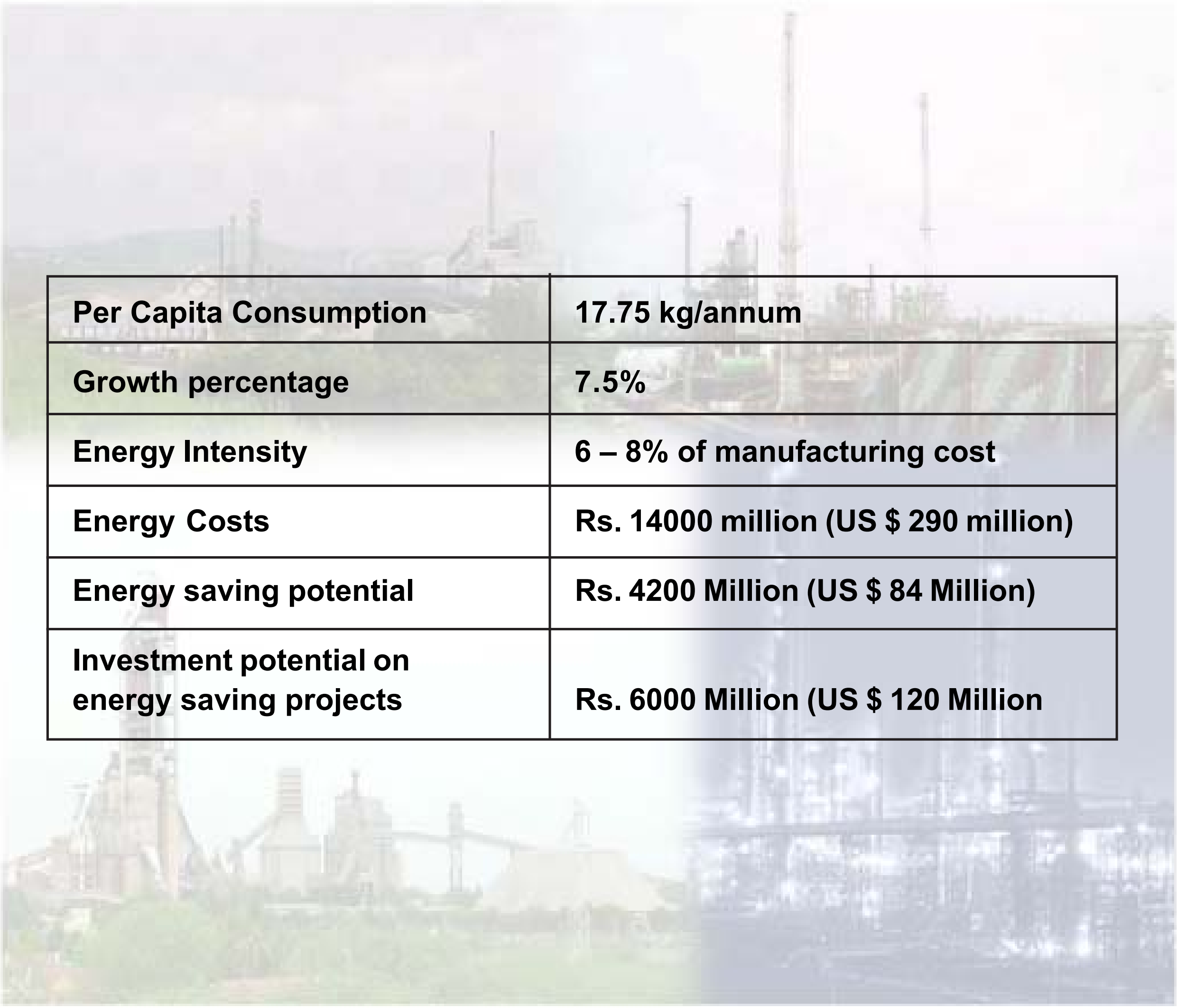
Sugar



Per Capita Consumption	17.75 kg/annum
Growth percentage	7.5%
Energy Intensity	6 – 8% of manufacturing cost
Energy Costs	Rs. 14000 million (US $ 290 million)
Energy saving potential	Rs. 4200 Million (US $ 84 Million)
Investment potential on energy saving projects	Rs. 6000 Million (US $ 120 Million

1.0 Introduction

India is the largest consumer and second largest producer of sugar in the world. With over 450 sugar factories located throughout the country, the sugar industry is amongst the largest agro processing industries in India, with an annual turnover of Rs. 150 Billion (US $ 3.3 Billion).

Sugar is a controlled commodity in India under the Essential Commodities Act, 1955. The government controls sugar capacity additions through industrial licensing, determines the price of the major input sugarcane, decides the quantity that can be sold in the open market, fixes the prices of the levy quota sugar and determines maximum stock levels for wholesalers, etc.

Sugar prices are the lowest in India when compared to the leading sugar consuming countries in the world. Converted in Indian rupees the price equivalent in China Rs. 25.78 per kg, in Indonesia Rs. 18.62 per kg and in Brazil and Pakistan it is Rs. 17.9 per kg. The price of sugar in India is Rs. 12.68 per kg.

With the price being lowest in India, the competitiveness of the industry lies in lowering the cost of production. One of the major area, almost all the major sugar industries have focused on, is energy efficiency.

2.0 Historical Industry Development

India has been known as the original home of sugarcane and sugar. Indians knew the art of making sugar since the fourth century.

The Indian sugar industry has not only achieved the singular distinction of being one of the largest producer of white plantation crystal sugar in the world but has also turned out to be a massive enterprise of gigantic dimensions.

Over 45 Million farmers, their dependants and a large mass of agricultural labor are involved in sugarcane cultivation, harvesting and ancillary activities constituting 7.5% of the rural population. The sugar industry employs over 0.5 Million skilled and unskilled workmen, mostly from the rural areas.

The average capacity of the sugar mills in the industry has considerably moved up from just 644 ton per day in SY1930-31 to 2656 ton per day. But still the growth in the Indian sugar industry was driven by horizontal growth (increase in number of units) compared to the vertical growth witnessed in other countries (increase in average capacity).

3.0 Energy consumption in Sugar Industry

Sugar industry is energy intensive in nature. The power & fuel consumption in the Indian sugar industry is in the order of Rs. 124.0 Crores. This is the contribution of sugar plants operating without co-generation facility.

The average energy consumption in an Indian sugar mill is about 38 units / ton of cane crushed. The average cane crushing in Indian mills is about 2700 TCD. The total power requirement in a standard sugar mill is in the order of 4.25 MW.

The total cane crushed in Indian sugar industry is about 360 Million tons. The total power consumption for this requirement is about 13.68 Billion kWh. This corresponds to equivalent power of about 3250 MW (considering average crushing of 175 days).

Energy efficiency in sugar industry offers the following benefits:

- In plants having cogeneration facility and where the state utility is able to purchase additional power generated from sugar plants, any improvement in energy efficiency levels of the plant results in increased export to the grid. This reduces the equivalent reduction in power generation from fossil fuel based power plants. This has a significant reduction in carbon emissions.
- In plants having cogeneration facility, but the state utility is not ready to purchase power, improvement in energy efficiency in the plant results in saving in bagasse. This either could be exported to other sugar plants, having cogeneration facility with state utility ready to purchase power, or can be sold to paper plants.
- In plants which do not have cogeneration facility, energy efficiency directly results in reduced power demand from the state utility. This results in higher profitability to the plant as well as significant reduction in GHG emission. These plants, however, are very few in number.

The Indian sugar industry offers good potential for energy saving. The estimated energy saving potential in the Indian sugar industry is about 20%. This offers potential of about 650 MW of electrical energy. This corresponds to about Rs. 2600 Crores investment, in newer power plants.

The investment opportunity in the Indian sugar industry is estimated to be in the tune of about Rs. 5000 Crores.

Per Capita Consumption of sugar in India

Indians by nature have a sweet tooth and sugar is a prime requirement in every household.

Almost 75% of the sugar available in the open market is consumed by bulk consumers like bakeries, candy makers, sweet makers and soft drink manufacturers.

The per Caipta sugar consumption in India is about 17.75 kg/annum. This is growing at a rate of 7.5% every year, on an average.

4.0 Cogeneration

The sugar industry by its inherent nature can generate surplus energy in contrast to the other industries, which are only consumers of energy. With liberalization and increased competition, the generation and selling of excess power to the electricity board, offers an excellent source of revenue generation to the sugar plants. This is referred to as commercial cogeneration and has been only marginally tapped in our country.

