Energy Conservation In The Sugar Industries: Case Studies

Installation of Thermo-compressors for the use of Low Pressure (LP) Steam

Background

The sugar industry has many processes and systems that use steam – both 'live' medium –pressure (MP) steam and exhaust steam. Some of the systems that are live steam users can be totally replaced with exhaust steam, while the live steam consumption can be partially replaced with exhaust steam in other cases.

One such live-steam user in a sugar mill is the adjoining distillery. A typical distillery requires steam at about 0.7-0.9 kg/cm^2 for the distillation column and about 1.0-1.2 kg/ cm^2 for the ENA column. The exhaust steam pressure of 0.4 kg/ cm^2 available from the sugar mill will not be able to cater to this requirement. Hence, live steam is drawn from the 8 kg/ cm^2 header and dropped to 1.5 kg/ cm^2 through a pressure-reducing valve, for use in the distillery.

Any conservation measures, which can replace/minimize the live MP steam consumption, can result in maximizing 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 "compress" the waste exhaust steam (typically about 0.4 kg/ cm^2) available in the sugar mill. The resultant LP steam (typically about 1.5 kg/ cm^2) can be utilized for any process steam requirement, such the distillation column and ENA column in a distillery.

This modification can result in minimizing the usage of MP steam consumption, effectively utilize the heat value of exhaust steam and maximize the cogeneration potential.

Before…

In a typical 4,000-TCD-sugar mill in Maharashtra, the turbine exhaust steam, amounting to about 6,300 kg/h at 0.4 kg/ cm^2 was continuously vented out. There were no process users in the sugar mill or the distillery that could utilize this exhaust steam of 0.4 kg/ cm^2 .

The distillery required 10 TPH of steam at 1.5 kg/ cm^2 the requirements for which were being met by a separate boiler. The sugar mill boiler met any additional requirement of steam. In both cases, steam was generated at 8 kg/ cm^2 and reduced to 1.5 kg/ cm^2 through a pressure-reducing value.

However, the expansion of steam through a pressure-reducing valve is not a good system, as no power is generated with pressure reduction.

The turbine's exhaust steam, instead of being vented out, could be converted to medium/high-pressure steam through thermo-compression and used to meet the steam requirements of the distillery.

After…

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

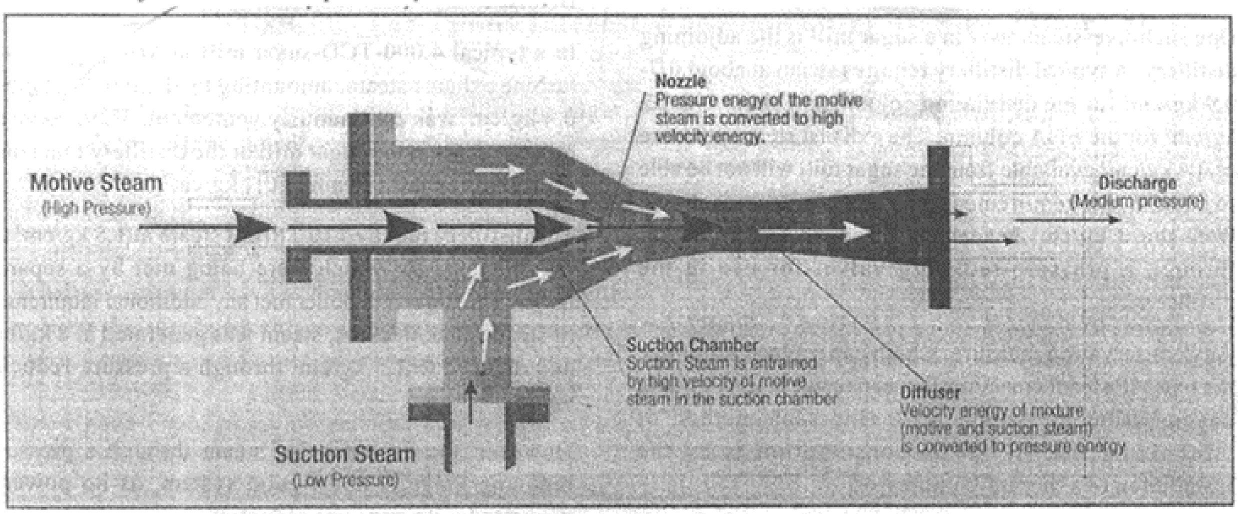
Benefits of Using a Thermo-compressor

- Increased cogeneration
- Additional power exported to the grid

Project Concept

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

Schematic of a Thermo-Compresor System



The resultant steam mixture than 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 localized process.

