Chapter 13

Sugar

13.1 Introduction

India has been known as the original home of sugar and sugarcane. Indian mythology supports the above fact as it contains legends showing the origin of sugarcane. India is the second largest producer of sugarcane next to Brazil.

Apart from sugar, the sugar industry produces certain by-products, which can be used for production of other industrial products. The most important by-product is molasses, which is utilized for production of chemicals and alcohol. In addition, the other important by product is bagasse. It is mainly utilised as a captive fuel in the boilers but it is also used as a raw material in the paper industry.

13.1.2 Number of Sugar Factories

There were 608 installed sugar factories in the country as on 31.12.2007. The sector-wise breakup is as follows:

Table 13.1

Sector	Number of factories
Cooperative	317
Private	229
Public	62
TOTAL	608 *

** This Includes closed sugar factories also*
Source: Department of Food & Public Distribution

13.1.3 Production of Sugar

During the sugar season 2007-2008, production of sugar is estimated at about 270 lakh tonnes as against the production of 280 lakh tonnes during the previous season 2006-2007.

Table 13.2: Production of Sugar

(Lakh Tonnes)

1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-2007 (Provisional)
128.44	154.52	181.93	185.10	184.98	201.32	139.58	130.00	193.21	280.00

Source: Department of Food & Public Distribution

13.2 Energy Profile

The energy requirements in a sugar mill are in the form of steam for process heating/turbo drives and electricity for running various drives. The sugar industry has the unique advantage of utilizing a captive fuel-bagasse, to meet its energy requirements. However, depending upon various factors like fibre content in the cane, quantity of juice, type of clarification process and evaporation effects, type of prime movers (steam driven or electric driven) etc., some sugar mills produce a small quantity of surplus bagasse while others are deficient by a small quantity. These mills, therefore, have to depend in a very limited way on external fuels like fuel oil, LSH, coal etc to supplement their energy requirements. Likewise, some sugar mills during the season can produce a little surplus power while others would be deficient in power by a small margin and hence the dependence on grid power is minimal.

Energy consumption in sugar plants depends on various factors such as its capacity, steam generation parameters, vintage, equipment used etc. Analysis of the energy consumption pattern in the sugar mills reveals that there exists significant scope for improving the energy efficiency in the Indian Sugar Industry. The major reason for the high energy consumption in the industry is the presence of large number of old, small capacity sugar mills which have not invested much over the years in modernizing or upgrading various process equipment. Apart from improving the end use efficiency in the plants, the other most promising energy conservation measure for the industry is to set up high-pressure cogeneration systems. This not only has the potential of opening up additional revenue streams for the sugar plants by way of sale of electricity, it can effectively contribute in reducing the ever widening gap between demand and supply of electricity in various power deficit regions in the country.

13.2.1 Energy consumption in Sugar Industry

Table 13.3

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

Source: CII-IREDA

The energy consumption in Indian sugar mills range from 0.7 to 0.87 GJ/ tonne of cane against a world average of 0.5 to 0.6 GJ/Tonne of cane crushed.

13.2.2 Energy efficiency in sugar industry

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.

13.3 Sugar Manufacturing process

The sugar manufacturing process normally comprises of juice extraction, juice clarification, evaporation, crystallization, centrifuging, drying, and packing. Steam generation using bagasse as the fuel and electricity generation, mostly through backpressure turbines forms an important part of any sugar factory.

13.3.1 Juice Extraction

The juice extraction plant consists of cane handling, cane preparation and milling sections.

a) Cane handling

Cane is brought mainly by trucks, trollies and bullock carts to the mill. The load is first weighed on a weighing bridge. The sugarcane is mechanically unloaded by a grab type attachment. A truck tippler is also sometimes provided to unload cane, facilitating loading of the sugar cane on to the cane carrier.

b) Cane Preparation

The sugarcane after delivery to the cane carrier is levelled in the leveler before it is fed to the cutter. The cutter shreds the cane to smaller sizes and prepares it for the fibrisor where the cane is converted to a pulp-like mass.

c) Milling

The prepared cane is passed through a milling tandem composed of four to six three-roller mills. The juice is extracted from the cane by squeezing under high pressure in these rollers. Extraction is maximised by leaching the disintegrated exposed cane with weak juice and make-up water in a counter current system. In the sugar industry, this leaching system is called "imbibition".

Mixed juice, which is a mixture of juice extracted normally from the first and second stage milling is fed to the next production stage. The fibrous matter or bagasse', which is left after milling, is used as a fuel for steam generation.

13.3.2 Juice clarification

The purification of juice involves (a) juice heating (b) sulphitation (c) clarification and (d) filtration.
The mixed juice from the mills is heated in raw juice heater(s). The common process employed in most of the mills in India is Double Sulphitation process. The heated juice is treated with chemicals like milk of lime and sulphur dioxide gas in a juice sulphiter. Various dissolved impurities in the mixed juice are precipitated out. The impurities precipitated are separated to obtain clear sparkle juice in clarifiers. Muddy juice, which settles at the bottom, is filtered in vacuum filters and the filtrate is recycled back to the system. The retention time in the clarifiers is

about 2-3 hours and this invariably results in an appreciable temperature drop. Hence the juice is again heated to obtain a temperature of about 105°C.