Integrated approach and Co-generation

Co-generation in sugar plant

The sugar plants have been adopting co-generation right from the beginning. However, the co-generation has been restricted to generating power and steam only to meet the operational requirements of the plant. Only in the recent years, with the increasing power demand and shortage, commercial cogeneration has been found to be attractive, both from the state utility point of view as well as the sugar plant point of view.

The sugar plant derives additional revenue by selling power to the grid, while the state is able to marginally reduce the 'demand-supply' gap, with reduced investments.

The sugar plant co-generation system can be in the one of the following ways

i. Conventional system

The old sugar plants, installed particularly in the sixties in India, have this type of system. These plants are characterized by

- 20 kg/cm^2 boiler
- Mill drives and shredder driven by individual turbines
- One or two back pressure power turbines, for meeting the remaining power requirements

These systems have low operating efficiency and result in little bagasse saving, after meeting the plant requirements. The non-season power requirement is met from the grid.

ii. Partly modified system

This type of system is prevalent in the plants installed in the eighties. These plants are characterised by

- 32 kg/cm^2 or 42 kg/cm^2 boiler
- Mill drives are partly steam driven and partly DC motor driven
- One / two back pressure turbines, meeting the power requirements of the plant.

These systems have slightly higher operating efficiency and result in little bagasse saving, after meeting the plant requirements. The non-season power requirement is met from the grid.

iii. Commercial co-generation system-only season

This type of system is prevalent in the plants installed in the early nineties. These plants are characterised by

- 42 kg/cm^2 / 64 kg/cm^2 boiler with bagasse and auxiliary fuel firing

- Mills are DC motor driven
- One/two back pressure turbines, for meeting the power requirements and the excess power is sold to the grid.

These systems have much higher operating efficiencies and result in excess energy being generated and sold to the grid during the season. The non-season power requirement of the plant is met from the grid.

iv. Commercial co-generation system – Both season and non-season

These are the latest systems installed very recently and operating in the sugar plants, predominantly in the state of Tamil Nadu.

These plants are characterised by

- 42 kg/cm^2 / 64 kg/cm^2 / 82 kg/cm^2 boiler
- Bagasse firing during season & firing with other fuel during non-season
- Mill drives are hydraulic or DC drives
- One / two extraction - cum - condensing turbine
- Turbine operates with nil condensing during season and maximum condensing during non-season. This scheme can be a very attractive alternative, if some cheap source of fuel is available.

These plants have the highest operating efficiency and the excess energy generated is sold to the grid during the season. During the non-season, the boilers are fired with the auxiliary fuel and the turbine is operated in the condensing mode. The excess power after meeting the plant requirements, is sold to the grid.

This alternative results in maximum revenue generation for the sugar plant and is very attractive if the auxiliary fuel is available at a cheaper cost.

5.0 Manufacturing Process & Target energy consumption

The target electrical and thermal energy consumption of a new sugar plant should be as given below

Specific Electrical Energy consumption	30 units/ton of cane with electric motors & DC Drives 24 units / ton of cane with diffusers
Specific Thermal Energy steam consumption	38% on cane

5.1 Electrical energy

Cane preparation

The cane preparation is the first operation in the production of sugar. The preparatory equipments include kicker, leveller, cutter, fibrizers and shredders. The degree of preparation has a major effect on the cane crushing capacity and extraction. The efficiency / capacity of the utilisation of the cane carrier system can be increased, with parallel loading of cane. The parallel loading of cane is possible with sling type unloading and hydraulic tipper unloading.

The typical cane preparation devices suggested are kicker and cutter followed by a fibrizer / shredder. The cane carriers need a variable speed mechanism, to regulate the flow of cane to the shredders. The shredders also need a variable speed mechanism, to take care of the varying load. The shredders have, either a steam turbine or a dynodrive for varying the speed, while the cane-carriers have a dynodrive. Both these systems are energy inefficient.

Hence, it is recommended to install DC motors or AC variable speed drives for the cane carriers.

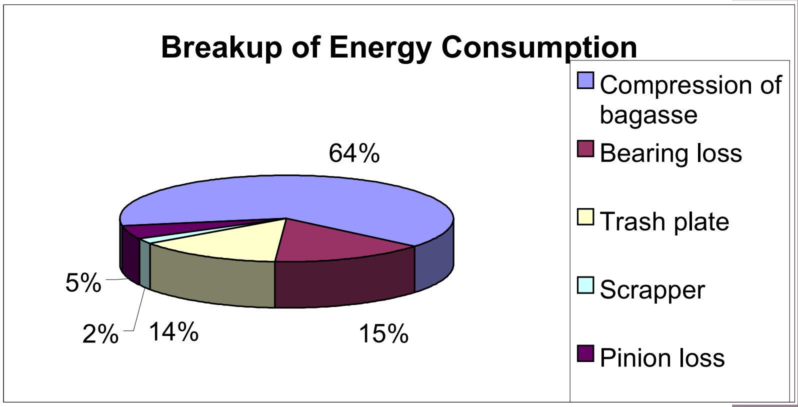
Target energy consumption in cane preparation section – 4.00 kWh / ton

Milling – operation

The prepared cane is crushed, to separate the juice and bagasse. The crushed juice is then taken up for further processing, while the bagasse is despatched to the boiler house.

The milling energy requirement, depends on the efficiency of conversion at the prime mover and the actual shaft power required at the mills.

The scrapper power and the pinion loss are standard for all mills, while the other three depend on the hydraulic pressure applied and the fibre loading.



The bearing loss of 15% in the case of white metal bearings, can be totally avoided, by replacing them with anti-friction roller bearings.

The power spent for compression of bagasse and power absorbed by trash plate due to the friction with bagasse, depends on the power applied to the top roller and trash plate setting.

A latest development in this regard, is the development of a Low-Pressure Extraction (LPE) system. This new system comprises of, a long train of two roller bearings, operating under low hydraulic pressure. The trash plates are eliminated, resulting in substantial reduction of power upto 35%.

Target milling power consumption – 9.5 units/ton of cane for conventional milling system.

Milling – prime mover

The installation of the right prime mover also has a major bearing on the energy efficiency of a sugar plant. In the Indian sugar industry, presently 3 types of prime-movers are being used as below

- Steam turbines
- Electric DC motors
- Hydraulic drives

Steam turbines

These have been used in all the older sugar units for driving the mills. These low capacity turbines are single stage turbines and have very low efficiencies of the order of 35-40%. The lengthy transmission also involves additional losses, making it more inefficient. Hence, steam turbines are not recommended for prime movers in the milling section.

Electric DC motors

These have much higher efficiency than the steam turbines and with better control & cleaner operations, are easily adaptable into any system. The DC drive also avoids the primary high-speed reduction gearbox, resulting in a higher overall efficiency of 51%. The steam turbines have been replaced with electric DC drives, resulting in considerable benefits in many sugar plants.

Hydraulic drives

The utilization of hydraulic drives for the prime-moves in the mill section, is also gaining rapid popularity among the sugar units. This involves a combination of an electric motor driven pump and a hydraulic motor, which operates by the displacement of oil. The speed is controlled, by varying the flow in a fixed displacement pump and by changing the pump swash angle, in a variable displacement pump. The over-all efficiency of a hydraulic system is nearly about 53%. The cost of hydraulic drives is higher than that of the DC drives. However, if the total cost, comprising of the building, transformer etc. are taken into account, the cost of installation of a hydraulic drive and a DC drive are nearly comparable.

5.2 Latest development in manufacture of sugar

Cane Diffusers

Cane diffusers have been the latest and the most energy efficient method in cane preparation. Modern sugar mills have adopted cane diffusion, in lieu of conventional milling tandem, considering the multi-pronged advantages, diffusion process offers over conventional milling process.

In Cane Diffuser, prepared cane is directly sent to Diffuser, which acts both as primary and secondary extraction equipment. Sugar in the prepared cane is systematically leached with water and thin juice. At the end of the diffusion process, diffused bagasse discharged from the diffuser is conveyed to De watering mill where moisture is reduced to 50%. De-watering mill outlet bagasse is sent to boiler and the mill juice is sent to Diffuser.