The resultant discharge steam is available at a pressure suited to 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

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

- Motive steam : 3,700 kg/h at 20 kg/ cm^2
- Suction steam : 6,300kg/h at 0.4 kg/ cm^2
- Discharge steam : 10,000 kg/h at 1.5 kg/ cm^2

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.

Cost Benefit Analysis

- Annual Energy Savings-Rs.6.0 million
- Investment –Rs. 2.0 million.
- Simple Payback Period – 4 months.

Continuous Vacuum Pan Technology

Batch Pans & Continuous Pans

Vacuum pans are important equipment used in the manufacture of sugar. The concentrated syrup from 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 the 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 characterized by:

- High hydrostatic head requirement.
- High Massecuite boiling temperature which cause color formation.
- Loss of fluidity of massecuite, particularly towards the end of the batch cycle.
- Higher boiling point elevation resulting in lower heat flux for a given steam condition.
- Very high steam consumption due to the non-uniform times of the loading, unloading and pan washing cycles.

The need to overcome these shortcomings led to the development of continuous vacuum pans (CVP), which have now been installed in many sugar plants. The technological development of these pans dates back to the 1970's, beginning with modifications in batch pans and adapting them to continuous operations. The design of these continuous systems aims to obtain maximum overall efficiency with complete automation. Experience with continuous pans has shown improved performances compared to batch pans with greater heat and mass transfer rates along with the possibility of using low-pressure vapors. CVP technology for continuous massecuite boiling in the sugar process offer several advantages, the most important being:

- Very low hydrostatic loads.
- Improved grain-size quality.
- Wide circulation passages.
- Heat balance optimization.

CVP Features

Each CVP comprises a horizontal pan divided into thirteen volumetrically graduated cells, constructed with transversal and longitudinal partitions running the entire length of the pan. The heating calendria uses horizontal steam tubes, which run through every cell.

The magma is fed into the first cell and the massecuite flows from cell to cell through openings located alternately in the upper level of the calendria and underneath it. The final massecuite is drawn off from the last cell. The molasses are fed into the bottom of each cell where it mixes with the massecuite before passing through the calendria.

Controls

CVP controls may be based either on a predictive mass balance of the pan or may be conductivity controlled. In predictive controls, the flow of the molasses introduced into the pan is calculated by algorithm in which the water contained in the liquor corresponds to the flow of steam into the pan whereby the outlet flow of the massecuite is controlled. In conductivity-based control, super saturation levels in various compartments is accessed by measuring conductivity in various compartments, which in turn regulate the liquor flow to the pan.

Advantages of CVP

1. Efficient Calendria: CVPs are equipped with horizontal calendria where the vertical movement of the massecuite from one tube to another breaks up and mixes with the thermal layers surrounding them.

This enhances exchange by providing greater heating area per unit of calendria and is not possible with a smooth vertical tube because of laminar flow.

2. Circulating steam in three passes enables the entire surface of the calendria to be swept systematically. The steam always circulates fast enough to ensure the complete impulsion of the condensate and the non-condensable gases. The extraction of non-condensable gases can be rigorously controlled, since the extraction point is located at the end of the steam pass. In comparison, a vertical calendria requires several extraction points for non-condensable gases, which usually involves bleeding of large quantities of steam at the same time. This also allows maximum evaporation rates, commensurate with maximum possible crystallization rates and facilitates the use of low –pressure steam, on account of increased transmission coefficients, brought about by higher circulation rates of the massecuite.

3. Very Low Hydrostatic Loads: CVPs ensure the lowest possible maximum hydrostatic load. The sloping top of the calendria, which facilitates the recirculation of the massecuite, enhances this effect. This corresponds to a practical gain in the range of 2 to 4^{O} C. This also minimizes heat injury to the sugar crystal.

4. Wide Passages for Recirculation: CVPs facilitate the natural recirculation of the massecuite by providing wide lateral recirculation passages, which are equivalent to 55% of the diameter of the shell whereas the ratios for the batch vacuum pans generally are from 30 to 40%.

