Energy Efficiency in Sugar Plant Steam and Power Generation

P.S.Sankarnarayanan, J.Gladstone Evans & C.Damodaran

The industrial sector in India is a major energy user, accounting for about 48 percent of the commercial energy consumption. The sector has become increasingly energy intensive overtime, which is partly due to the investments made in basic and energy-intensive industries to achieve self-reliance. There are wide variations in energy consumption among different units within the same industry using comparable technology. The energy saving potential in this Sugar sector is estimated to be 25%, making it the sector with the maximum potential in the economy.

It is also estimated that over 5% to 10% saving is possible simply by better housekeeping and another 10% to 15% with small investments towards low-cost retrofitting, use of energy-efficient devices and controls etc. The quantum of saving is much higher if high cost measures like major retrofitting, process modifications etc., are considered.

The increasing global trade liberalization and growing global competition have made productivity improvement, including energy cost reduction, an important benchmark for economic success. To realize the potential of energy efficiency, the Government of India enacted the Energy Conservation Act 2001 which came into force since 1st March 2001. under the provisions of the Act, the Bureau of Energy Efficiency (BEE) was established with effect from March 1 2002. BEE is the recommended body of the union government for implementing the provisions of the Energy Conservation Act, BEE recently declared the Government's commitment to reduce the energy consumption of the Public sector buildings by 30% in 5 years and conducted the first meeting of consultants, Energy Service Companies, Possible Vendor ESCOs with a view to discuss the methodology for implementing energy efficiency in buildings through performance contract route.To motivate and encourage sugar industry to take up energy conservation measures seriously, the Government has been announcing fiscal incentives periodically. The incentives range from 100 % depreciation benefit to concessional import duties for energy saving equipment. Funding is also available through sources like IREDA for energy conservation projects.

Energy Conservation at Design Stage of a Plant is the most recommended mode of practice. The technical specification of the equipment to be procured should be properly drawn keeping energy efficiency in mind at all stages. The specification should also explain the Bid evaluation criteria based on the energy efficiency and the loading to be followed for the consumption of power and fuel should be well defined. Typically a equipment specification from Avant-Garde will carry the following loading factors on the Bids.

The PURCHASER's evaluation of a bid will take into account, in addition to the bid price, the following factors, in the manner and extent indicated below:

Since the operating costs of the equipment under procurement form a major part of the life cycle cost of the equipment, these costs will be evaluated as follows:

i. the cost of auxiliary power consumption shall be based on Rs.1,20,000/- (Rupees one lakh and twenty thousand only) per kW. For the computation of this cost, only the continuously running auxiliary equipment will be considered. In computing this figure the prevailing energy cost is considered for a period of five years.

ii. The cost of fuel:For bagasse, the cost shall be based on Rs.15,000/- per kg of fuel additional consumption per hour. This is typically computed by costing the bagasse for a period of five years.

iii. The efficiency of the machine is reflected by the gross power output at the generator terminals, as the input steam and the extraction steam requirements have been specified by the bid documents. For the purpose of evaluation of the bids with respect to the productivity or the efficiency of the machine, only the gross power output at the generator terminals will be compared. The evaluation will be made on the basis of Rs.1,20,000/- (Rupees one lakh twenty thousand only) per kW.

iv. Short fall in capacity for every 0.1% reduction in steam output is penalized Rs. 10,000 for Bagasse firing. This is computed by costing the loss of power production for a period of five years.

Of course, the loading and penalties are after providing due consideration for tolerances as per acceptable industrial norms and will vary from project to project depending on the power cost at that location.

As a part of the ADB energy efficiency support project (executed by CII), a manual on energy efficiency at design stage for major plant equipment has been prepared. A energy conservation case study booklet in sugar industry is also compiled which covers extensively on the opportunities to conserve energy in the sugar industry. Avant-Garde has contributed as a team member in the contents of these booklets and manual.

For an existing sugar unit there is no one preset procedure to conduct an energy audit which can be tailor adopted. What works in one plant need not be suitable for another. Much depends on the existing machinery, the operating and maintenance philosophy, history of the plant and the training, attitude and culture of the plant personnel. Much depends upon the appreciation and encouragement being given by the management for identifying and implementing energy conservation measures.

Avant-Garde has been concentrating among other things, to improve energy efficiency in steam and power generating plant of the sugar unit. Innumerable jobs on configuring co-generation schemes have been taken up to improve the energy efficiency hand in hand with performance improvement of steam generators. Performance improvement and energy conservation activities result in saving in bagasse, which can be either sold or can be used for additional power generation, which can be a source of additional revenue to the sugar plant.

There are various configurations possible for cogeneration beginning from incidental cogeneration to full fledged cogeneration. The full cogeneration can be implemented either in one or more stages. Adopting higher pressure power cycle will increase the power output from the same bagasse. For example, 100 kg of bagasse can produce the following power output.