Cane diffusion Process

The Juice extraction process in the cane diffuser system is as follows:

i. Cane is prepared up to a Preparation Index (PI) of over 85 %.

ii. Prepared cane is delivered to the diffuser. The cane is heated at entry to the diffuser to a temperature of 83 Degree C by scalding juice. Scalding juice is the juice from the initial compartment of the diffuser and is heated from a temperature of about 69^{o}C to 90^{o}C.

iii. The diffusion percolation bed is a moving conveyor on which the cane bed height is between 1200 mm to 1400 mm.

iv. The diffuser is divided in 13 circulation compartments. Juice from each compartment is re-circulated in counter current direction to cane blanket movement, from low brix area to high brix area.

v. The scalding juice is limed in order to maintain a pH of about 6.5 in the diffuser in order to prevent inversion of sucrose.

vi. Average temperature of the material inside the diffuser is about 78^{o}C

vii. Draft juice from the diffuser is at about 69^{o}C and is sent directly to the sulphitation vessel

viii. Diffusion bagasse at exit of the diffuser is at supersaturated moisture and is de-watered in a single six-roller mill. Final bagasse moisture is about 51 %.

ix. Imbibition is applied directly in the diffuser. Hot condensate at 84^{o}C from the evaporator last effect is used for imbibitions.

Draft juice is measured by a mass flow meter. Screening of draft juice is not necessary because the bagasse bed through which the juice percolates, itself acts as a screen.

Mill section – auxiliaries

The auxiliaries in the milling action are the juice transfer pumps, in between the drives and the imbibitions water pump. In majority of the plants, the pumps are designed for the maximum capacity, with a large cushion. This results in either the discharge valve being throttled or the inlet tank of the pump becoming empty at regular intervals. Both these are energy inefficient operating methods.

Hence, it is recommended to install –

- High efficiency centrifugal pump and
- Variable Frequency Drive (VFD) for controlling the flow to the system for the juice transfer pumps and imbibition water pumps.

Juice preparation

The juice preparation involves the weighing & heating of juice, sulphitation and clarification, to make it fit for the process of evaporation. The juice preparation section, comprising of the juice pumps, is also a major electrical energy consumer.

Final juice heater Tubular/Plate heat exchanger (PHE)

The juice heaters over a period of time get scaled up and the pressure drop increases. To take care of this, stand-by juice heater is to be installed for each of the primary and secondary juice heaters. In the case of the final juice heater, the stand-by is optional. Target energy consumption in juice preparation section - 2.00 units / ton of cane.

Evaporator, crystalliser & pans

These are minor consumers of electricity primarily in the form of transfer pumps and recirculation pumps in FFE. The aspect that needs to be taken care is the installation of the right capacity & head pumps with high efficiency.

Target energy consumption - 1.00 unit / ton of cane

Pump house (Evaporator and Vacuum Pans)

The juice after preparation goes to the evaporator, for further concentration into syrup, which gets further concentrated in the vacuum pans. The evaporators and the vacuum pans are maintained at lower pressures, through injection water pumps.

It is recommended to use multi-jet condensers with hot water spray for jet water. The water-cooling system can be one of the following

- Cooling tower
- Mist cooling/spray pond cooling

Target energy consumption for pump house - 3.50 units / ton of cane

Boiler house

The boiler and its auxiliaries are also major consumers of power in a sugar plant. The major power consumers in the boiler house are the I.D, F.D, P.A & S.A fans and the BFW pumps. The energy consumption can be kept at a bare minimum, by adopting the energy efficiency aspects at the design stage itself.

Target energy consumption for boiler house - 2 units/ton of cane

Centrifugals

The centrifuge section, where the sugar is separated and washed from molasses, is also a major consumer of power. Presently, two types of centrifuges are in operation in the industry – batch and continuous centrifugals.

Target power consumption in centrifugals – 6.00 units/ton of cane

5.3 Steam Consumption

The sugar industry is a major consumer of steam, with the evaporators and vacuum pans consuming substantially quantities for concentration of juice and manufacture of sugar. Apart from these, the juice heaters, centrifuges, sugar dryers and sugar melting also consume some steam. The washing of pans and other equipment need some marginal steam.

Evaporator

The evaporator is the major steam consumer in a sugar plant. 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. Further to the concentration to a higher level, the concentrated syrup is transferred to the vacuum pan section, for evapo-crystallisation, to produce sugar.

Several types of evaporators are used in the sugar industry. The commonly used are the quadruple and quintuple-effect short-tube evaporators. Typically, the steam enters the first effect at a pressure of 1.1 kg/cm^2, at a temperature of 105^{o}C and the vacuum in the last effect is around 650 mm Hg.

The multiple effect evaporators have higher steam economies of 3 to 5, depending on the number of effects.

Falling film evaporators (FFE)

This is another popular evaporator, which is being considered by many sugar industries. In this type the juice travels from top to bottom and as it descends, it takes the entrained vapour along with it to a lower chamber, where the vapour and liquid are separated.

The falling film evaporators have many advantages over the conventional evaporators as below

- The FFE's have better heat transfer, as there is no elevation in boiling point due to hydrostatic pressure.
- The average contact time between juice and steam in a falling film evaporator is about 30 seconds as against 3 minutes in the Kestner evaporator and 6-8 minutes in the conventional short tube evaporator.
- The design of the evaporators is such that, the juice is in contact with the heating surface in a thin layer over the length of the heating surface.

The installation of falling film evaporator has therefore, immense potential for installation in the Indian sugar industry for achieving substantial savings in steam. Hence, all new plants should strongly consider installation of FFE for the first three effects and at-least for the first two effects to begin with.

Target steam consumption in evaporators – 34% on cane

Vacuum pans

The vacuum pans are used for further concentrating the massecuite produced in the evaporators, to finally produce sugar and molasses. Conventionally, the Indian sugar industries have been using the batch pan. With the recent introduction of the continuous pans, there has been a reduction in the steam consumption to the extent of 15 – 20%.

Apart from the steam reduction, the utilization of continuous vacuum pans also result in

- Improved grain
- Reduced sugar loss
- Better control and systems.
- Reduced power consumption for injection water pumps.

Hence, by design all new plants should install only continuous vacuum pans. Other steam consumers The other miscellaneous steam consumers in a sugar plant are

- Sugar dryers
- Sugar melter
- Centrifuge wash water super heater
- Other washing /cleaning application

6.0 Energy Saving Projects in Sugar Industry

The energy saving projects in sugar industry are detailed below:

Cane Preparation & Juice Extraction

Short Term Projects

- Avoid recirculation in the filtrate juice by installing next lower size impeller

Medium Term Projects

- Install lower size pump for weighted juice pump/Install VFD for weighed juice pump
- Install correct size pump for crusher
- Install correct size pump for imbibition water pump
- Install lower capacity pump for juice transfer at III mill and minimize recirculation
- Install lower head pump with VFD for raw juice pump
- Install next lower size impeller for mill IV juice transfer pump
- Install right size pump for imbibition water pumping
- Install Variable Frequency Drive for Imbibition Water Pump
- Install variable frequency drive(VFD) for cane carrier drives
- Install VFD for weighed juice pump

Long Term Projects

- Install DC drives/hydraulic for mill drives & shredder
- Install electronic mass flow meters for all three mills and avoid use of weighed juice transfer pump.

