible brix levels in the vacuum pans is passed to the crystallisers. From the crystallisers, the concentrated and cooled mass, comprising of molasses and crystals are fed to the centrifugal, so that the mother liquor and the crystals are separated, to obtain the sugar in the commercial form.

The recent trend among the sugar mills is to install fully automatic centrifugal. The many operations involved in the centrifuge are - starting, charging, and control of charging speed, closing the massecuite gate, acceleration, washing with superheated wash water & steam, drying at high speed, change to low speed & control of discharging speed, opening the discharge cone, drying out the sugar, and starting the next charge. An assembly of controls, programmed to operate in the correct sequence, carries all these out.

At the end of the drying period, the centrifugal is stopped by means of a brake, which generally consists of brake shoes provided with a suitable friction lining and surrounding a drum, on which they tighten when released. Substantial amount of energy is expended in the process.

Of late, regenerative braking systems have been developed, which will permit the partial recovery of the energy expended.

Previous status

One of the 4000 TCD sugar mills, had DC drives for their flat bottom high speed centrifugal of 1200 kg/h capacity used for A - massecuite separation.

The regenerative type of braking system was considered for these high speed centrifugal to partially recover the energy expended during the discharge cycle.

These centrifugal had the conventional type of braking system, with no provisions for recovery of energy expended during changeover to low speed or discharging speed. The power consumption in these centrifugal was of the order of 2.0 – 2.5 units/100 kg of sugar.

Energy saving project

The regenerative type of braking system was installed for the entire flat bottom high speed centrifugal used for A - massecuite curing.
Concept of the project

One of the most important characteristics of a regenerative braking system in an electric centrifugal is that, it permits the partial recovery of the energy expended, during the discharge cycle.

With AC current, this is obtained by means of a motor of double polarity, which can work with half the normal number of poles. This regeneration is effective only down to about 60% of the normal speed. However, this corresponds to more than half the stored energy. With DC motors, a much greater proportion of the stored energy can be recovered.

With the present day motors, supplied with thyristor controls, regenerative braking is obtained by reversing the direction of the excitation current, as the supply is unidirectional. The motor, thus, works as a generator and the power generated (by recovery of energy during braking) is fed back into the system.

Implementation status, problems faced and time frame

The regenerative type of braking system was installed for one of the flat bottom DC motor driven high-speed centrifugal on a trial basis. Once, the satisfactory and stable operating parameters were achieved, it was extended to the remaining centrifugal also.

There were no particular problems faced during the implementation of this project. The implementation of the project was carried out over two sugar seasons

Benefits achieved

The regenerative braking system recovers about 1.34 k\text{\textit{X}}1 /100 kg of sugar produced, during the discharge cycle and feeds it back into the system. Hence, the net power consumption of the centrifugal with the regenerative braking system, is only 0.66 kW /100 kg of sugar produced.

Financial analysis

This project was implemented as a technology up gradation measure.
Continuous centrifugal machine
Installation of Jet Condenser With External Extraction Of Air

Background

The evaporators and pans are maintained at low pressures, through injection water pumps. These are one of the highest electrical energy consumers in a sugar mill. The multi-jet condenser, which are presently used in the sugar plants, do both the jobs of providing the barometric leg, as well as removing the non-condensibles.

The water injected into these condensers comprise of, spray water for condensation and jet water for creating vacuum. The water used for condensation needs to be cool, while the jet water can be either hot or cold. So only a part of the water used in the condenser needs to be cooled.

However, the vacuum levels which they give is less uniform and varies slightly with the temperature of the hot water, which in turn depends on the quantity of vapour to be condensed.

They have higher water consumption and more powerful pumps, with consequent high electric power demand.

To overcome these disadvantages, the latest trend among the major sugar mills has been to replace these multi-jet condensers with a jet condenser with external extraction of air.

Previous status.

One of the sugar mills with an installed capacity of 2500 TCD, had the multi-jet condensers for the creation of vacuum and condensation of vapours from the vacuum pans and evaporator.

There were 11 injection water pumps of 100 HP rating, catering to the cooling water requirements of these condensers. These pumps were designed to handle an average maximum crushing capacity of 3200 TCD.

With the expansion plans, for increasing the installed crushing capacity to 4000 TCD, the installation of jet condensers with external air extractor was considered.