5. Conservation of Energy: CVPs, with their enhanced performance offers substantial energy savings, especially an appreciable reduction in the steam consumption. Use of very low-pressure steam and increased thermal efficiency are possible as a result of a better transmission co-efficient brought about by the higher circulation rate of massecuite. Steam consumption achieved is appreciably lower in CVPs when compared with conventional batch vacuum pans

Comparison of Savings in Steam Consumption in CVP & Batch Pans

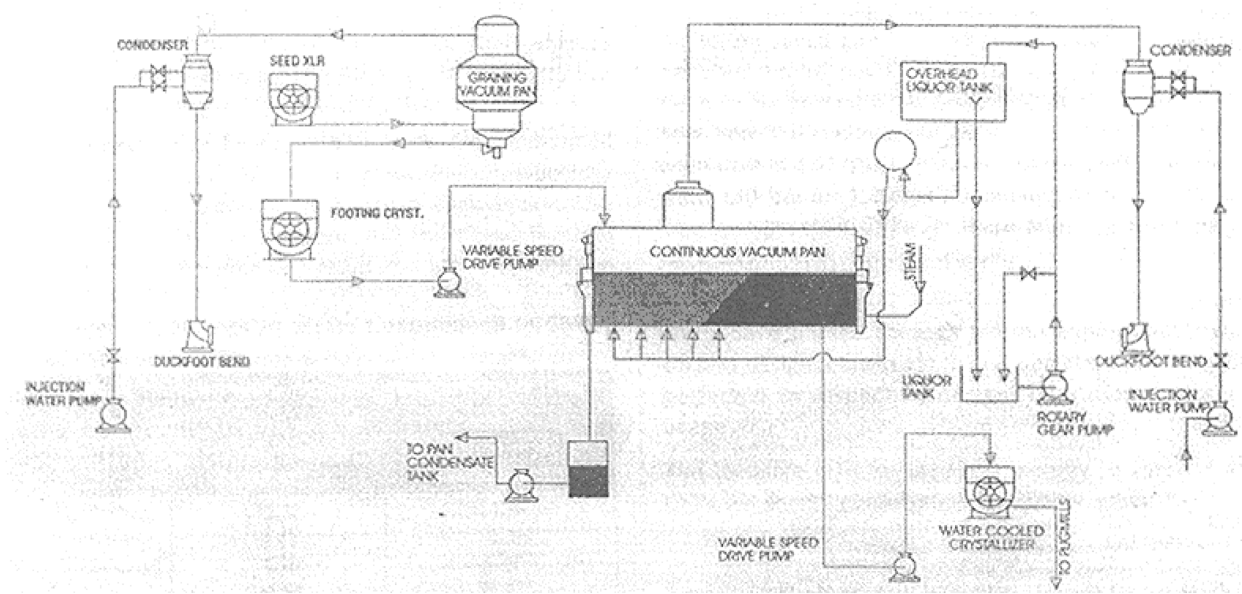
Identity Pan Configuration for a Typical 2500-TCD Plant

	CVP Configuration Steam Consumption (T/hr)	Batch Pan Configuration Steam Consumption (T/hr)
A – Pan Boiling	12.38	13.76
B – Pan Boiling	4.22	5.3
C – Pan Boiling	4.38	6.43
Total	**20.98**	**25.49**

(Savings in steam consumption for CVP installations = 3.97% on cane)

- Average steam demand when CVPs are used is 10 to 13% lower when compared to batch vacuum pan-based factories.
- Power required for condensing and cooling reduces considerably.

In a sugar mill having a high efficiency cogeneration system, the steam saved can be used in a condensing turbine to generate surplus power. Based on the assumptions above, the revenue generated by generating surplus power of 1.73 MW from the steam saved by using CVPs (3.72 t/h – HP equivalent of 4.51 t/h of LP steam) and the savings in injection water (80 kW for 1,200 m^3 h) amounts to Rs 145.42 lakhs. The investments in CVPs for these mills are therefore paid back within one crushing season.



Conclusions

CVPs have passed through all the experimental stages such as design, construction, and operation and have been perfected in respect of design, operation and energy usage.

This therefore calls for the sugar industry to consider using CVPs for energy conservation and better productivity.

Energy Conservation & Payback Analysis

Parameter	Value
Sugar plant capacity	2,500 TCD
Saving in steam consumption due to A', B', 'C' CVP installation	4.51 T/hr
Equivalent bagasse quantity for above saving in steam	2.05 T/hr
Bagasse saving for a season of 150 days	7,380 T
Bagasse saving in terms of Rupees per season	Rs.22.14 lakhs
Saving in injection water due to CVP system installations	1,200 m^3 /hr
Savings in power due to reduction In injected water	80 kWh
Saving in power per season of 150 days	288 MW
Cost of power saved per season	Rs. 11.52 lakhs
Total savings per season due to CVP system installations	Rs. 33.66 lakhs
Additional investment on CVP system installation over batch vacuum pan installation	Rs. 105 lakhs
Simple payback on CVP system installation	3 seasons (approx.)