Juice Heating, Sulphitation, Clarification & Crystallization

Short Term Projects

- Reduce rpm of existing reciprocating compressors (centrifugal house) by 20%
- Utilize L P steam for sugar dryer and sugar melting

Medium Term Projects

- Avoid condensate water pumps at juice heaters and evaporators
- Commission load/unload mechanism for sulphur air compressors
- Improve flash steam utilization for S K condensate and quad-1
- Improve sealing of the stand-by blower, avoid damper control and reduce impeller size of the sugar drier blower

- Install lower size pump for clarified pumping/install VFD for clarified juice pump
- Install lower size pump for sulphite juice tank/install VFD for sulphite juice pump
- Install right pump for filter condenser water pumping
- Install rotary blower in place of Compressor for supplying air to syrup sulphur burner
- Install thermic fluid /pressurized hot water heat recovery system for utilizing sulphur furnace exhaust steam for sulphur melts
- Install Variable Frequency Drive for super heated wash water pump
- Install VFD/small size pump/lower size impeller for mill IV juice transfer pump
- Optimize operation of spray pump
- Provide VFD for booster vacuum pump of vacuum pans (1-12)
- Provide VFD for rotary blowers of sulphur burner
- Reduce RPM of sulphur burner compressor
- Reduce rpm of vacuum pumps for drum filter
- Segregate high vacuum and low vacuum requirements of Oliver filter
- Segregate spray water and jet water and use cold water only for spray

Long Term Projects

- Modify new injection pumping system and avoid use of cooling tower pumps

Cogeneration system

Short Term Projects

- Arrest air infiltration in boilers
- Arrest identified steam leaks and improve the working of steam traps in identified areas
- Avoid recirculation of boiler feed water pump in WIL boiler
- Down size impeller of SA fan
- Improve combustion efficiency of all the boilers
- Improve insulation in identified areas
- Rationalize condensate collection system
- Reduce RPM of power plant air compressor
- Replace feed water make-up pump with low duty ump
- Use exhaust steam for deaerator water heating

Medium Term Projects

- Convert identified MP steam users to LP steam users

- Install a flash vessel to recover the flash from the boiler continuous blow down & HP steam header traps drain and connect to exhaust header
- Install correct size pump for the condensate transfer pump
- Install L P steam heater in delivery of boiler feed water pump
- Install steam jet ejectors in place of vacuum pumps for vacuum filters
- Install thermo compressors with 150 psi steam for compressing 8 psi and 12 psi exhaust vapors to 16 psi
- Install variable fluid coupling for boiler ID fans
- Install Variable Frequency Drive for Auxiliary Cooling Water (ACW) pump
- Install Variable Frequency Drive for Condenser Water pump
- Install Variable Frequency Drive for SA & PS fans and operate in open loop control
- Install VFD for Boiler feed water pump
- Optimize capacity of boiler house compressor
- Replace identified fans with correct size high efficiency fans

Long Term Projects

- Commission de-aerator and utilize L P steam for heating condensate water in de-aerator
- Install heat exchanger to preheat boiler feed water
- Install small turbine for utilizing 43/8 ata steam

Distillery

Short Term Projects

- Increase the temperature of fermented wash from 83 degree C to 90 Degree C by installing Additional plates
- Install additional standby PHE for fermented wash heating
- Install lower head pump for fomenter circulation pump

Long Term Projects

- Install steam ejector and utilize LP steam for distilleries

Auxiliary areas

Short Term Projects

- Avoid/reduce over flow of cold water OH tank by installing next lower size impeller for pump
- Install level based ON / OFF control for service water pumps

- Install LIC for service tank/Install correct size pump for service tank
- Install temperature cut-off switch for cooling tower fans

Medium Term Projects

- Arrest compressed air leakages at packing section
- Convert ‘V’ belt to flat belt drive at the identified equipment
- Install auto drain valve for instrument air compressor
- Install correct size pumps for hot water pumping at cooling tower
- Install FRP blades for process Cooling Tower fans
- Install next lower size impeller for hot water process cooling tower pump
- Install Variable Frequency Drive for Cooling Tower fans
- Install Variable Frequency Drive for service water pump
- Provide cooling tower for identified equipments and stop use of fresh water
- Segregate the low vacuum and high vacuum of Oliver filter

Electrical

Short Term Projects

- Convert delta to permanent star connection for the identified lightly loaded motors
- Install automatic star - delta - star converter in the identified lightly loaded motors
- Optimize the plant operating frequency, if operating in island mode
- Optimize the plant operating voltage

Medium Term Projects

- Improve the P.F of the Identified feeders and reduce the cable loss
- Install automatic slip ring controller for the cane leveler
- Install soft starter cum energy saver at the lightly loaded motors
- Replace filament lamps installed in panel on/off indications with energy efficient led lamps
- Replace identified faulty capacitor banks

Energy Efficient Equipment

Medium Term Projects

- Replace dyno drives with variable frequency drives in identified equipments
- Replace eddy current drive in cane carrier with variable frequency drive

- Replace old rewound motors with Energy Efficient motors

Lighting

Short Term Projects

- Avoid daytime lighting in identified areas
- Increase the natural lighting by installing translucent sheets and switch off the identified light
- Install 50 KVA step down transformer at the main lighting circuit

Medium Term Projects

- Convert the 100 incandescent lamps with 40W fluorescent lamps
- Convert the existing 200 W 300W & 500 W incandescent lamps with 160W choke less LML lamps
- Convert the existing 40W fluorescent tubes with 36 W slim tubes
- Covert the 400 W high pressure mercury vapor lamps (HPMV) with 250 W energy efficient high pressure sodium vapor lamps (HPSV)
- Install automatic voltage stabilizer in lighting feeder and operate at 205 -210 volts
- Install energy efficient Copper chokes for identified fluorescent lamps

7.0 Detailed description of capital intensive energy saving projects

13 no of capital intensive energy saving projects are described in detail. These projects have been chosen as they have high saving and investment potential with high replication possibility.

Case study 1

Install diffusers in lieu of milling tandem

Background

Installation of milling tandem is practiced conventionally in sugar plants in India. Milling is highly power and labour oriented equipment. The present trend is to adopt diffusion as an alternative to Milling, considering several advantages diffusion offers over milling.

It is a low cost extraction process. In conventional milling mass transfer operation is by leaching followed by high pressure squeezing. In diffusion process, the physico-chemical principle of diffusion is adopted. Here sugar molecules moves from higher concentration to lower concentration due to concentration gradient.

Rate of diffusion is proportional to the temperature, concentration gradient and the area of liquid and solid contact.

The Juice extraction process in the cane diffuser system is as follows:

1. Cane is prepared to a Preparation Index (PI) of 85 %+, ensuring long fiber preparation. The heavy duty swing hammer fibrizor described above is suitable for meeting this requirement.
2. Prepared cane is delivered to the diffuser. The cane is heated at entry to the diffuser to a temperature of 83^{o}C by scalding juice, which is at a temperature of about 90^{o}C.
3. The diffusion percolation bed is a moving conveyor on which the cane mat height is between 1200 mm to 1400 mm.
4. The diffuser is divided in 13 circulation compartments. Juice from each compartment is re-circulated in counter current manner to cane blanket movement, from low brix area to high brix area.
5. The scalding juice is limed in order to maintain a pH of about 6.5 in the diffuser in order to prevent inversion of sucrose.
6. Average temperature of the material inside the diffuser is about 78 Degree C
7. Draft juice from the diffuser is at about 69 Degree C and therefore is sent directly to the sulphitation vessel because it is already at the required temperature for sulphitation.
8. Diffusion bagasse at exit of the diffuser is at supersaturated moisture and is de-watered in a single six-roller mill. Final bagasse moisture is 51 % plus.
9. Imbibition is applied directly in the diffuser. Hot condensate at 84 Degree C from the evaporator last effect is used for this. Imbibition quantity at Andhra Sugars is 320 % on Fiber.
10. Draft juice is measured by a mass flow meter. Hence the juice is delivered to the sulphitation vessel in a closed pipe without appreciable loss of temperature. Screening of draft juice is found to be not necessary because the bagasse bed through which the juice percolates, itself acts as a screen.

Energy Saving Project

A 2500 TCD plant in India has installed cane diffuser by design. The power consumption in a standard sugar mill, utilizing a milling tandem for juice extraction is 17.8 kWh / ton. In the plant under discussion, the average power consumption in the juice extraction section is 11.4 kWh / Ton. This results in a decrease of 6.4 kWh / Ton of cane crushed.

The other spin off benefits on installation of diffuser are:

- Increased extraction
- Lower power consumption
- Lower maintenance cost
- Reduction in Unknown loss
- Reduction in Lubrication Cost
- Reduction in Sugar Loss in filter cake
- Availability of More Bagasse

Financial Analysis

The additional .. saving benefit was Rs 8.0 million. Considering an average crushing of 2500 TCD for an operating season of 180 days, the reduction in power consumption is 28.8 Lakh units. This results in an energy cost saving of Rs. 8.0 million / season (Considering power export cost of Rs. 2.75 / kWh). The diffuser was installed by design.

Replication Potential

This project has tremendous replication potential. In India, the number of sugar mills over 2500 TCD capacity is more than 320. Considering an average crushing of 150 days and power export cost of Rs. 2.75 / kWh, the total energy saving potential is over Rs. 2.112 Billion/ season.

Considering an investment of Rs. 90 Million per diffuser, the investment potential for installation of diffusers in Indian sugar industry is Rs. 28.8 Billion.