Energy saving project

Along with the expansion plans of 4000 TCD crushing capacity, the multi-jet condensers were replaced with jet condensers having external air extractor facility.
Concept of the project

The jet condensers with external extraction of air also work on the same principle as that of the jet condensers. The nozzle is placed at such a height that the water discharged by it can be aspirated into the condenser. Since the quantity of air is very small, the water leaves the nozzle at a temperature practically equal to that at which it enters. The difference is not easily detectable, by a thermometer.

Hence, a pump of low head can be utilised and it may be arranged, so that, it is not necessary to pump the water, leaving the water actuated ejector condenser (which is used to ensure condensation in the barometric column).

For this, it is sufficient that the water level in the intermediate channel below the ejector should be about 4 m above the level in the channel at the foot of the barometric column. The water in the intermediate channel is, thus aspirated into the condenser, as soon as the vacuum approaches its normal value.

Implementation status, problems faced and time frame

There were no problems faced during the implementation of this project, except for the initial problem of identifying the ideal layout. The entire project was taken up during the sugar off-season.

Benefits achieved

There was a significant drop in water consumption in these condensers, in spite of an increase in crushing capacity (average maximum crushing of 4800 TCD). This resulted in reduction in the number of injection water pumps in operation.

The new injection water pumping system includes - 5 nos. of 135kW pump and 1 no. of 335 kW pump. Thus, there is a net reduction in the installed injection water pumping capacity of about 470 kW (30% reduction). The actual average power consumption also has registered a significant drop of nearly 180 kW which amounts to an annual energy saving of 5,18,400 units (for 120 days of sugar season).

Financial analysis

The annual benefits achieved are Rs.1.30 million (assuming a cogeneration system with 120 days of sugar season and saleable unit cost of Rs.2.50/ kWh). This required an investment of Rs 2.53 million which had a simple payback period of 24 months.
Jet condenser with external extraction of air
Avoiding the Operation Of Hot Well Pumps by Utilisation of Gravity Flow For the Injection Water Return Header

Conventional system

The vacuum pans and evaporators have multi-jet or air extractor condensers, to create the desired vacuum levels. These condensers are located at an elevation of about 10 - 12 m and utilise cold-water spray for condensing the vapours. Injection water pumps are used to pump cold water to these condensers.

The hot return water from these condensers flows down the tail pipe to a hot water channel on the ground level. From here, the hot water is pumped to the cooling tower top or the spray pond for cooling.

Thus, we have two sets of pumps for the condenser cooling water system - cold well pumps (better known as injection water pumps) for supply of water to the condensers and hot well pumps for pumping water from the hot well to the top of the cooling tower.

Most of the recently installed sugar mills have avoided the installation of the hot well pumps, by connecting the return hot water line from the condensers, directly to the top of a cooling tower.

Present system

The injection water pumps, comprising of the cold well and hot well pumps are a major consumer of electrical energy in any sugar mill.

To minimise the energy consumption of the injection water pumps, the recent sugar mills have installed the following measures by design:

- The hot water from the condensers discharges into a channel
- This trough is connected directly to the top of the cooling tower
- The operation of the hot well pump is completely avoided

Benefits achieved

The operation of the hot well pumps at the injection water pump house was completely avoided by this modification. This resulted in a power saving of 300 kW amounting to about 1.30 million units per annum (for 180 days of operation)
Financial analysis

The annual energy saving was Rs 3.37 million. This did not require any investment as the system was installed by design.

Gravity flow for the injection water return header
## COMPARISION OF DIFFERENT CASE STUDIES