Steam Cycle parameter ata / Deg.C	Power Generation at 2.5 ata BP kW
45 / 440	32.8
67 / 480	37.8
87 / 510	40.0

Hence, it is advisable to adopt 87 ata 510°C power cycle for new full fledged cogeneration plants. Designing the cogen. Plant for minimum in house power consumption will maximize the power export. Avant-Garde has commissioned the first two cogen projects in India, which are based on the 87 ata power cycle. The in-house power consumption, which is normally predicted as 10% of the gross power generation has been reduced to as low as 7.3%. The main features are adopting VFD for boiler feed pump, ID, FD & SA fans, compressor and continuous bagasse feeding system. Adopting VFD alone has resulted in 2% savings. Proper sizing of piping, auxiliaries, good plant engineering etc., have contributed to the remaining savings. For more recent projects VFD has been adopted for circulating water pumps, cooling tower, condensate extraction pumps etc.

By reducing the moisture content in bagasse the efficiency of boiler can be increased. Typically for a 87 ata 515 Deg C Boiler with feed water at 170 Deg C, excess air at 30%, and back end temperature of 150 Deg C, the boiler efficiency can vary between 66.6% to 74.8% for variation in moisture level from 45 % to 55 %. There is a variation of 0.8% in efficiency of boiler for every percent of moisture variation in bagasse. Bagasse drying can certainly help improve boiler efficiency. Steam drying of bagasse has to be carefully configured in the heat balance of the plant, while optimizing the power cycle. This is an area which needs further detailed study and is yet to be implemented.

The study of the performance improvement in boilers involves the study of the boiler both during shut down and when it is operating. The methodology of the study involves the following activities.

A team of experienced boiler design engineer and service engineer is formed. This team studies the available information and data on the boiler to be studied and identifies the requirement whether to study the boiler in shut down condition or both during operating and in shutdown condition.

Field study consists of understanding the boiler and data collection. The study includes tests on all energy consuming equipment for their performance. Complete scaffolding in the boiler with approach to all pressure parts is required before undertaking the inspection. The boiler is thoroughly inspected from the inside and all irregularities such as gas baffle bypasses in boiler bank area, leakage in the flue and air passages, pattern of ash deposition and accumulation on the pressure parts and ducting, pattern of erosion on the pressure parts if any, signs of overheating of the pressure parts, the quality and condition of refractory etc.

Based on the data collected and for the existing configuration of the pressure parts the thermal calculation of the boiler is performed. This identifies the areas for improvements and addition of heat transfer surfaces.

The various options and areas for performance improvement are identified and budgetary costs involved for implementation with savings are identified. The energy saving / performance improvement opportunities are short term or long term. A consolidated report is prepared and discussed with the plant personnel for implementation. Some of the activities will need more detailed engineering which are identified and taken up for further design. Some of the key areas identified based on the various performance improvements conducted in sugar plant boilers are as follows.

WORKING THE BOILER AT RATED PRESSURE, FLOW AND TEMPERATURE:

Many of the boilers are not working at the rated parameter. Drop in temperature and pressure of steam at the inlet of turbine drives leads to reduced power out-put and higher consumption of steam.The heat transfer area provided for the water wall, bank tubes, economizer, air heater and the super heater are recalculated and additions are suggested if required. If the turbine drive can accept it, the boiler outlet steam temperature itself can be increased. Higher temperature of steam decreases the specific steam consumption of the turbine. In many of the existing Boiler, the superheater is of single stage design and for better steam temperature control, it is recommended to divide the superheater suitably into two stages with intermediate Desuperheating facility.

REDUCING THE PRESSURE DROP IN STEAM LINE FROM BOILER TO TURBINE:

Detailed study is taken up for calculation of the pressure drop in steam piping from boiler to various user points. In many cases, piping has been modified as the plant has expanded capacity and equipment added without much of engineering into the pressure drop consideration. Recalculating the pipe sizing and retrofitting has resulted in increase in the inlet pressure to the prime movers and reducing the steam consumption. This study is highly recommended for old sugar plants, the returns have been found to be very attractive.

COMBUSTION EFFICIENCY IMPROVEMENT:

The Preparation of cane has become more fine at present and the carry over of fines to the superheater area and its subsequent combustion in the higher zones has created problems of deposition in the superheater area. In some of the boilers the ash accumulation has warranted shutdown of the boiler for clearing once in every 10 days. The carry over of unburnt carbon with the flue gases have increased. The total review of the fuel feeding system, air distribution in the furnace both primary and secondary air system, the over fire air system location etc., is recommended. With modifications such as introduction of improved design of pneumatic distributors, rotating dampers, additional over fire air nozzles, increasing the quantum of secondary air etc., have resulted in improved combustion and increasing the turbulance in the furnace resulting in reduced unburnt carbon losses. The burning of fines at higher elevation is also considerably reduced the down time of the boilers.