Cost benefit analysis

- Annual Savings - Rs. 8.0 millions
- Investment - Rs. 90 millions

Project-1: Install diffusers in lieu of milling tandem

Savings/Year (Rs Million)	**8.0**
Investment (Rs Million)	**90.0**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Inflow																					
Energy saving (A)		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Out flow																					
Initial Cost (B)	90.0																				
Less Depreciation (C)		90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		-82.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Tax @ 30.5 % on (D)		0.0	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Cash Inflow after Tax	**-90.0**	**-82.0**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**
Cumulative cash flow		**-82.0**	**-76.4**	**-70.9**	**-65.3**	**-59.8**	**-54.2**	**-48.6**	**-43.1**	**-37.5**	**-32.0**	**-26.4**	**-20.8**	**-15.3**	**-9.7**	**-4.2**	**1.4**	**7.0**	**12.5**	**18.1**	**23.6**

NPV (Rs. Million)	**-126.6**
IRR	**-4.27%**

Observations

* **This project has only two installations in india**
* **This has tremendous potential for attracting CDM benefits**
* **This has got high potential for reducing CO2 & other GHG emissions**
* **Evaluation is to be done based on reduction in power intake and carbon benefits to make them attractive**

Basis for Calculation

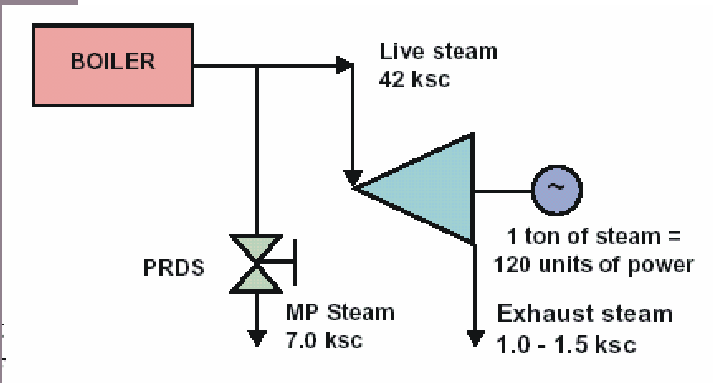
* **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
* **NPV & IRR are calculated for 20 years**
* **Corporate tax is considered as 30.5 % (as existing in India presently)**
* **Interest on investment is considered as 12 % for Calculating NPV**

Case study 2

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:

Benefits of using exhaust steam for sugar drier and melter

- Increased co-generation
- Additional power export to grid

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.

Previous Status

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 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 co-generation. 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**.

Cost benefit analysis

- Annual Savings - Rs. 0.2 millions
- Investment - Rs. 0.02 millions
- Simple payback - 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 atleast 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.

Project-2: Utilisation of Exhaust Steam for Sugar Drier and Sugar Melter

Savings/Year (Rs Million)	0.2
Investment (Rs Million)	0.02

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inflow																
Energy saving (A)		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Out flow																
Initial Cost (B)	0.0															
Less Depreciation (C)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		0.18	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Tax @ 30.5 % on (D)		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cash Inflow after Tax	**0.0**	**0.13**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**	**0.14**
Cumulative cash flow		**0.1**	**0.3**	**0.4**	**0.5**	**0.7**	**0.8**	**1.0**	**1.1**	**1.2**	**1.4**	**1.5**	**1.7**	**1.8**	**1.9**	**2.1**

NPV (Rs. Million)	**0.9**
IRR	**634.96%**

Basis for Calculation

*** Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
*** NPV & IRR are calculated for 15 years**
*** Corporate tax is considered as 30.5 % (as existing in India presently)**
*** Interest on investment is considered as 12 % for Calculating NPV**

Case study 3

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 onfigurations 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.

Mist Cooling System

Previous status

In a 4000 TCD sugar mill, the cooling systemconsisted of a spray pond. There were 5 pumps of 75 HP rating operating continuously, to achieve the desired cooling parameters. The materials of construction of the spray nozzles were Cast Iron (C.I). These nozzles had 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 pnd 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 proposal

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 totality over 2 sugar seasons.

Benefits Achieved

The cooling achieved with the mist cooling system was about 31 - 32 °C (i.e., a sub-cooling 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**.

Cost benefit analysis

- Annual Savings - Rs. 0.32 millions
- Investment - Rs. 0.50 millions
- Simple payback - 19 months

Project-3: Installation of Conical Jet Nozzles for Mist Cooling System

Savings/Year (Rs Million)	0.32
Investment (Rs Million)	0.5

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Out flow											
Initial Cost (B)	0.5										
Less Depreciation (C)		0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		-0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Tax @ 30.5 % on (D)		0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cash Inflow after Tax	**-0.5**	**-0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Cumulative cash flow		**-0.2**	**0.0**	**0.3**	**0.5**	**0.7**	**0.9**	**1.2**	**1.4**	**1.6**	**1.8**

NPV (Rs. Million)	**0.4**
IRR	**23.75%**

Basis for Calculation

* **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
* **NPV & IRR are calculated for 10 years**
* **Corporate tax is considered as 30.5 % (as existing in India presently)**
* **Interest on investment is considered as 12 % for Calculating NPV**

Case study 4

Installation of Regenerative Type Continuous Flat Bottom High Speed Centrifugal for A - Massecuite Curing

Background

Continuous centrifugal machine

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, control of charging speed, closing 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 were of the 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. All these are carried out by an assembly of controls, programmed to operate in the correct sequence.

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.

Benefits of regenerative type continuous centrifuge

Reduction in centrifuge power consumption

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 were of the partially recover the energy expended during the discharge cycle.

Energy saving project

The regenerative type of braking system was installed for all the 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 kW/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 upgradation measure.

Replication Potential

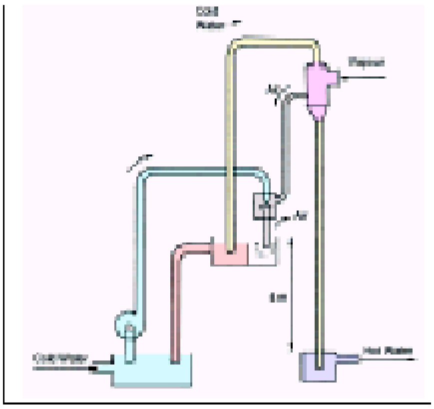
This project has a high replication potential of implementation in more than 75 plants in the country.

Case study 5

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.



Jet condenser with external extraction of air

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. 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.

They have a higher water consumption and require 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.

Benefits of jet condenser with external extraction of air Reduction in injection water pump power consumption

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 works 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, inspite 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 100 HP pump and 1 no. of 250 HP pump. Thus, there is a net reduction in the installed injection water pumping capacity of about 350 HP (30% eduction). 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**.

Cost benefit analysis

- Annual Savings - Rs. 1.30 millions
- Investment - Rs. 2.53 millions
- Simple payback - 24 months

Project-5: Installation of Jet Condenser with External Extraction of Air

Savings/Year (Rs Million)	1.30
Investment (Rs Million)	2.53

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Out flow											
Initial Cost (B)	2.5										
Less Depreciation (C)		2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		-1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Tax @ 30.5 % on (D)		0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Cash Inflow after Tax	**-2.5**	**-1.2**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Cumulative cash flow		**-1.2**	**-0.3**	**0.6**	**1.5**	**2.4**	**3.3**	**4.2**	**5.1**	**6.0**	**6.9**

NPV (Rs. Million)	**0.7**
IRR	**15.98%**

Basis for Calculation

- **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
- **NPV & IRR are calculated for 10 years**
- **Corporate tax is considered as 30.5 % (as existing in India presently)**
- **Interest on investment is considered as 12 % for Calculating NPV**

Case study 6

Installation of 30 MW Commercial Co-generation Plant

Background

Commercial co-generation plant

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 possible 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 the sugar mill.

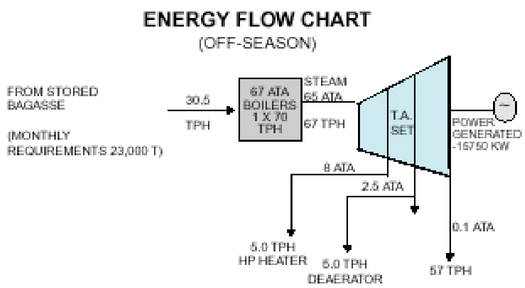
The bagasse is fired in the boiler, for producing steam at high pressures, which is extracted through various back-pressure turbines and used in the process. This simultaneous generation of Commercial

co-generation plant 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 the excess bagasse, has been 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, with substantial additional revenue for the mills. This also contributes to serve the national cause in a small way, by bridging the ‚Demand- Supply™ gap.