Rs.1 lakh = Rs. 100,000

Source: Cane Cogen India July 2002

Energy from Cane Trash in Colombia

A pre-feasibility study of the technical and economical viability of producing electric power from green harvest residues of sugar cane in Colombia was prepared by their sugar industry, sponsored by the Global Environmental Facility (GEF) and managed by the Center de Investigacion de Ia Cana (CENICANA).

The overall conclusion states that the viability depends on the satisfactory development of systems for collection in the field and transport to the generating site. If the costs of these systems can be reduced to less than approximately US$ 8 per ton, with 35% moisture content, electricity generation from green residues could provide an excellent investment opportunity for the Colombian sugar industry and economy.

Depending on the options selected (baling or chopping of residues, and modified or actual boilers), the industry could contribute 300-700 MW of electricity. At the same time, additional jobs would be created in rural areas and emissions of CO_2 , CO, methane, NO_x and particulate associated with the burning of cane and cane residues in the field would be lowered.

Uncertainties and risk factors that need to be addressed:

- Transport and collection systems are at present hypothetical and have not been rigorously field-tested.
- Modifications of equipment and facilities would be required by factories to produce electrical power (these, however, would use well-proven technology).
- The attractiveness of investments in private power production, and the amount of power that mills choose to produce, also depend on decisions by public authorities concerning such matters as loan rates, import duties, and power prices.

In the evaluation process, two systems of collection and transport of residues were considered–chopping and baling. In the assessment of the conversion of energy in the residues to electrical energy, anaerobic fermentation in landfills, integrated gasification–combined cycle (IGCC), and direct combustion in bagasse boilers were considered. The landfill possibility had not been evaluated previously in the case of cane residues; it was initially considered a possibility as residue moisture content is not critical and transport distances of the bulky residues could be drastically reduced. The analysis of landfill systems indicated, however, that they are not economically viable for Colombian conditions due to high initial costs of collecting and transporting residues.

The application of a biomass integrated gasification/gas turbine system could eventually become the best solution for the use of residues in power generation. However, no viable systems using gasified biomass with relatively low calorific values to generate power through gas turbines are being used commercially. For this reason, the Colombian industry will continue to observe the progress in the Brazilian Copersucar GEF project on the establishment of a commercial demonstration plant and depending on results, make future decisions.

The use of residues as fuel in traditional and modified boilers to produce power is the most attractive option for the Colombian sugar industry. However, the analysis demonstrates that power generation is technically feasible in many mills with very little investment. Increased investment and adjustments could significantly improve the performance of the boilers originally designed primarily for sugar operations.

Some Results of the Analysis

- Availability of Residues: In the most widely grown varieties, more than 30% of the total biomass at harvest is in the form of residues. In the absence of rain the moisture content decreases by 3-5% per day when the trash is left in the field. Density of residues was extremely low at less than 100 kg/rn^3 but could be increased to 600 kg/ rn^3 (average) with a compression of 250 k Pa; the calorific value was 10,000 KJ/kg at 35% moisture.

- Collection, Handling and Transportation of Residues: The estimated cost for collecting, handling, loading, and transportation of residues is between US$ 7.4-11.7/t and US$ 0.81 – 1.28/GJ. Locally available coal with 24,423 kJ/kg can be replaced if collection and transport costs can be reduced to around the equivalent of US$ 8/t with moisture content of 35% and US$ 4.3/t at 65% moisture.
- Combustion Technology: Of the three options studied, regular combustion in boilers was found to be the most technically viable. The cost of trash handling operations in factory (storage, breaking and shredding for baled trash, partial drying with chimney gases, mixing with bagasse, etc.) is between US$ 3.4-6.2/t, while for chopped trash the cost is between US$ 1.1-3.4/t.

The total cost of the operations on the field and in the factory is between US$ 10.8 – 17.5/t for baled residues and US$ 8.7 – 15.1/t for chopped trash. These figures give a final cost of US$ Wh 0.05-0.1/k. This cost figure is within the range that makes generation from residues an attractive option. A prototype residue chopper based on a commercially available Claas forage harvester was used to chop residues on a semi-commercial basis. The residues were then mixed with bagasse and burned in standard boilers with no negative effects on steam quantity or quality. The results are sufficiently promising that CENICANA is commissioning a commercial version of the residue chopper for further trials in 2000.

Reference: Cane Cogen India July 2002