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Case study</th>
<th>Advantages</th>
<th>Investment (In Millions)</th>
<th>Financial benefits (Annual savings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Installation of 30 MW commercial co-generation plant</td>
<td>• Additional revenue generation through power export to grid. • Contributes in national cause in reducing demand-supply gap</td>
<td>Rs.820.6</td>
<td>Rs 204.13 (Simple payback in 48 months)</td>
</tr>
<tr>
<td>2</td>
<td>Replacement of steam driven mill drives with electric DC motors</td>
<td>• Increased drive efficiency • Additional power export to grid</td>
<td>Rs 42.00</td>
<td>Rs 62.37 (Simple payback in 9 months)</td>
</tr>
<tr>
<td>3</td>
<td>Installation of an extensive vapour bleeding system at the evaporators</td>
<td>• Increased steam economy • Reduction in steam consumption</td>
<td>Rs 6.50</td>
<td>Rs 11.00 (Simple payback in 8 months)</td>
</tr>
<tr>
<td>4</td>
<td>Installation of Variable Speed Drive (VSD) for the weighed juice pump</td>
<td>• Reduction in juice power consumption • Steady juice flow to juice heaters and sulphitor • Better quality in sulphitation</td>
<td>Rs -</td>
<td>Rs 0.236 (Simple payback in 10 months)</td>
</tr>
<tr>
<td>5</td>
<td>Utilisation of Exhaust Steam for Sugar Drier and Sugar Melter</td>
<td>• Increased cogeneration • Additional power export to grid</td>
<td>Rs 0.02</td>
<td>Rs 0.2 (Simple payback in 2 months)</td>
</tr>
<tr>
<td>6</td>
<td>Avoiding or Minimisation of Continuous Recirculation in Boiler Feed Water Pump by Provision of Automatic Recirculation Control Valve (ARC Valve)</td>
<td>• Reduction in feed water pump power consumption</td>
<td>Rs 0.25</td>
<td>Rs 0.43 (Simple payback in 8 months)</td>
</tr>
<tr>
<td>7</td>
<td>Installation of Rotary Blower In Place Of</td>
<td>• Reduction in energy consumption</td>
<td>Rs 0.10</td>
<td>Rs 0.06 (Simple payback)</td>
</tr>
<tr>
<td></td>
<td>Compressor for Syrup Sulphur Burner</td>
<td>Installation of Thermo-compressor for use of Low Pressure Steam</td>
<td>安装</td>
<td>in 20 months)</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>-----</td>
<td>---------------</td>
</tr>
<tr>
<td>8</td>
<td>Installation of Hydraulic Drives for Mill Prime Movers</td>
<td>Increased drive efficiency</td>
<td>Reduced maintenance</td>
<td>Rs 2.00</td>
</tr>
<tr>
<td>9</td>
<td>Installation of Fully Automated Continuous Vacuum Pans for Curing</td>
<td>Facilitates use of low pressure steam</td>
<td>Vapour from II effect for A and B pans</td>
<td>Improved grain size and reduction in sugar loss</td>
</tr>
<tr>
<td>10</td>
<td>Installation of Free Flow Falling Film Evaporator (FFFFFE)</td>
<td>High pressure steam at 1.5 kg/cm² can be used</td>
<td>Extensive Vapour bleeding with marginal flow to condenser</td>
<td>Reduction in steam consumption of 3 -4% on cane</td>
</tr>
<tr>
<td>11</td>
<td>Installation of Belt Conveyors for cane carriers, Bagasse conveyors to Boilers and Sugar conveyor to the Hoppers</td>
<td>Reduction in energy consumption</td>
<td>Ease of operation</td>
<td>Reduction in maintenance</td>
</tr>
<tr>
<td>12</td>
<td>Installation of Conical Jet Nozzles for Mist Cooling System</td>
<td>Lower cooling water temperature</td>
<td>Steady vacuum in condenser</td>
<td>Reduction in pump power consumption</td>
</tr>
<tr>
<td>13</td>
<td>Installation of Regenerative Type Continuous Flat Bottom High Speed Centrifugal for A – Massecuite Curing</td>
<td>Reduction in centrifuge power consumption</td>
<td>Rs -</td>
<td>RS -</td>
</tr>
<tr>
<td>Page</td>
<td>Description</td>
<td>Benefits</td>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Installation of Jet Condenser With External Extraction Of Air</td>
<td>• Reduction in injection water pump power consumption</td>
<td>Rs 2.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Simple payback</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>in 24 months)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Avoiding the Operation Of Hot Well Pumps by Utilisation of Gravity Flow for</td>
<td>• Avoiding of hot well pump</td>
<td>Rs 3.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the Injection Water Return Header</td>
<td>• Reduction in pump power consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An attempt was made at GMR Industries limited for conservation of steam & energy in sugar industry.