REDUCING EXCESS AIR LEVELS:

By reducing the excess air level of operation in the boiler, the efficiency of the boiler is improved. Presently, most of the sugar plant boilers are operating at excess air levels above 50% and they can be rectified to operate between 30 to 35% level. The major contributing factors for excess air level increases are leakage in flue gas ducting, expansion bellows, furnace refractory work, roof seals, hoppers, air heater etc., The refractory arrangement in the brick walls needs review and redesign to provide proper expansion provision and sealing at corners, openings etc., The expansion movement diagram of the boiler should be remade and proper provisions for expansion movements have to be made to avoid cracking of refractory walls, membrane panels, pressure part penetration points and all other critical areas. Very high clearance between the rotor and stator of the rotary ash discharge valve at grate hopper, drum hoppers, dust collector hoppers etc., also lead to air ingress into the boiler.

INDUCED DRAFT SYSTEM

Over the years due to reblading of the ID fan impeller the performance of the fans are found to have degenerated. The new design of impeller has efficiencies above 80 % as compared to older versions which are between 50% to 60%. Retrofitting of the ID fan impeller with higher efficiency type improves the performance of the boiler. Frequent back fires in the boiler damages the boiler parts and causes leakages leading to air ingress. Puffing in the furnace also increases the unburnt carbon losses due to carry over and makes it difficult for the boiler, operators to operate, maintain and control. The pressure drop in the flue gas path across the bank area, ducting, economizer, air heater and mechanical dust collector are to be studied. The number of cyclones in the dust collector is generally found inadequate leading to very high pressure drop. Additions Can be made to the cyclones to improve the efficiency and also decrease the pressure drop across the dust collector. It is advisable to retrofit the mechanical dust collector with Electro Static Precipitator which helps in meeting the pollution control requirements and also reduces the pressure drop drastically.

AUTOMATION AND COMBUSION CONTROL

Introducing auto control loops for drum level control, combustion control with oxygen trimming, furnace draft control etc., and result in steady operation of the boiler with high degree of efficiency. All the new boilers which are for cogeneration adopt DCS control for optimum functioning. Introduction of continuous bagasse feeding system with storage facility for bagasse at the boiler front makes combustion control possible. The multi fuel firing capability of the boiler also increases with auto controls.

OTHER OPTIONS:

In this paper only a few of the areas which are commonly encountered in boiler performance improvement are highlighted. There are many other methods which can be adopted for improving the energy efficiency of the sugar plant steam generator and power generation system. The cycle efficiency of the plant can be improved further with additions of high pressure deaerator, LP heater, HP heater, flash steam recovery and many other similar options.

ENERGY CONSERVATION IN EXISTING POWER PLANT CHECK LIST OF KEY FACTORS

- Improvement in back end gas temperature
- Rectification of leakage in ducting and the entire flue gas path.
- Arresting of air / flue gas bypass especially through boiler bank baffles, economizer flue gas bypass ducting.
- Proper maintenance of insulation in boiler, furnace, ducting and piping including fittings.
- Boiler thermal expansion movement check with respect to supports.
- Modifications in air / flue gas flow pattern and elimination of ash accumulation in ducting.
- Minimizing the losses due to boiler drum blow down.
- Arresting water and steam leakage in boiler and piping.

- Improvement / restriction of furnace outlet temperature of flue gas to avoid slagging in superheater area.
- Introduction of direct spray type desuperheater in superheater assembly by dividing the superheater into two sections in single stage superheater design.
- Review of superheater and pressure part supports.
- Addition of long retractable soot blowers in front of superheater.
- Ensuring uniform distribution of controlled quantity of fuel on the grate.
- Review of the grate design and maintainability.
- Operating the boiler at its rated parameters i.e capacity, pressure and temperature
- Review of the performance of the existing steam drum internals and steam drier arrangement.
- Review of the existing heating surface area provided in the boiler.
- Review of the boiler design and space availability with respect to increase in boiler capacity
- Review of the existing main steam pipe sizing and pipe routing
- Review of the capacity and head of equipment selected such as, ID, FD & SA fans, boiler feed pumps, etc
- Reduction of unburnt carbon loss in bottom ash and fly ash.
- Review of the dust collector equipment performance.
- Review of boiler operating practices such as furnace cleaning time etc
- Review of boiler water quality and feed water quality.
- Inspection of deaerator and review of its performance.
- Review of HP and LP dozing system capacity and selection.

GUIDE LINE FOR QUANTIFYING ENERGY CONSERVATION

10°C reduction in back end temperature - 0.6% increase in boiler efficiency
10 % reduction in excess air - 0.4% increase in boiler efficiency
1 % reduction in bagasse moisture - 0.8 % increase in boiler efficiency

- For 1.0 TPH steam generation with 0.5 % increase in boiler efficiency, there is saving of 3 kg/hr of bagasse.
- For 1.0 TPH steam generation, by installing flash steam recovery system, there is a saving of 1.18 kg/hr of bagasse.