13.3.3 Evaporation

The juice is concentrated from 15 Brix to around 60 Brix in a multiple-effect evaporator. The vapours are bled from evaporators for juice heating in various heat exchangers and for boiling of massecuite in vacuum pans. This is the major steam consuming section of plant.

13.3.4 Crystallisation

Crystallisation is an important unit operation, which in sugar industry is known as Pan boiling. Major part of the crystallization process is done in most of the sugar plants in batch type vacuum pans. A mixture of the molten liquid and crystals, known as "massecuite" is then transferred to crystallizers where the process is completed by cooling the mass under stirred condition.

13.3.5 Centrifuging

The massecuite from the vacuum pans is sent to the centrifuges, where the sugar crystals are separated from molasses. These centrifugal machines can be batch type or continuous type. There are separate centrifugal machines for `A' type, `B' type and `C' type massecuites. The molasses separated out from this section is a useful byproduct, which is an excellent raw material for distilleries.

13.3.6 Drying, grading and packing

The moist crystals obtained from centrifugal machines normally contain about 15-20% surface moisture. They are dried in traditional dryers, graded according to crystal sizes and then packed in bags.

13.4 By-products

The main by-products from any sugar industry are: (i) bagasse (ii) molasses and (iii) filter cake.

Bagasse: Bagasse is an important by-product of sugar. It is rich in cellulose fibre and can be used as a major substitute raw material in the paper and pulp industry, replacing wood and bamboo thus reducing deforestation. Costly imports of pulp and waste paper can be avoided thus conserving the outflow of foreign exchange. Bagasse has also been suggested as a base material for cattle feed after mixing with molasses in varying proportions. The other important product, which can be manufactured from bagasse, is furfural, which is a very versatile chemical with good potential for commercial usage. Presently, almost all the sugar mills utilize this bagasse as an in-house fuel in boilers for steam generation. Number of mills are now planning to utilise the bagasse efficiently in high-pressure boilers for co generating electricity for export to the grid/neighboring units.

Molasses: Molasses, the other important by-product, is a storehouse of organic chemicals. Industrial alcohol is produced from molasses, which in turn can be used to manufacture chemicals like ethyl benzene, lactic acid, tartaric acid, citric acid, diethyl phthalate, etc. Industrial alcohol can be used as a fuel extender as a substitute to the scarce petroleum products.

Filter cake: When cane juice is clarified and filtered, the resulting cake is known as filter mud or filter cake. It contains most of the colloidal matter precipitated during clarification and has around 63% organic matter. This cake is of great manurial value and is mostly taken by the growers in their own transport after delivering cane to the factory, for use in the fields.

13.4.1 Co- Gen in Sugar Mills

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 boards, 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.

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.

13.5 Technologies & Measures for Energy Efficiency Improvements

Various technologies for energy efficiency improvement are discussed briefly. Some of these technologies are already in use in India while many are in the development phase or not yet commercialized in India. Besides these technologies, one very important step, Indian sugar mills can adopt is to produce smaller sized sugar instead of bolder sugar grains. Simply because of the bolder grain size, 2 to 3% more energy is consumed by the industry.

13.5.1 Improved reliability, economics of steam and power generating systems with film forming polyamines

Technology Description

Corrosion and scaling in boilers and turbines continue to pose problems in maximizing steam and power generation at a minimum cost. The corrosion products (iron and copper oxides) coming with the condensate cause heat insulating deposits in boilers resulting in failures, loss of efficiency, frequent cleaning and increased cost of operations. Traditionally, multiple chemicals like phosphates hydrazine or sulfite have been used to reduce the corrosion and scaling but due to its major drawbacks a " film barrier approach" has been gaining increasing acceptance. It utilizes the film forming properties of aliphatic amines on divalent wet metal surfaces. Organic formulations containing film-forming amines, combination of neutralizing amines, dispersants and complexing agents provide much superior protection to the metal surfaces in boilers and turbines against corrosion scaling and carryover. The selection of the types of amines to be used, is determined by the properties such as vapor/liquid distribution ratio, dissociation constant, basicity, etc. The product has been applied in sugar mills in India for more than five years.

Advantages

- Complete protection against corrosion and scaling.
- Clean and scale free surface.
- No cleaning of boilers/turbines required for years.
- Simplified dosing and monitoring.
- Flexibility in operation, as film stable over a pH range of 4 to 11.
- Cost saving due to improved heat transfer and reduced blow downs.

13.5.2 Direct production of white sugar in a cane sugar mill

Technology Description

An economical process is disclosed for the direct production of white sugar from clarified juice. Juice from a cane sugar mill, or sugar beet juice, is first contacted with hydrogen peroxide, before passing through granular activated carbon. The juice is then passed through cationic and anionic resins to remove inorganic compounds, colorants, and other impurities. Then the juice may be concentrated and sugar crystallized. White sugar is produced directly, without the need for an intermediate raw sugar crystallization.

Advantages

- The process does not require membrane separation and involves adsorption of colour and other impurities using granular activated carbon and ion exchange resins.
- Chemical regeneration of the carbon is utilized, which enhances the attractiveness of the process.