The reports are as follows:

GMR Industries limited established a sugar plant of 2500 TCD capacity in the year 1997 and modernized and improved the crushing capacity to 3125 TCD. Subsequently full fledged cogeneration facility of 16MW capacity added during the year 2001. The Cogeneration plant operates during season with Bagasse from sugar operation and during off season on saved Bagasse, other biomass fuels. The surplus power generated is sold to AP Transco. Keeping in view of the cogeneration, we have opted for electrical drives to the mills. In association with CII and Tata energy research institute, we have identified severa. energy saving improvements in the plant. Prior to taking up the energy saving initiatives the power consumption per ton of cane in the sugar plant excluding boilers is detailed below section wise:

<table>
<thead>
<tr>
<th>Section</th>
<th>Actual Consumption in KW</th>
<th>KWH/MT of cane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane preparation</td>
<td>1050</td>
<td>8.3</td>
</tr>
<tr>
<td>Mill house</td>
<td>950</td>
<td>7.5</td>
</tr>
<tr>
<td>Clarification</td>
<td>180</td>
<td>2.5</td>
</tr>
<tr>
<td>Evaporator</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>Pan house</td>
<td>45</td>
<td>6.0</td>
</tr>
<tr>
<td>Centrifugal and</td>
<td>535</td>
<td></td>
</tr>
<tr>
<td>Auxillaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar house</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Crystallisers</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Cooling towers</td>
<td>218</td>
<td>3.7</td>
</tr>
<tr>
<td>Injection &amp; service</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>water pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETP</td>
<td>35</td>
<td>1.0</td>
</tr>
<tr>
<td>Lighting</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3618</td>
<td>29</td>
</tr>
</tbody>
</table>

We have provided “Energy Meters” in all the MCC (motor control centers) of different sections and the actual load is recorded as mentioned above.

Energy Conservation Initiatives:

I. Operating motors on star connection instead of delta connection:

We find several motors in sugar plants operated at less than 50% load. The power factor of these motors will be low due to this reason. In such cases, we could reduce the power consumption by operating the motors on star
connection, which will reduce the motor input voltage v3 times. The details of such motors is given below:

<table>
<thead>
<tr>
<th>Motor description</th>
<th>Rated KW</th>
<th>Actual consumption KW</th>
<th>% of loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary Screen</td>
<td>7.5</td>
<td>3.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Final molasses pump</td>
<td>7.5</td>
<td>1.8</td>
<td>24.3</td>
</tr>
<tr>
<td>CL molasses pump drive</td>
<td>7.5</td>
<td>2.0</td>
<td>26.8</td>
</tr>
<tr>
<td>CL molasses pump drive</td>
<td>7.5</td>
<td>2.8</td>
<td>37.9</td>
</tr>
<tr>
<td>Sugar melter</td>
<td>7.5</td>
<td>2.0</td>
<td>27.1</td>
</tr>
<tr>
<td>Sugar elevator II</td>
<td>11</td>
<td>2.0</td>
<td>18.2</td>
</tr>
<tr>
<td>Weighed molasses transfer pump</td>
<td>15</td>
<td>3.4</td>
<td>22.7</td>
</tr>
<tr>
<td>Sugar bin elevator I</td>
<td>7.5</td>
<td>1.9</td>
<td>26.0</td>
</tr>
<tr>
<td>Sugar bin elevator I</td>
<td>7.5</td>
<td>1.6</td>
<td>21.6</td>
</tr>
<tr>
<td>B continuous pan grain pump</td>
<td>7.5</td>
<td>0.85</td>
<td>11.3</td>
</tr>
<tr>
<td>C continuous pan grain pump</td>
<td>7.5</td>
<td>0.54</td>
<td>7.2</td>
</tr>
<tr>
<td>Sugar melter screw pump</td>
<td>15</td>
<td>3.1</td>
<td>20.7</td>
</tr>
<tr>
<td>Belt conveyor 3</td>
<td>5.5</td>
<td>2.3</td>
<td>21.6</td>
</tr>
<tr>
<td>Melter</td>
<td>7.5</td>
<td>2.1</td>
<td>28.0</td>
</tr>
<tr>
<td>Crystallisers-5 nos</td>
<td>11</td>
<td>3</td>
<td>27.3</td>
</tr>
</tbody>
</table>

We achieved savings of 3KW by connecting the above motors in star connection.