This case study describes the installation of a commercial co-generation plant in a 5000 TCD mill.

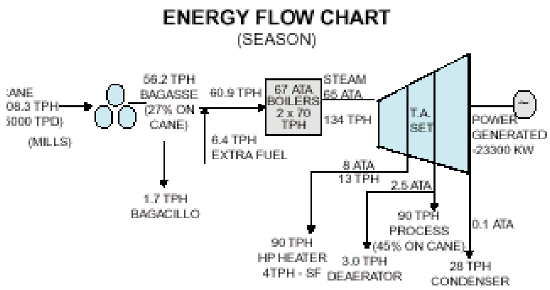


Previous status

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

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 750 BHP steam turbines
- 1 number 900 BHP shredder turbine

The plant had an average steam consumption of 52%. The powerrequirement of the plant during the sugar-season was met by the internal generation and during the non- season from the 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. The new turbine installed was an extraction-cum- condensing turbine. A provision was also made, for exporting (transmitting) 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 900 HP DC motors for mills 2 numbers of 750 HP DC motors for mills 2 numbers of 1100 kW AC motors for fibrizer

Implementation methodology, problems faced and time frame

Two high capacity, high-pressure boilers and a 30 MW turbine was 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 utilising 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 the 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 = 5,18,321 units/day
- During off-season = 2,49,929 units/day

Typical power exported to 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 (off-season)

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

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

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.

Cost benefit analysis

- Annual Savings - Rs. 204.13 millions
- Investment - Rs. 820.6 millions
- Simple payback - 48 months

Project-6: Installation of 30 MW Commercial Co-generation Plant

Savings/Year (Rs Million)	204.13
Investment (Rs Million)	820.6

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13
Out flow											
Initial Cost (B)	820.6										
Less Depreciation (C)		820.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		-616.5	204.1	204.1	204.1	204.1	204.1	204.1	204.1	204.1	204.1
Tax @ 30.5 % on (D)		0.0	62.3	62.3	62.3	62.3	62.3	62.3	62.3	62.3	62.3
Cash Inflow after Tax	**-820.6**	**-616.5**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**
Cumulative cash flow		**-616.5**	**-474.6**	**-332.7**	**-190.9**	**-49.0**	**92.9**	**234.8**	**376.6**	**518.5**	**660.4**

Year	11	12	13	14	15	16	17	18	19	20
Inflow										
Energy saving (A)	204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13	204.13
Out flow										
Initial Cost (B)										
Less Depreciation (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C	204.1	204.1	204.1	204.1	204.1	204.1	204.1	204.1	204.1	204.1
Tax @ 30.5 % on (D)	62.3	62.3	62.3	62.3	62.3	62.3	62.3	62.3	62.3	62.3
Cash Inflow after Tax	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**	**141.9**
Cumulative cash flow	**802.2**	**944.1**	**1086.0**	**1227.8**	**1369.7**	**1511.6**	**1653.5**	**1795.3**	**1937.2**	**2079.1**

NPV (Rs. Million)	**-438.0**
IRR	**6.76%**

Observations

* This is a very high long term project
* Evaluation is to be done based on reduction in power intake and carbon benefits
* These kind of projects needs to be supported at lower / concessional interest rate to make them attractive

Basis for Calculation

* Investment being for energy efficient equipment, 100 % depreciation is considered in the first year
* NPV & IRR are calculated for 20 years
* Corporate tax is considered as 30.5 % (as existing in India presently)
* Interest on investment is considered as 12 % for Calculating NPV

Note :

Critical factors affecting power generation

The efficient operation of a co-generation system depends on various factors. This has a direct bearing on the loss in power generation and 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 of bagasse : 6800 to 10200 units
- 1% increase in process steam consumption : 4200 units
- 1% drop in crushing rate : 5000 to 7400 units
- 1 hour downtime : 20600 units
- Drop in 1 ton of cane availability : 60 units

The above figures are based on the following operational parameters:

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

Replication Potential

The sugar plants in India have tremendous potential for commercial cogeneration ie producing steam at a higher pressure and selling the extra power generated to the grid. The total cogeneration potential yet to be tapped in India has been estimated to be about 100 MW. The investment potential for alteast say about 50 plants is **Rs 4000 million.**

Case study 7

Replacement of Steam Driven Mill Drives with Electric DC Motor

Background

Electric DC drive for mill

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

The recent installation of commercial cogeneration 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 cogeneration power in a sugar mill, is to replace the smaller 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 low efficiency mill turbines, with better 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 the 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.

Benefits of electric DC drives for mill prime movers

- Increased drive efficiency
- Additional power export to grid

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 cogeneration plant. This offered an excellent opportunity for the plant team to replace the low efficiency steam turbine driven mills, with DC motors or hydraulic drives and maximise the cogeneration 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 cogeneration 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 number 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 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 cogeneration plant was commissioned. The modifications carried were as follows:

- Four numbers of 900 HP and two numbers of 750 HP DC motors were installed in place of the six numbers of 750 HP mill turbines
- Two numbers of 1100 kW AC motors were installed for the fibrizer, in place of the single 900 HP 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:

Sl. No.	Parameters	Steam turbine	DC drive
1	Main drive efficiency, %	35.0	90.0
2	Overall system efficiency, %	26.6	39.5
3	Steam input/kWh of power delivered to the mill, in kg		
	• at 15 Ata	25	16.83 *
	• at 66 Ata	-	7.97 *
4	Steam consumption per mill (average load of 300 kW), in TPH		
	• at 15 Ata	7.50	-
	• at 66 Ata	-	2.39 *
5	Saving in steam, in TPH	-	5.11
6	Equivalent saving in power, in kW	-	850

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 realise maximum savings. This amounts to about

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**.

Cost benefit analysis

- Annual Savings - Rs. 62.37 millions
- Investment - Rs. 42.00 millions
- Simple payback - 9 months

Project-7: Replacement of Steam Driven Mill Drives with Electric DC Motor

Savings/Year (Rs Million)	62.37
Investment (Rs Million)	42

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		62.37	62.37	62.37	62.37	62.37	62.37	62.37	62.37	62.37	62.37
Out flow											
Initial Cost (B)	42.0										
Less Depreciation (C)		42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		20.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
Tax @ 30.5 % on (D)		6.2	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Cash Inflow after Tax	**-42.0**	**14.2**	**43.3**	**43.3**	**43.3**	**43.3**	**43.3**	**43.3**	**43.3**	**43.3**	**43.3**
Cumulative cash flow		**14.2**	**57.5**	**100.9**	**144.2**	**187.5**	**230.9**	**274.2**	**317.6**	**360.9**	**404.3**

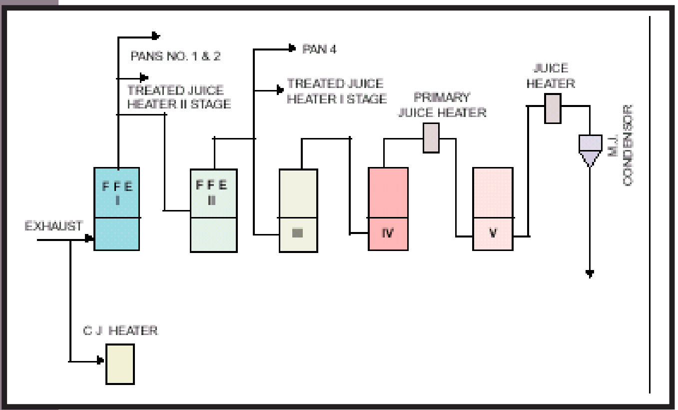
NPV (Rs. Million)	**176.9**
IRR	**73.37%**

Basis for Calculation

*** Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
*** NPV & IRR are calculated for 10 years**
*** Corporate tax is considered as 30.5 % (as existing in India presently)**
*** Interest on investment is considered as 12 % for Calculating NPV**

Case study 8

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 these consumers, the evaporators 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. In the older mills, the evaporators are triple/quadruple effect and the vapour from the first effectis used for the vacuum pans and from the second effect for juice heating.

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 ton of steam).