13.5.3 Mini Sugar Plant (Khandsari plants)

Technology Description

The sugarcane is fed to the cane carrier provided with Cutters. Sugarcane is chopped into pieces and conveyed to the sugarcane mill. Juice is extracted by crushing unit, screened and collected in raw juice tank and pumped into sulphitation towers. Lime and compressed sulphur-di-oxide gas is mixed with juice. After sulphitation, juice is discharged into cracking bels for single boiling where non-sugars become precipitated from the cracking bel. Juice is pumped into settling tank. The heavy precipitated mud and other impurities settle down at the bottom and clear juice is discharged from the valves of the settling tanks and flows by gravity to boiling bels. The muddy juice from the bottom of the settling tanks is discharged in mud tank and is forced into filter press by means of a mud pump. Filtered juice also goes to the juice boiling bels and mud cake is retained in the press and removed when the press is opened. Clear juice from settling tank and filter press is boiled in open pan juice boiling bels and concentrated. The syrup thus formed is sent manually to crystallizers. Proper crystallization takes place in 48 to 72 hours. After washing, sugar is taken out of centrifugal machine and dried. First quality sugar is dried, graded and bagged. Molasses, which come out of centrifugal machine, is reboiled in Molasses Boiling Bels and sent to crystallizers. The process of crystallization, centrifuging, drying and bagging is repeated to obtain second

quality sugar and final molasses. Molasses is a by-product in the process and can be used as raw material for alcohol industries.

Advantages

- In non-sulphitation plants, suphitation processing equipment is eliminated from the process.

13.5.4 Sugar-cane waste conversion into char

Technology Description

The Appropriate Rural Technology Institute (ARTI), India, at pune has developed a charring process for converting sugar-cane trash into high-value char. Dried leaves of sugar cane, or sugar-cane trash, resist biodegradation and cannot be used either as cattle fodder or as a raw material for making compost. The innovative process is especially suitable for handling large amounts of loose biomass at high speeds and on a continuous basis. Char obtained by this process can be converted into briquettes easily by a variety of well-established briquetting methods. The eco-friendly oven-and-retort type kiln from ARTI is constructed using bricks and mud. The oven is loaded with a retort (1 kg capacity) filled with sugar-cane trash and a fire is lit below the oven using some of the trash itself as fuel. As the retort heats, the trash inside is converted to char and the pyrolysis gas escapes from a hole in the lid of the retort. A cast-iron grate separates the firebox of the chulha and the retort inside the oven. The retort is loaded upside down in the oven so that the pyrolysis gas passes into the firebox and burns, thereby generating additional heat for charring. Moreover, as the pyrolysis gas is used in the kiln itself, venting or flaring is prevented.

Advantages

- The kiln has a conversion efficiency of 30 per cent and operates as a continuous-batch process.

13.5.5 Quintuple 3rd effect vapour for sugar melting

Technology Description

In a multiple effect evaporator, vapour bleeding in the later bodies will bring steam economy. But extensive use of this vapour is presently limited to first two bodies due to low temperature of vapours and high scaling patterns in later bodies.

With the installation of condensate flashing system, vapour generation in individual bodies is being augmented by flash vapor in condensate and hence requiring less evaporation. This is leading to more vapours to condenser, as waste. To avoid this, extensive use of vapour of the third body in a quintuple effect evaporator is planned. With increase in pressure of exhaust steam used at first body of evaporator, the pressure conditions of individual bodies changed to higher side matching with the pressures of quadruple effect.

Navbharat Ventures has initiated a project replacing vapour of the second body being used at pan floor and SJ1 heating with vapour of the third body. There is no financial requirement as the same vapour line is used to draw vapour from the third body of quintuple effect evaporator to utility points. Steam saving achieved through extensive use of vapour from third body by converting evaporator system in to quintuple from quadruple is upto 3.5%.

Advantages

- Reduction in steam consumption

13.5.6 Condensate flashing system

Technology Description

Cane contains about 70% of water. This water is extracted along with juice in milling by adding some more water to the cane bagasse, which is called imbibition. Mixed juice is required to be heated up to 102°C to stall microbiological action on it and to increase the rate of reaction with chemicals (lime and SO_2 gas) added. When concentrated by separating water content in multiple effect evaporation, the vapor condensate takes away heat utilized for heating, often into drain. As was the case of reducing pressure in bodies of multiple effect evaporators in sequence enabling use of vapor for boiling in the subsequent bodies, it is proper to use flash heat in hotter vapor condensates, in subsequent bodies by circulating the condensate sequentially. SEDL (Spray Engineering Devices Ltd.) has improvised the design of the flash vessel for heat recovery from condensate of evaporator, pans and surface contact heaters.

Haidergarh Chini Mills, Barabanki (UP), with help of SEDL has installed a Condensate Cigar along with Plate Heat Exchanger (PHE) at the evaporator station to utilize the waste heat of excess condensate by using flash vapour. Further, PHE facilitated to recover extra heat going along with exhaust condensate to boiler feed water tank. This has stopped the usages steam, which was required for super heating the wash water (up to 115º C) during centrifugal operation.