Investment: Rs12000/- (overload relays change)
Power saved: 3KW
Annual savings: 11880KWH @ 3.05 = Rs 3634/-

We are operating in star connection since three seasons and there is no problem to the motors.

II. Star delta controllers for fluctuating loads:
Motors operating at less than 50% capacity with fluctuating loads can be operated with auto star delta controllers to save energy. The details are furnished below:

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Motor Description</th>
<th>Rated KW</th>
<th>Actual consumption in KW</th>
<th>% loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Magma pump SLT-B</td>
<td>15</td>
<td>1.2</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Magma pump set drive -C after</td>
<td>15</td>
<td>2.8</td>
<td>18.7</td>
</tr>
<tr>
<td>3</td>
<td>Magma pump set drive -C</td>
<td>15</td>
<td>2.9</td>
<td>19.3</td>
</tr>
<tr>
<td>4</td>
<td>Dry seed magma mixture</td>
<td>11</td>
<td>1.5</td>
<td>13.6</td>
</tr>
<tr>
<td>5</td>
<td>Dry seed magma pump</td>
<td>11</td>
<td>3.2</td>
<td>29.1</td>
</tr>
<tr>
<td>6</td>
<td>Molasses conditioner A heavy</td>
<td>7.5</td>
<td>0.95</td>
<td>12.7</td>
</tr>
<tr>
<td>7</td>
<td>Molasses conditioner B heavy</td>
<td>5.5</td>
<td>0.9</td>
<td>16.4</td>
</tr>
<tr>
<td>8</td>
<td>B magma pump</td>
<td>15</td>
<td>6.4</td>
<td>42.7</td>
</tr>
<tr>
<td>9</td>
<td>MOL stirrer - 1</td>
<td>7.5</td>
<td>2.6</td>
<td>34.7</td>
</tr>
<tr>
<td>10</td>
<td>MOL stirrer - 2</td>
<td>7.5</td>
<td>2.5</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Investment: 1.14 lakhs
Power saved: 6KW
Annual savings: 24048KWH @ 3.05 = RS 73346/-

Operate on star connection continually is not possible due to fluctuating loads.

**III. Replacement of the normal motors with energy efficient motors.**

In general sugar plants are having normal efficiency motors of 89%, By replacing these motors with energy efficient motors available in the market, we can improve the efficiency upto 92% while replacing the motors care is taken to optimize the capacity of the motor suitable to the requirement. The details of the motors replaced and the incidental benefit achieved are given below:

<table>
<thead>
<tr>
<th>Application</th>
<th>Existing Motor</th>
<th>Energy Efficient Motor</th>
<th>Savings in KW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rated KW</td>
<td>Measured KW</td>
<td>Rated KW</td>
</tr>
<tr>
<td>Fibrizer Pusher</td>
<td>22</td>
<td>4.1</td>
<td>11</td>
</tr>
<tr>
<td>Machine</td>
<td>No. of Cycle s per Hr</td>
<td>Power Consumption / Cycle</td>
<td>Power Consumption / Mt*of M/c.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------</td>
<td>---------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Unscreened Mix. Juice pump-1</td>
<td>18.5</td>
<td>13.1</td>
<td>18.5</td>
</tr>
<tr>
<td>Unscreened Mix. Juice pump-2</td>
<td>18.5</td>
<td>13</td>
<td>18.5</td>
</tr>
<tr>
<td>Bagacillo Blower</td>
<td>15</td>
<td>13.8</td>
<td>15</td>
</tr>
<tr>
<td>Clear Juice Pump</td>
<td>18.5</td>
<td>18</td>
<td>18.5</td>
</tr>
<tr>
<td>Syrup Pump</td>
<td>15</td>
<td>9.4</td>
<td>15</td>
</tr>
<tr>
<td>Sugar Grader</td>
<td>18.5</td>
<td>4.31</td>
<td>9.3</td>
</tr>
<tr>
<td>Condensate Ext. Pump</td>
<td>15</td>
<td>12.6</td>
<td>15</td>
</tr>
<tr>
<td>Total Savings</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Investment : 1.73 Lakhs

Power saved : 8.43 KV

Annual Savings : 32978 KWH@3.05 = Rs. 100582/-

This is mainly advantageous for motors below 25KW capacity.