Typically, the present day mills, use a quintuple effect evaporator system.

Extensive vapour bleeding - the extensive use of vapour coming out of the 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.

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

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.

Conventional system

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 II- or III- effect for heating (from 35 °C to 70 °C) in the raw (or dynamic) juice heaters
- Vapour bleeding from I- 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)

The specific steam consumption with such a system for a 2500 TCD sugar mill is about 45 to 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 practise 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 of sulphited juice heater
- Vapour bleeding from the I- effect, for heating in the C-pans, graining pan and second stage of sulphited juice heater n 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 to 2700 TCD : 41% on cane
- At 2700 to 2800 TCD : 40% on cane
- At 2800 to 3000 TCD : 39% on cane
- At 3000 TCD and above : 38% on cane

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

Cost benefit analysis

- Annual Savings - Rs. 11.00 millions
- Investment - Rs. 6.50 millions
- Simple payback - 8 months

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.

Project-8: Installation of an Extensive Vapour Bleeding System at the Evaporators

Savings/Year (Rs Million)	11.0
Investment (Rs Million)	6.5

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		11	11	11	11	11	11	11	11	11	11
Out flow											
Initial Cost (B)	6.5										
Less Depreciation (C)		6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		4.5	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Tax @ 30.5 % on (D)		1.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Cash Inflow after Tax	**-6.5**	**3.1**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**
Cumulative cash flow		**3.1**	**10.8**	**18.4**	**26.1**	**33.7**	**41.4**	**49.0**	**56.6**	**64.3**	**71.9**

NPV (Rs. Million)	**32.7**
IRR	**85.36%**

Basis for Calculation

*** Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
*** NPV & IRR are calculated for 10 years**
*** Corporate tax is considered as 30.5 % (as existing in India presently)**
*** Interest on investment is considered as 12 % for Calculating NPV**

Case study 9

Installation of Variable Speed Drive (VSD) for the Weighed Juice Pump

Background

Variable Frequency Drive Panel

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 fibres. 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, SO2 is injected continuously for colourremoval.

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 : 23 kW

Benefits of variable speed drive for weighed juice pump

- Reduction in juice pump power consumption
- Steady juice flow to juice heaters and Sulphitor
- Better quality of sulphitation

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 rateand 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 inimproved 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.

Benefits Achieved

The installation of a Variable Frequency 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 atleast another 40 - 50%.

Financial Analysis

The annual energy saving achieved (with the installation of a dyno-drive) was **Rs.0.236 million.** The investment made wa **Rs 0.25 million**, with an attractive payback period of **12 months.**

Cost benefit analysis

- Annual Savings - Rs. 0.24 millions
- Investment - Rs. 0.25 millions
- Simple payback - 12 months

Replication Potential

Every sugar plant has about 10 -12 juice pumps in operation. The potential for application for VFD exists in atleast 3 pumps. This project has been taken up only in few of the newer sugar plants. The investment potential (100 plants x Rs 0.5 million/plant) is Rs 50 million.

Project-9: Installation of Variable Speed Drive (VSD) for the Weighed Juice Pump

Savings/Year (Rs Million)	0.24
Investment (Rs Million)	0.25

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Out flow											
Initial Cost (B)	0.3										
Less Depreciation (C)		0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Tax @ 30.5 % on (D)		0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cash Inflow after Tax	**-0.3**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Cumulative cash flow		**0.0**	**0.2**	**0.3**	**0.5**	**0.7**	**0.8**	**1.0**	**1.2**	**1.3**	**1.5**

NPV (Rs. Million)	**0.5**
IRR	**43.48%**

Basis for Calculation

* **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
* **NPV & IRR are calculated for 10 years**
* **Corporate tax is considered as 30.5 % (as existing in India presently)**
* **Interest on investment is considered as 12 % for Calculating NPV**

Case study 10

Installation of Thermo-compressor for use of Low Pressure Steam

Background

The sugar industry has many steam users - both iolively 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.

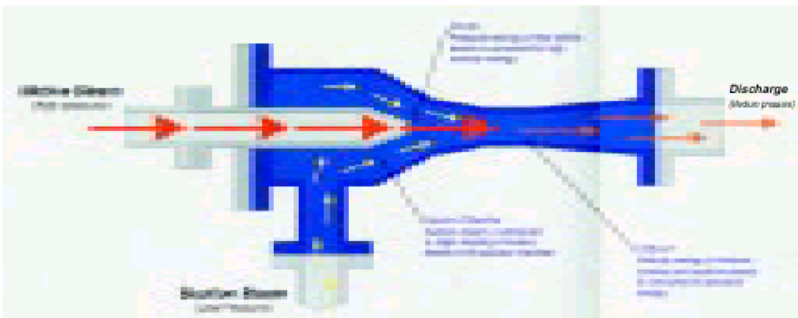
Any conservation measure, which can replace/ minimise the live MP steam consumption, can result in maximising the cogeneration in a sugar mill. One such method of minimizing the MP steam consumption is by the installation of a thermo- compressor.

The thermo-compressor, by passing a very small quantity of MP steam can iacompresslr 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.



Schematic of thermo compressor system

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.

Benefits of thermo compressor

- Increased co-generation
- Additional power export to grid

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 requirements of the distillery.

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 thenozzle. 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.The outlet steam pressure and quantity can be designed, by varying the velocity and quantity of the motive steam and fine-tuning the configuration of the thermo-compressor.

Implementation methodology, problems faced and 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

- 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.

Cost benefit analysis

- Annual Savings - Rs. 6.0 millions
- Investment - Rs. 2.00 millions
- Simple payback - 4 months

Replication Potential

there are about 50 plants in India with distillery integrated with the sugar mill. The possibility of installing a thermo compressor exists in majority of the plants. The investment potential for this project is therefore Rs 100 million.

Project-10: Installation of Thermo-compressor for use of Low Pressure Steam

Savings/Year (Rs Million)	6.0
Investment (Rs Million)	2.0

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inflow																
Energy saving (A)		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Out flow																
Initial Cost (B)	2.0															
Less Depreciation (C)		2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		4.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tax @ 30.5 % on (D)		1.2	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Cash Inflow after Tax	**-2.0**	**2.8**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**
Cumulative cash flow		**2.8**	**7.0**	**11.1**	**15.3**	**19.5**	**23.6**	**27.8**	**32.0**	**36.1**	**40.3**	**44.5**	**48.7**	**52.8**	**57.0**	**61.2**

NPV (Rs. Million)	**25.2**
IRR	**165.21%**

Basis for Calculation

- **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
- **NPV & IRR are calculated for 10 years**
- **Corporate tax is considered as 30.5 % (as existing in India presently)**
- **Interest on investment is considered as 12 % for Calculating NPV**

Case Study 11

Installation of Hydraulic Drives for Mill Prime Movers

Hydraulic drive for mill prime mover

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 a very high specific steam consumption.

These steam turbines are single stage impulse type turbines. They are characterised by very low efficiencies of 35 to 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 the other case study described. This case study highlights the benefits of installing hydraulic drives in place of steam turbines for themill prime movers.

Benefits of hydraulic drives for mill prime movers

- Increased drive efficiency
- Stable operation
- Reduced maintenance

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

- For 6 mill system- 600 BHP rating steam turbine x 3 nos. (2 mills driven by a single steam turbine)
- For 4 mill system - 600 BHP rating steam turbine x 2 Nos. (2 mills driven by a single steam 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 turbines 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 to 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 drives, during the capacity upgradation 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 torquedelivered 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
- Upgradable 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 an 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 (constant crushing) are being achieved, at almost negligible maintenance costs.

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.**

Cost benefit analysis

- Investment - Rs. 25.00 millions

Case study 12

Install nozzle governing system for multi jet condensers

Background

Sugar Syrups are normally boiled at 0.15 bar absolute pressure generating water vapours at 52 degree C saturation temperature. Each Sugar factory releases 30 - 200 Ton Vapours through 5 - 30 boiling vessels called Vacuum Pans. Latent Heat of these vapours is absorbed by cold water sprayed in the individual Condenser attached to each vessel. Air and non-condensable gases are removed by inbuilt Water Jet Ejectors of the Condenser. Temperature of water increases due to absorption of Latent Heat of the Vapour. Either Cooling Tower or Spray Pond cools this heated water by transferring this heat to ambient air by heat and mass transfer.