Advantages

- It reduces the steam consumption in the boiling house by 2.0- 3.0% on Cane depending on the operating conditions of the Boiling House.
- It improves the water management of the Plant.
- Space requirement is less due to its compact size and alignment.
- The sparge tube entry for condensate helps in proper diffusing of condensate and hence improves the efficiency for flashing.
- Easy to maintain, trouble free, reliable and long life due to stainless steel construction.

13.5.7 Film Type Sulphur Burner

Technology Description

Sugar juice clarification (purification) process requires sulphur dioxide as a clarification and bleaching agent. It is produced from expensive (imported) sulphur in the conventional tray type batch burners, in Indian sugar factories, which are inefficient, resulting in high processing cost, poor clarification and poor sugar quality. The new "film type sulphur burner" which was tried at Upper Doab Sugar Mills, Shamli in collaboration with M/s. Digital Utilities (India) Pvt. Ltd., New Delhi, produces SO_2 with consistent quality, high efficiency, low consumption and well regulated operation made possible by the new 'film burning' concept and requisite automation. The film type sulphur burner technology has been adopted in

more than 64 sugar factories all over India. The system consists of Sulphur Melter, Variable Flow Sulphur Pump, Sulphur Furnace with Checkered Refractory Bricks and refractory lining. SO_2 cooler and instrumentation and control system for control of Sulphur feed, combustion air feed etc. The Molten Sulphur flows from top of the furnace downward forming a thin film on the refractory bricks. The film burns efficiently in contact with air to produce SO_2. SO_3 formation is negligible. Depending on the temperature of the furnace, 6-9% SO_2 can be obtained in the exit gases. Operation of the burner is controlled in accordance with process demands i.e SO_2 quantity and quality, sulphur feed rate etc. through use of instrumentation and control system etc .

Advantages

- Extremely steady burning, with capacity variation 70- 300 kg/hr,
- Zero sublimation and minimal SO_3 generation,
- Optimum sulphur consumption,
- Burning rate variation without any change in concentration,
- Compatible to automation for juice sulphitation & pH control,
- Maintenance free, long life and zero pollution

13.5.8 Bagasse Drier

Technology Description

This is a novel concept of drying bagasse as well as controlling the air pollution. Bagasse Drier is a unique device wherein the hot flue gases are mixed with the wet bagasse from mills. This wet bagasse gets dried up and accumulates all the ash and unburnt carbon with it. This dried bagasse with all the unburnt and ash is fed into the boiler. Thus it acts in two ways. One it dries the wet bagasse there by increasing the system efficiency and saving bagasse. Second, it acts as pollution control device and reduces the SPM of the flue gas. DSCL sugar, Rupapur implemented this technology in the year 2005-2006.

Advantages

- Improved efficiency with better pollution control.

13.5.9 Planetary Gearbox for crystalliser

Technology Description

The mill drive and transmission of its power to mills is an important area of the sugar factory in respect of investment and maintenance cost and energy saving. The conventional mill drive of the present day consists of either DC motor or steam turbines. These drives are operated at about 1000/5000 rpm whereas the power developed by the prime movers is required to be transmitted to the mills at less than 5 rpm. Therefore, a set of high speed and slow motor gear trains is used to achieve the eventual operating speed and the power requirement at the mill. These drives are not only cumbersome occupying huge space but also needs high maintenance and operating cost. The sugar industry has been in search of an efficient and compact alternative to the above inefficient system. Planetary gearbox is an energy efficient, cost effective compact alternative to the conventional drive comprising of gear trains and also hydraulic drive. EID Parry has successfully replaced the existing worm wheel reduction system with the planetary gearbox arrangement for all crystallizers under its energy saving schemes for the year 2005-2006.

Advantages

- Improved efficiency resulting in energy savings

13.5.10 Advanced bagasse based cogeneration

Technology Description

Cogeneration is broadly defined as the coincident generation of useful thermal energy and electrical power from the same input fuel. Any process plant requiring steam for process, the pressure of steam required for most of the process applications being low, holds very good potential for cogeneration of power. Sugar plants are particularly interesting applications for cogeneration, since bagasse, one of the by-product from the mill, is available almost at no cost as feed stock to fuel the steam generators of the cogeneration plant. The sugar manufacturing process requires a large quantum of thermal energy in the form of steam and also the bulk of the steam required for the processing is needed at low pressure i.e. in the range of 2.0 to 2.5 bar (atm). However, to date, sugar plants had limited power and heat generation to meet only their own in-house demands, which is called as an incidental cogeneration, and hence their existing energy potentials had not been fully exploited. The advanced cogeneration system, aims at significantly improving the overall energy efficiency of the sugar factory, enabling the plant to generate surplus power. The surplus power could be exported to the electricity grid, which can generate additional financial resources for the plant. Energy efficiency and the export of power to the grid is made feasible by the employment of high pressure and high temperature steam cycles and by the utilization of the surplus bagasse to produce more steam and hence more electricity. Thermodynamically, energy recovery from the Rankine cycle is more dependent on the steam inlet temperature than the pressure and the higher the inlet steam temperature; higher will be the cycle efficiency. However, the practically attainable limits of temperatures are influenced by the metallurgy of the boiler tubing, piping and the turbine components and the complexity of the creep fatigue interaction for the materials at higher temperatures. Temperatures up to 400°C require use of ordinary carbon steel and beyond 400°C, low-grade alloy steels are employed. Above 500°C, the requirements with regard to the material selection are stringent and expensive. Above 550°C, the requirements are very stringent and prohibitively expensive. It is extremely important that the selection of temperature is done keeping in mind the nature of industry, and the experience gained in that industry. The sugar factories employ cogeneration system of 480°C and 65 bar (atm). With the technological advancement, some sugar plants in India implemented the advanced cogeneration system of 515°C and 105 bar (atm) pressure for increasing energy efficiency and the financial profitability.