IV. Replacement of several low capacity machines with single high capacity machine.

0) Installation of Single “A” Batch Centrifugal (High Capacity)

We have replaced two 700 Kg/charge AC motors with one 1750 kg/charge DC drive with re-generative breaking system. For a crushing capacity of 3500 TCD at a recovery of 10.5%, we are operating one 1750 kg/charge machine and one 700 kg/charge machine as against earlier situation of four 700 kg/charge machines. The regenerating system in the DC motor drive will pump power while the machine is decelerating. This facility is not available with the pole changing AC motor. There is adequate power saving due to the above change.
**B. Installation of Single 'B' Continuous Centrifugal (High Capacity)**

In place of 1150 mm dia. three continuous centrifugal machines, we have installed one 1500 dia machine. This one machine is able to give 18 T capacity of B massecuite, which is possible only with three machines of 1150 mm dia machine. The power saving due to this is 45 KW.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Capacity</th>
<th>Power consumption / Hr.</th>
<th>Power Consumption for 18MT (Full Capacity to 1500 Dia Machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>700 Kg/Ch</td>
<td>6T</td>
<td>42KW</td>
<td>125KW</td>
</tr>
<tr>
<td>1500 Dia</td>
<td>18T</td>
<td>80KW</td>
<td>80KW</td>
</tr>
</tbody>
</table>

Net Savings : 45 KW

Investment : 13.89 Lakhs

Annual Savings : 1.95LakhKWH @ 3.05 = Rs. 5.95 Lakhs/

**C)** We had total 12 numbers of condensate pumps for evaporators, juice heaters and pans which are replaced with two pumps through a centralised condensate pumping system. The pumps which were running earlier and presently are as follows.

<table>
<thead>
<tr>
<th>Sr.N o.</th>
<th>Description</th>
<th>Before Modification Actual Consumption</th>
<th>After Modification Actual Consumption KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SK Condensate Pump</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>1st Body Condensed Pump</td>
<td>4.73</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>VC Condensate Pump</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2nd Body condensed Pump</td>
<td>3.53</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3rd Body Condensed Pump</td>
<td>4.6</td>
<td>33 KW Single</td>
</tr>
<tr>
<td></td>
<td>4\textsuperscript{th} Body Condensed Pump</td>
<td>4.34</td>
<td>Pump</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>7</td>
<td>Dyn JH Cond. Pump</td>
<td>4.13</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>SJH Con. Pump – 2 Nos.</td>
<td>5.16</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Pan Condensate Pump – 2 Nos.</td>
<td>14.3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Clear JH Condensate Pump</td>
<td>5.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>61.13</strong></td>
<td></td>
</tr>
</tbody>
</table>

Power saving with centralized system (61.13 – 6 - 33) : 22 KW

Net Savings : Rs. 4.3 Lakhs/-

Investment : 22KW

Annual Savings : 95040KWH @ 3.05 = Rs. 2.9Lakhs/-

V. Installation of Variable speed drive for cane carrier, pumps, fans etc.

A) 55 KW dyno drive cane carrier moto is replaced with variable frequency drives. The net saving due to this is about 26 KW.

Power Consumption with Dyno Drive 42.1KW

Present load with VFD : 16KW

Savings : 26.1KW

Investment : 4 Lakhs

Power saved : 26.1KW

Annual Savings : 1.17 LakhKWH@3.05 = Rs. 3.57 Lakhs/-

B) Most of the pumps, fans etc in the sugar industry will be operating at different flow rates.