The Condenser consists of multiple Spray and Jet Nozzles. Spray & Jet Nozzles are primarily needed for condensation and for non-condensable gas/air ejection through tail pipe for the creation of vacuum in the Pan. The cold water flowing in from Spray-Pond /Cooling Tower is supplied to the Condenser by Injection Pumps under pressure for the said purpose.

Conventional Systems

Following methods are adopted to control the flow of water in the Condenser to maintain correct vacuum and reduce consumption of water. Both the methods use pressure governing to regulate water flow.

Single Valve Control

A common control valve regulates pressure to both Jet & Spray Nozzles. Control valve starts regulating water pressure when both vapour and non-condensable gases load are simultaneously within limits of the Condenser. Any increase in either vapour or air load beyond Condenser capacity at reduced pressure will lead to 100% opening of valve. Thus vacuum is maintained with set values.

Double Valve Control

Two separate control valve regulate the pressure of Jet & Spray Nozzles separately. At lower vapour load the Spray Nozzles control valve starts regulating the water pressure. Similarly at lower non-condensable gases load it’s control valves saves water and controls vacuum by lowering jet box pressure. Any increase in vapour or air load beyond Condenser capacity at reduced pressure will lead to 100% opening of that valve. Thus vacuum is maintained within the set values.

Drawbacks in Conventional Systems

The efficiency of Condenser is reduced due to loss of pressure Head and lowering in Spraying Pressure owing to throttling of valve and the basic purpose of the equipment to create the desired vacuum fails.

The vapour and air load variation in Condenser is 0 to 125% of designed capacity separately. Initially, air load is more, in the middle vapour load more and by the end there is no air/ vapour load. So Condenser's requirement varies from time to time.

Proposed nozzle governing system

Spray & Jet Nozzles should always work at high differential pressure to achieve mist formation (for condensing) and impact (air extraction). In the proposed automation system, water supply is controlled by opening or closing of number of Spray & Jet Nozzles. So a Nozzle always works at high pressure and efficiency. Here all the Nozzles are transferring entire pressure energy into the Condenser resulting in good efficiency even at 15% capacity. Here there is no loss of energy in the throttling. where almost 75% energy loss takes place after the valve at 50% flow rate (92% Energy loss at 25% flow rate). So nozzle governing system is far superior then controlling system.

Advantage in this system

The nozzle governing system for Multi-jet Condenser will ensure optimum utilisation of hydraulic energy of water provided to it by the Pumps. It also ensures best Condenser efficiency even at 25% load.

Energy Saving Project

In a 6750 TCD plant, a nozzle governing system was introduced for controlling the water flow to the condenser. A 6750 TCD [Tons (Cane) Crushing per Day) Plant was consuming 1150 kWh of Power at Cooling & Condensing System, which has now been brought down to 450 kWh, after the installation.

Benefits of the project

There was a substantial reduction in power consumption of the injection water pumps. The power consumption of injection with pumps reduced from 1150 units/ton to 450 units/ton.

Financial Analysis

The annual saving achieved on account of the automation system resulted in **Rs 19.0 millions**. The investment made was **Rs 5.0 millions**, which was paid back in **3 months.**

Project-12: Install nozzle governing system for multi jet condensers

Savings/Year (Rs Million)	19.0
Investment (Rs Million)	5.0

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		19	19	19	19	19	19	19	19	19	19
Out flow											
Initial Cost (B)	5.0										
Less Depreciation (C)		5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		14.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Tax @ 30.5 % on (D)		4.3	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Cash Inflow after Tax	**-5.0**	**9.7**	**13.2**	**13.2**	**13.2**	**13.2**	**13.2**	**13.2**	**13.2**	**13.2**	**13.2**
Cumulative cash flow		**9.7**	**22.9**	**36.1**	**49.3**	**62.6**	**75.8**	**89.0**	**102.2**	**115.4**	**128.6**

NPV (Rs. Million)	**66.5**
IRR	**216.55%**

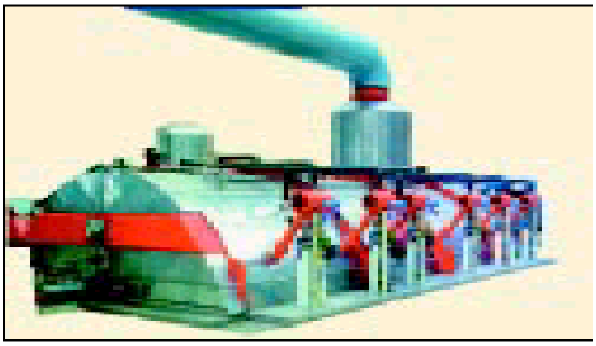
Basis for Calculation

*** Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
*** NPV & IRR are calculated for 10 years**
*** Corporate tax is considered as 30.5 % (as existing in India presently)**
*** Interest on investment is considered as 12 % for Calculating NPV**

Case Study 13

Installation of Fully Automated Continuous Vacuum Pans for Curing

Background



Typical continuous vacuum pan set up

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:.

v 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

v Batch vacuum pans of 80 Tons holding capacity (3 nos.)
  - 2 nos. for A - massecuite
  - 1 no for B massecuite

v Continuous vacuum pan of 135 tons holding capacity
  - 1 no. 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 reduces 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.

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.

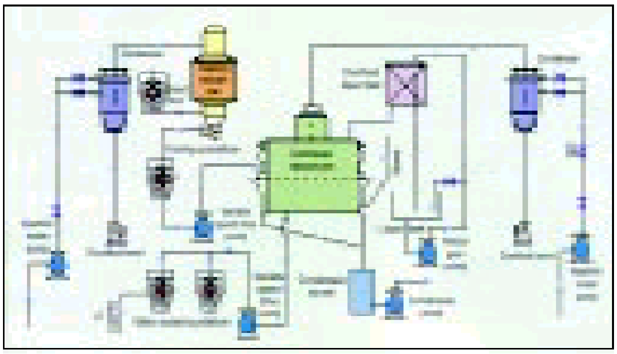
Concept of the project

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


Schematic arrangement of continuous vacuum pans

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:

v Continuous vacuum pans of 40 tons holding capacity (5 nos.)

- 1 no. for A - massecuite
- 2 nos. for B - massecuite
- 2 nos. for C - massecuite

v Continuous vacuum pans of 80 tons holding capacity (2 nos.)

- 2 nos. for A - massecuite

v Continuous vacuum pan of 135 tons holding capacity (4 nos.)

- 2 nos. 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:

v 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

v The vapour bleeding from the I - effect of evaporator, for heating in the C- pans

- The continuous pans enable stabilised operation of the evaporators

v Reduction (10 - 20%) in steam consumption as mentioned below:

Identity	Steam consumption (kg/ ton of massecuite)	
	With batch vacuum pan	With continuous vacuum pan
A - massecuite	Not available	Not available
B - massecuite	242	229
C - massecuite	354	313

- 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**.

Cost benefit analysis

- Annual Savings - Rs. 19.26 millions
- Investment - Rs. 100.0 millions
- Simple payback - 63 months

Replication Potential

The installation of continuous vacuum pans through a proven project has been taken up only in about 20% of the plants. The potential of replication is therefore very high. However, the commercial viability of the project is high, only in case of plants with commercial cogeneration.

Project-13: Installation of Fully Automated Continuous Vacuum Pans for Curing

Savings/Year (Rs Million)	19.26
Investment (Rs Million)	100.00

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow											
Energy saving (A)		19.26	19.26	19.26	19.26	19.26	19.26	19.26	19.26	19.26	19.26
Out flow											
Initial Cost (B)	100.0										
Less Depreciation (C)		100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Income (D)=A-C		-80.7	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Tax @ 30.5 % on (D)		0.0	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Cash Inflow after Tax	**-100.0**	**-80.7**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**
Cumulative cash flow		**-80.7**	**-67.4**	**-54.0**	**-40.6**	**-27.2**	**-13.8**	**-0.4**	**13.0**	**26.3**	**39.7**

NPV (Rs. Million)	**-108.4**
IRR	**-6.78%**

Basis for Calculation

* **Investment being for energy efficient equipment, 100 % depreciation is considered in the first year**
* **NPV & IRR are calculated for 10 years**
* **Corporate tax is considered as 30.5 % (as existing in India presently)**
* **Interest on investment is considered as 12 % for Calculating NPV**

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India
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Fax : 91 44 4402324,
E Mail:Sissta@Md4.Vsnl.Net.In

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