Advantages

- High efficiency of the plant as well as reduced cost of energy (heat and electricity)
- Increased power reliability and quality
- Increased financial profitability of the plant
- Reduced emissions.

13.5.11 Wet Cell Gasification

Technology Description

Bagasse has traditionally been burned in boilers to help fuel the operations for sugar mills. The problem with burn boilers, particularly older burn boilers is their outputs, not only of useful process heat, but pollution. The burn boilers also require dry feedstock, as very wet feedstock will choke the boiler. Slag and residue forming on boiler tubes and the system can also pose a challenge for consistent operations. The wet cell gasification technology is generally far cleaner than burning or burn boilers. The EWC (Ecology Wet Cell) gasification unit is a two-stage updraft gasifier. In the first stage, the biomass is gasified in a starved oxygen environment. In the second stage, the producer gas is consumed in a powerful double vortex combustor producing 100,000,000 (one hundred million) Btu per hour of heat at approximately 1010°C. The temperature has been successfully varied for particular applications to as high as consistent 1204°C. Where there is a large amount of waste or biomass by products and agricultural residue this robust gasification to heat system can provide a very useful solution. This gasification unit can also handle human and animal waste mixed in with biomass, a very fibrous materials that cause real problems with other feed systems.

Advantages

- Produces large volume of heat effectively and reliably for various applications
- Running on a combination of biomass sources.

13.5.12 Mechanical Vapour Compression (MVR) technology to recover low-pressure waste steam

Technology Description

Thermal separation processes such, as evaporation and distillation are energy intensive. The need for reducing energy costs has led to multi-effect plants, then to thermal vapour compression and finally to the use of mechanical vapour compression systems. In mechanical vapour compression, positive displacement compressions or multi-stage centrifugal compressors are generally used to raise the pressure and temperature of the generated vapours. Since mechanical compressors do not require any motive steam, all vapours can be compressed to elevated pressure and temperature, eliminating the need for a subsequent recovery system. The energy supplied to the compressor constitutes the additional energy input to vapours. After the compression of the vapour and its subsequent condensation through transfer of heat to process fluid, the hot condensate leaves the system, which can be used as feed water/liquid for boilers. The technology was developed in the year 2005.

Advantages

- Low specific energy consumption.
- High performance co-efficient.
- Gentle evaporation of the product due to low temperature differences.
- Reduced load on cooling towers.
- Simple process for operation and maintenance.

Taking the ratio of cost of steam-generation of the equivalent cost of electrical energy as 1:3, the MVR gives economic effect of 17/3 =5.66. The capital cost, installation and operation costs are much lower.

13.5.13 Mill Drives (AC/DC)

Technology Description

DC mill drives are used in most sugar plants in India to drive the milling tandem with four to five 500-1000 HP drives. This is in vogue in most of the plants now with conversion of turbo-steam drive to electrical drive with cogeneration of power for export being the order of the day. However, the new development of using AC drive instead of DC drive has the following advantages.

Advantages

- Efficiency of AC motor is higher than DC motor
- Low maintenance cost than DC motor
- Less harmonics than DC motor
- Overall power saving of 3-5% is possible with AC drive for milling tandem in place of DC drives.

13.5.14 Adoption of Falling Film Evaporator

Technology Description

The steam consumption of sugar factory, mainly depends upon the system available for the concentration of juice. Adoption of falling film evaporator at the evaporator station, offers better steam economy. Falling film evaporator is usually a conventional 1-1 exchanger designed to operate vertically. The liquid solution enters from the top at such a rate that the tubes do not flow full of liquid, but instead, liquid descends downwards along the inner walls of the tubes as a thin film. Vapour evolved from the liquid is carried downwards with the liquid, and leaves from the bottom of the unit. Since a large number of mills are planning to increase their installed capacities, one of the cost effective ways to achieve the dual objective of better steam economy and increase of throughput in the evaporator section would probably be to add a first evaporator as a falling film evaporator. The concentrated juice from this evaporator body, which can be falling film evaporator, can thus be fed to the existing evaporator setups to continue further evaporation.

Advantages

- Reduced steam consumption
- High heat transfer rates.
- Increased throughput of the evaporator
- Minimal internal pressure drop.