Any mother operating at the rated speed will not give optimum power consumption in lower operating loads. In case of the operation at different flow conditions variable frequency drives will be useful for maximum saving of power. The details of variable frequency drives introduced in our factory are given below:
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description of Equipment</th>
<th>Power Consumption with VFD in KW</th>
<th>Power Consumption with out VFD in KW</th>
<th>Saving</th>
<th>Flowrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw Juice Pump</td>
<td>47.90</td>
<td>23.00</td>
<td>25.00</td>
<td>140 TCH</td>
</tr>
<tr>
<td>2</td>
<td>Sulphited Juice Pump</td>
<td>60.45</td>
<td>41.90</td>
<td>18.55</td>
<td>140 TCH</td>
</tr>
<tr>
<td>3</td>
<td>Imbibition Water Pump</td>
<td>18.00</td>
<td>8.00</td>
<td>10.00</td>
<td>140 TCH</td>
</tr>
<tr>
<td>4</td>
<td>Injection Water Pump</td>
<td>72.00</td>
<td>60.00</td>
<td>12.00</td>
<td>140 TCH</td>
</tr>
<tr>
<td>5</td>
<td>Service Water Pump</td>
<td>43.2</td>
<td>25.80</td>
<td>17.40</td>
<td>140 TCH</td>
</tr>
<tr>
<td>6</td>
<td>Cooling Tower Fan</td>
<td>39.00</td>
<td>25.00</td>
<td>22.00</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Boiler FD Fans - 2 Nos</td>
<td>78.00</td>
<td>63.00</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Boiler SA Fans - 2 Nos</td>
<td>132.00</td>
<td>84.00</td>
<td>48.00</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Cooling Tower Fans - 2 Nos</td>
<td>25.00</td>
<td>22.00</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Condensate extraction Pump</td>
<td>12.60</td>
<td>10.60</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>173.00</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Investment : 47.7 Lakhs

Power Saved : 173 KW

Annual Savings : 9.43 Lakhs KWH @ 3.05 = Rs. 28.76 Lakhs/-

VI. Lighting System

A) All light fittings are designed for 210 to 215 V. whereas power from our generation is available at 230 to 240 V. By introducing Voltage controllers in the circuit, we are able to step down the voltage to 210 V which is resulting in power saving as detailed below:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Voltage Controller Rating in KVA</th>
<th>Power Consumption with out Voltage Controller / Day</th>
<th>Power Consumption with Voltage Controller / Day</th>
<th>Saved KWH/ Day</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Factory Lighting</th>
<th>100</th>
<th>520</th>
<th>460</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Administrative office</td>
<td>50</td>
<td>260</td>
<td>230</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>Executive quarters and Guest House</td>
<td>50</td>
<td>380</td>
<td>330</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Total Saving KWH/Day</td>
<td></td>
<td></td>
<td></td>
<td>140</td>
</tr>
</tbody>
</table>

Investment : 2.41 Lakhs

Power saved : 140 KW H/Day

Annual Savings : 51100 KWH @3.05 = 1.56 Lakhs/-

B) By introducing electronic chokes, we can reduce the power consumption substantially (about 20%). Further the electronic choke does not require starter. We are replacing the conventional chokes with the electronic chokes in a phased manner.

VII. Other Initiatives for power saving:

a. Planetary gears

Wherever new crystallizers are being installed, we are preferring the planetary gears with very low motor capacities. In the conventional crystallizers 15 HP normal motor with gear box and worm and worm gears from part of the drive system. This can be replaced with a single 3 HP planetary gear. Apart from power saving, we can avoid the maintenance cost and oil consumption for the gears. For old crystallizers, we can operate the motor on permanent star connection as suggested earlier in this paper.

b. Rotary screen

In the present arrangement cush cush from the rotary screen in transmitted to the mill through the screw conveyer. By relocating the rotary screen we have managed falling of cush cush directly into the rake carrier. By this we can avoid screw conveyors and save 4 KW of power.

Power saved : 4 KW

Annual Savings : 17280KWH @ 3.04 = Rs. 52704/-

VIII. Installation of Capacitor Banks:
We found from our energy meters that some of the MCCs cable losses are more. The cause for power losses in the cables is voltage drop from PCC outgoing to MCC incoming. To improve MCC input voltage we have installed capacitor banks. And also we have replaced all high power loss old capacitor banks with good condition capacitors. The net power savings with capacitors banks is 16.4KW

| Power saved | 16.4 KW |
| Annual Savings | 70848KWH @ 3.05 = Rs. 216086/- |

C. The details of power consumption at different crushing rates achieved after implementing the energy conservation measures in our factory are furnished below for information.