13.5.15 Vertical Continuous Vacuum Pan for Massecuite Boiling

Technology Description

After concentration of juice in multiple effect evaporators, the subsequent process to turn the thick juice into crystal form is accomplished in the vacuum pans. The use of batch type vacuum pans in most of the mills results in considerable fluctuations of steam consumption and irregular sugar quality. It results in variation in syrup brix of about 4-4.5 Bx. The batch pan boiling destabilises the continuous process in

other stations and imbalances steam balance of the plant. The use of fully auto-controlled continuous pan has many advantages over the conventional batch pans. It helps in maintaining a steady consumption of vapours thus eliminating the problems associated with fluctuating vapour flows. Accordingly, there will not be any variations in the syrup brix. This ensures the uniform functioning of the evaporator station, and also boiler steam generation. This system automatically manages the steady conditions for development and uniform growth of crystals eliminating the uncertainties of human operational errors.

Advantages

- Reduction in steam consumption eliminates the fluctuations in the vapour demand thus steadiness of operation is achieved.
- Reduction in boiling point elevation avoids heat injury and colour formation.
- Maximum exhaustion of mother liquor.
- No fines and conglomerates.

13.5.16 Low Pressure Extraction (LPE) System

Technology Description

The conventional methods of juice extraction suffer from drawbacks of high power consumption, high maintenance costs and require skilled operators. The new LPE system is an efficient alternative, which utilizes combination of solid-liquid extraction and conventional milling technology at low hydraulic pressures. Further, it is not dependent on operator's skill. The system uses perforated rollers in modules of 2. A total of 8 modules (16 rollers) were used during the trial runs. Hydraulic pressure of 110 bar is used. Due to perforations in the rollers extracted juice is quickly drained out. Re-absorption of juice is negligible. The system is driven by electric motors and operation is automatically controlled. The system was successfully commissioned in 1999 for commercial use. Commercial plant at a capacity of 5000 TCD commissioned at Shree Renuka Sugars in 2006.

Advantages

- Low capital cost (about 60%)
- Low power consumption to the extent of 35%
- Extraction comparable to 4-mill system (about 95%)
- Low maintenance cost
- No special skills required
- Very low retention time
- No chemical control.

13.5.17 Membrane filtration for Sugar Manufacturing

Technology Description

The conventional method of manufacturing produces sugar with high sulphur content. That is also brown in colour due to which it does not attract many takers in the export market. Membrane filtration is the process for production of sulphur free, refined quality sugar without going through conventional refining. In this process, high temperature tolerant polymeric membrane modules are employed for sugarcane juice clarification for production of high quality sugar. These membrane modules are capable of withstanding continuous exposure to hot juice without any visible signs of deterioration. The pilot plant was successfully commissioned and operated at Simbholi Sugar mills in 2000-2001.

Advantages

Greater Sugar recovery since less sugar loss in molasses
Sparkling clear sugar cane juice with purity higher (by 0.9 units), reduced juice colour (by about 50%)
Shorter juice boiling times and faster crystal growth rates increase productivity
Easy to integrate, install and scale up with limited space requirement
Easy to operate with minimum maintenance requirement.

13.6 Case Studies

Case Study 1: Energy Conservation Achievements at a Major Sugar Industry

Brief

During the period 2006-2007, the unit implemented 15 energy conservation projects with an investment of Rs.17.2 Million achieving a saving of Rs. 7.742 Million.

Energy Savings

The major energy conservation projects are presented below: -

Project	Description	Annual Savings (Rs. Million)	Investment (Rs. Million)	Payback Period (months)
Quintuple 3rd effect vapour for sugar melting	A new sugar melter for B & C sugar was designed in-house to utilize quintuple 3rd effect vapour instead of exhaust steam	1.171	1.082	11
Plate heat exchanger for turbine condensate heating	Installing the plate heat exchanger enabled heating turbine condensate along with DM water make-up from 40 ^{0}C to 98^{0}C with quintuple 3rd effect vapour avoiding use of LP steam	0.643	0.270	5
Avoiding FFE transfer pump	Juice transfer scheme was modified and resulting head difference was utilized to completely avoid 15 kW juice transfer pump at falling film evaporator	0.1113	Nil	Immediate
Quintuple 1st effect vapour for FBD sugar dryer air heating	It is general practice to use MP steam for heating air in fluidized bed sugar dryer. The project utilized the same heat exchanger with quintuple 1st vapour as heating medium to heat FD air	0.1098	Nil	Immediate
Quintuple 1st effect vapour condensate as superheated wash water	Replaced usage of MP steam heated condensate with Quintuple 1st effect vapour condensate for washing sugar crystals in batch centrifugals	0.072	0.042	7
Clear juice in place of hot condensate	Clear juice is utilized to the possible extent at pans, continuous centrifugals and melter replacing the use of hot process condensate. Thus reduced evaporation load	0.084	0.065	9
Pipe line to utilize soda-boiling vapour	The vapour from soda boiling are being effectively utilized for process heating by mixing them with the vapour of the main stream, instead of venting to atmosphere as a normal practice	0.263	Nil	Immediate

Case Study 2: Energy conservation projects at a major unit at Villupuram

1. Replacement of Low-pressure cogeneration system with High-pressure cogeneration system:

Brief

The cogeneration set up had three low-pressure boilers providing steam to the process and turbine generators. Historically the factory has not exported any power to the grid. It was decided to install high-pressure cogeneration system. The configuration of the system is as follows

Boilers	Turbines
1 x 120 TPH, 87 kg/cm^2	1 x 22 MW

The plant was commissioned during June 2005. After captive consumption the surplus power has been fed to the State grid.

Energy Savings

Surplus power exported to grid	15 MWh
Power exported to State grid for the year 2005-06	40.1 Million kWh
Revenue from power export /for the year 2005-06 in Million Rs	125.3
Actual investment in Million Rs	80
Payback Period	8 months

2. Replacement of Eddy current drive with Variable frequency drive for Cane carrier & Rake carrier:

Brief

The speed control of the cane carrier and the rake carrier were accomplished by eddy current drives. The eddy current drives were replaced with energy efficient variable frequency drives.

Energy Savings

Energy consumption /day with Eddy current drive	2160 kWh
Energy consumption/day with VFD's	1680 kWh
Energy savings/day	480 kWh
Annual Energy savings	86400 kWh
Excess revenue generated Rs in Million	0.26

3. Replacement of slat type bagasse conveyor with belt conveyor:

Brief

A 45 kW slat conveyor was being used to convey bagasse from the mills to the cogeneration power plant material handling system. A 15 kW belt conveyor replaced this slot type conveyor

Energy Savings

Slat conveyor Energy consumption /day	*756 kWh*
Belt conveyor Energy consumption/day	*360 kWh*
Energy savings/day	*396 kWh*
Annual Energy savings	*71280 kWh*
Excess revenue generated Rs in Million	*0.214 kWh*

Case Study 3: Install diffusers in lieu of milling tandem

Brief

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.

Before Improvement	***After Improvement***
A new sugar mill initially decided to adopt milling in tandem	*The mill was later on opted for the diffuser and it was installed by design*

Energy savings

Reduction in power consumption : 2.88 Million units
(Considering an average crushing of 500 TCD for an operating season of 180 days)
Energy cost saving : Rs. 8.0 Million / season
(Considering power export cost of Rs. 2.75 / kWh)

Case Study 4: Utilisation of Exhaust Steam for Sugar Drier and Sugar Melter

Brief

Before Improvement	***After Improvement***
In this 2500 TCD sugar mill, medium pressure steam at 7.0 kg/cm², generated by passing live steam at 42 kg/cm², through a pressure reducing valve (PRV), was being used for sugar drying and melting	*Exhaust steam generated by passing live steam through the turbine was available at around 1.2 kg/cm². The exhaust steam was utilised in place of live steam for sugar melting (blow-up) and sugar drying.* *Replacement of live steam with exhaust steam in these two users increased the cogeneration by about 35 units, which could be sold to the grid.*

Energy savings

Annual savings : Rs. 0.2 Million
Investment required : Rs. 0.02 Million
Payback Period : 2 months

Case Study 5: Installation of Conical Jet Nozzles for Mist Cooling System

Brief

The spray pond is one of the most common types of cooling system in a sugar mill. In a spray pond, warm water is broken into a spray by means of nozzles. The evaporation and the contact of the ambient air with the fine drops of water produce the required degree of cooling. There are many types of nozzle configurations available for different spraying applications. Most of them aim to give a water spray the form of a hollow cone. A good spray nozzle should be of simple design, high capacity and high efficiency. Of the various types of spray nozzles, the conical jet nozzles have been found far superior on all the above parameters. Hence, the recent trend among the new sugar mills is to install the conical jet nozzles, to achieve maximum dispersion of water particles and cooling.

Before Improvement	***After Improvement***
In a 4000 TCD sugar mill, the cooling system consisted 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). *The maximum cooling that could be achieved with the spray pond was about 34 - 35 °C.*	*The spray pond system was modified and conical jet nozzles were installed to achieve mist cooling. The material of construction of the conical jet nozzles is PVC, which enables better nozzle configuration achievement. 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.* *The better cooling water temperatures, maintained steady vacuum conditions in the condensers thus minimising the frequent vacuum breaks, which occurred in the condensers.*

Energy savings

Annual savings : Rs. 0.32 Million
Investment required : Rs. 0.50 Million
Payback period : 19 months

Case Study 6: Installation of Regenerative Type Continuous Flat Bottom High Speed Centrifugal for A - Massecuite Curing

Brief

Before Improvement	***After Improvement***
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. 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 regenerative type of braking system was installed for the entire flat bottom high speed centrifugal used for A - massecuite curing.* *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.*

Energy savings

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.

Case Study 7: Installation of Jet Condenser with External Extraction of Air

Brief

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-condensables.

Before Improvement	After Improvement
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.	The jet condensers with external extraction of air system were installed. There was a significant plant drop in water consumption in these condensers, in spite of an increase in crushing capacity (average maximum crushing of 4800 TCD). This resulted in reduction in the number of injection water pumps in operation. The new injection water pumping system includes - 5 nos. of 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% reduction). The actual average power consumption also has registered a significant drop of nearly 180 kW, which amounts to an annual energy saving of 5,18,400 units (for 120 days of sugar season).

Energy savings

Annual savings	: Rs. 1.30 Million
Investment required	: Rs. 2.53 Million
Payback period	: 24 months

Case Study 8: Installation of 30 MW Commercial Co-generation Plant

Brief

Before Improvement	After Improvement
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 power requirement of the plant during the sugar-season was met by the internal generation and during the non- season from the grid. 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.