<table>
<thead>
<tr>
<th>Crushing</th>
<th>3200</th>
<th>3400</th>
<th>3600</th>
<th>3800</th>
<th>3900+</th>
<th>4000+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane Preparation</td>
<td>7.28</td>
<td>7.06</td>
<td>6.93</td>
<td>6.61</td>
<td>6.58</td>
<td>6.40</td>
</tr>
<tr>
<td>Mils</td>
<td>7.68</td>
<td>7.66</td>
<td>6.96</td>
<td>6.81</td>
<td>6.82</td>
<td>6.80</td>
</tr>
<tr>
<td>Clarification</td>
<td>2.89</td>
<td>2.65</td>
<td>2.23</td>
<td>2.18</td>
<td>2.15</td>
<td>2.02</td>
</tr>
<tr>
<td>Boiling House</td>
<td>3.23</td>
<td>3.40</td>
<td>3.49</td>
<td>3.48</td>
<td>3.43</td>
<td>3.23</td>
</tr>
<tr>
<td>Pump House</td>
<td>2.55</td>
<td>2.53</td>
<td>2.98</td>
<td>2.85</td>
<td>2.83</td>
<td>2.61</td>
</tr>
<tr>
<td>ETP, Lighting, Colony and others</td>
<td>0.39</td>
<td>0.37</td>
<td>0.35</td>
<td>0.33</td>
<td>0.32</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>24.04</td>
<td>23.67</td>
<td>22.94</td>
<td>22.26</td>
<td>22.13</td>
<td>21.37</td>
</tr>
</tbody>
</table>
I have taken these power conservation initiatives from 2002-03 crushing season and the power consumption details pertaining to three years is detailed below month-wise including stoppages.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UNITS</td>
<td>CANE</td>
<td>KWH/MT</td>
<td>UNITS</td>
<td>CANE</td>
</tr>
<tr>
<td>October</td>
<td>40000</td>
<td>1080</td>
<td>37.04</td>
<td>289716</td>
<td>11310</td>
</tr>
<tr>
<td>November</td>
<td>342759</td>
<td>13170</td>
<td>26.03</td>
<td>204752.7</td>
<td>68120</td>
</tr>
<tr>
<td>December</td>
<td>244232</td>
<td>78600</td>
<td>31.07</td>
<td>227182</td>
<td>73860</td>
</tr>
<tr>
<td>January</td>
<td>201950</td>
<td>62930</td>
<td>32.09</td>
<td>243065</td>
<td>81610</td>
</tr>
<tr>
<td>February</td>
<td>241441</td>
<td>83000</td>
<td>29.09</td>
<td>233496</td>
<td>85580</td>
</tr>
<tr>
<td>March</td>
<td>233055</td>
<td>78500</td>
<td>29.69</td>
<td>256649</td>
<td>94780</td>
</tr>
<tr>
<td>April</td>
<td>242746</td>
<td>79690</td>
<td>30.46</td>
<td>243615</td>
<td>85290</td>
</tr>
<tr>
<td>May</td>
<td>957225</td>
<td>22731.02</td>
<td>42.11</td>
<td>242808.8</td>
<td>83473.9</td>
</tr>
<tr>
<td>June</td>
<td></td>
<td>130128</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>129342</td>
<td>41621</td>
<td>30.90</td>
<td>166858</td>
<td>573793.9</td>
</tr>
</tbody>
</table>
There FutureProjects:

a. Installing VFD for rake Elevator, inter rake carriers, Magma pumps and Super heat wash-water pumps.
b. Providing Level controller for sugar Dust Collector Pump to operate intermittently.
c. Automation of massecuite feeding to continuous centrifugal machine.
d. Full plant automation.
e. Installation of HT Motors to Fibrizor Drive.

Conclusion:

• The higher crushing rate and optimum utilization of the plant capacity will reduce the power consumption without any modifications or improvement.
• By making necessary changes / modification in the available equipment / system we can avoid unnecessary pumping or head loss which will contribute for power saving.
• As for as possible opting for minimum number of high capacity machine instead of several number of low capacity machines will also save lot of power and maintenance cost.
• By working out pay back period we can take up the replacement of the existing inefficient machine / motors with efficient motors / machines or variable frequency drives progressively will help in saving of substantial power.
• It is advisable to have an energy audit done by competent agency like CII, TERI for every factory to identify various energy saving measures so that they can be implemented progressively depending on the investment funds available and pay back period.
• In the present global scenario reducing the cost of production through various measures like, energy conservation is essential to sustain in the competitive world. It is a continual improvement process and hence participation of the employees of the factory at all levels is essential to achieve this result with the
support of the management. There is a lot of scope to reduce power consumption further and we wish the industry will take initiative in this direction to achieve maximum benefit for sustaining.
SEED MELTING FLOW DIAGRAM