Energy savings

Enhancement in power generation	: 9 MW to 23 MW.
Surplus power generation for exporting to the grid	: 14 MW
Annual savings	: Rs. 204.13 Million
Investment required	: Rs. 820.6 Million
Payback period	: 48 months

Case Study 9: Replacement of Steam Driven Mill Drives with Electric DC Motor

Brief

Before Improvement	After Improvement
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 decided to replace the steam driven mills with electric DC motors, along with the commissioning of the cogeneration plant. These drives have very high efficiencies of 90%. Benefits of electric DC drives for mill prime movers • Increased drive efficiency • Additional power export to grid The power saved (850 kW/mill) by the implementation of this project, could be exported to the grid

Energy savings

Annual savings	*: Rs. 62.37 Million*
Investment required	*: Rs. 42.00 Million*
Payback period	*: 9 months*

Case Study 10: Installation of an Extensive Vapour Bleeding System at the Evaporators

Brief

Before Improvement	**After Improvement**
In a typical 2500 TCD sugar mill, the quintuple effect evaporators were in operation. 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. *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)* *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.*	*The plant upgraded by installation of the extensive vapour utilisation system at the evaporators. The extensive use of vapour bleeding at evaporators was adopted at the design stage itself in this case. This has resulted in improved steam economy.* *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 kg/cm^2.* *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.* *The specific steam consumption achieved (as % cane crushed) is: 41% 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).*

Energy savings

Annual savings	*: Rs. 11.00 Million*
Investment required	*: Rs. 6.50 Million*
Payback period	*: 8 months*

Case Study 11: Installation of Variable Speed Drive (VSD) for the Weighed Juice Pump

Brief

Before Improvement	**After Improvement**
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* *The flow from the weighed juice tank was not uniform.* *Moreover, the pump was designed for handling the maximum cane-crushing rate.*	*Variable Frequency Drive was installed for the weighed juice pump and 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%).*

Energy savings

Annual savings	*: Rs. 0.24 Million*
Investment required	*: Rs. 0.25 Million*
Payback period	*: 12 months*

Case Study 12: Installation of Thermo-compressor for use of Low Pressure Steam

Brief

Before Improvement	**After Improvement**
In a typical 4000 TCD sugar mill in Maharashtra, the turbine exhaust steam at 0.40 kg/cm^2 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 kg/cm^2. The distillery required 10 TPH of steam at 1.5 kg/cm^2. 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 kg/cm^2 and reduced to 1.5 kg/cm^2 through a pressure-reducing valve.	*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.* *The resultant 1.5 kg/cm^2 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.*

Energy savings

Annual savings	*: Rs. 6.0 Million*
Investment required	*: Rs. 2.0 Million*
Payback period	*: 4 months*

Case Study 13: Installation of Hydraulic Drives for Mill Prime Movers

Brief

Before Improvement	*After Improvement*
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 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. The modified 4-mill system was provided with a hydraulic drive of 600 kW rating.*

Energy savings

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.

Case Study 14: Install nozzle governing system for multi jet condensers

Brief

Before Improvement	*After Improvement*
A 6750 TCD Plant was consuming 1150 kWh of Power at Cooling & Condensing System	*A nozzle governing system was introduced for controlling the water flow to the condenser. 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.*

Energy savings

Annual savings	*: Rs. 19 Million per year*
Investment required	*: Rs. 5 Million*
Payback period	*: 3 months*

Case Study 15: Installation of Fully Automated Continuous Vacuum Pans for Curing

Brief

Energy savings

Before Improvement	*After Improvement*
In a 6000 TCD plant,batch vacuum pans were installed for A-massecuite and B- massecuite and continuous vacuum pans for C-massecuite curing.	*Consequent to the capacity upgradation to 8000 TCD, continuous vacuum pans were installed for A-massecuite, B- massecuite and C-massecuite curing.*

Energy Savings

- *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*

Annual savings	*: Rs. 19.26 Million*
Investment required	*: Rs. 100 Million*
Payback period	*: 63 months*

References

1. Annual Report 2007-08 Ministry of Consumer Affairs, Food & Public Distribution, GoI.
2. The Indian Sugar Industry Sector Road map 2017; KPMG in India
3. CII - IREDA Publication: "Investors Manual on Energy Efficiency".
4. Stasticial Abstract 2007- CSO
5. LBNL - 62806; World Best Practice Energy Intensity Value for Selected Industrial Sectors, February 2008.
6. TERI Energy Directory and Yearbook 2007
7. LBNL - 57293; Assessment of Energy use and energy savings potential in selected industrial sector in India, August 2005.
8. Japan Energy Conservation Directory
9. LBNL - 54828: Emerging Energy Efficient Technologies in Industry case studies of selected technologies - May 2004
10. National Energy Map of India: Technology Vision 2030
11. Report of the working group on Power for 11th Plan (2007-12)
12. Report of the working group on R&D for the Energy Sector for the formulation of the 11th Five Year Plan (2007-12)
13. Report of the working group on new and renewable energy for 10th Five Year Plan (2007-12)
14. BP Statistical Review, June 2008
15. www.indiansugar.com
16. www.eeii.org.in
17. www.energymanagertraining.com
18. www.avantgarde-india.org