ELECTRICITY COGENERATION IN CANE SUGAR FACTORIES—
THE OUTPUT FROM AN ISSCT WORKSHOP

By

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Abstract

In late October 2000, 90 delegates from 16 countries met in Mauritius for the ISSCT Factory Engineering and Energy Section workshop on cogeneration of electricity by cane sugar factories. This paper reviews and summarises that workshop. The workshop consisted of three days of technical presentations and discussion plus two days of visits to the cogeneration facilities at four factories on Mauritius. Some delegates also took the opportunity to visit the cogeneration plant at the two mills on Reunion. The technical sessions considered biomass collection, factory process changes, boiler optimisation, bagasse gasification, the interaction between the sugar mill and the power utility and the incentives that were needed to enable sugar mills to convert economically to generate export electrical power. At the closing technical session, delegates felt that effective development of gasification technology held the greatest potential for long-term benefit, while the greatest unknown was the practical lower limit on process steam use in a cane (as opposed to a beet) factory.

Introduction

On Monday 22 October 2000, 90 ISSCT members from 16 countries assembled at the Mauritius Sugar Industry Research Institute, Reduit, Mauritius to begin five days of deliberations, discussions and factory visits. These activities constituted the workshop on 'Cogeneration' organised under the auspices of the Engineering and Energy Section of ISSCT. This paper attempts to condense and summarise those five day's activities.

Objectives

The overall objective of the workshop was to review and discuss all aspects of cane sugar factory cogeneration of electricity leading to an improved understanding of the current state of cogeneration technology, the incentives for its implementation, and the future developments that could enhance the viability of cogeneration operations.

The workshop was a relatively informal interchange of ideas and knowledge between practising industry technologists and was definitely not an academic conference. All delegates were encouraged to participate actively in the interchange and discussion. The informal nature of the workshop means that there are no formal papers for this author to refer to although copies of the overhead presentations were available from many speakers. As is usual with ISSCT workshops, no proceedings from the workshop were produced. This summary of the workshop, therefore, draws heavily on the available overhead presentations plus the personal recollections of the author.

Opening sessions and scene setting

An important reason for holding a cogeneration workshop in Mauritius is that cogeneration has become an inherent part of the sugar industry there. Similarly, in parts of India, the pressure for cane sugar factories to develop electricity cogeneration facilities is also great.

It was, therefore, very appropriate that the speech of welcome to the workshop delegates was given by a member of the government of Mauritius who was able to outline the policy process that led Mauritius to its current cogeneration status. It was similarly appropriate that this address should be followed by the keynote speaker, Dr Ram Tyagarajan, chairman and managing director of Thiru Arooran Sugars Ltd., Chennai, India, who outlined the development of cogeneration in his company and within India generally from an industrial rather than a governmental point of view. He indicated that India currently had 27 cogeneration facilities (nominal capacity 278 MW) with a further 53 in various planning stages (a further 790 MW). From a commercial point of view the biggest hurdle was still to produce a cogeneration proposal that was ‘bankable’.

Biomass storage, trash collection and cane cleaning

Cane trash (i.e. the dried and green leaves) can provide an additional source of fibre to boost electricity export. Current harvesting methods are tending to send increasing amounts into the factory with the cane. In the factory, the trash has a variety of negative effects including increasing the fibre that the extraction train has to handle and bringing in products which eventually increase sucrose losses to molasses. A compromise is to allow the trash to come to the factory with the cane supply, but separate it from the cane stalk before the extraction train, and send the trash straight to the boilers.

KEYWORDS: ISSCT Workshop, Cogeneration, Electricity, Energy Efficiency.
The first paper in this session was presented by Mr Raymond Rivalland, St Aubin Mill, Mauritius. He outlined the development and operation of a cane cleaning plant installed at his factory. The mill estimated that 5% trash in the cane supply cost the factory over US$250,000 per annum in sucrose lost in bagasse, in extra sucrose lost in molasses, in extra days of factory operation and in the energy required to process the trash. (They report actual trash levels approaching 10%.) If the cane could be cleaned and the trash passed around the milling train, the cost of processing the trash would be only the energy consumed by the cleaning plant. The electricity generated from this trash was estimated to be worth just under US$250,000.

On this basis, a collaborative team designed, financed and constructed a pneumatic trash separator (Figure 1). The design concept was to billet the cane before separating and shredding the trash and pneumatically conveying it to the bagasse belt after the milling train. Any innovative design unfortunately must experience some unexpected problems. The billeting system caused problems because it sprayed an unacceptable level of juice on to the trash and hence produced unacceptable sucrose losses. The billeting system was removed and the cleaning system reworked so that the trash is now removed from whole stalk cane in a counter-flow pneumatic chamber. The trash shredding system worked well, but the mill has experienced problems with a rotary valve that metered the trash out of the cyclone separator on to the bagasse belt.

Fig. 1—The pneumatic cane cleaning plant at Union St Aubin sugar mill, Mauritius.

Delegates subsequently heard details of the cane cleaning system installed at a Brazilian factory (from Dr Regis Leal, Copersucar Technical Centre, Brazil) and the plans to install a cane cleaning plant in Australia (from Mr Cam Palmer, New South Wales Milling Cooperative, Australia). The three systems use quite different approaches to cleaning. The Brazilian system cleans the cane as it leaves the cane feeder tables and at interchange points on bagasse conveyors, while the planned Australian system will use a large single pass cleaning chamber into which the billets are launched.

Dr Leal also outlined an investigation to identify the cost and benefits of various options for bringing the trash into the factory as well as the development of the cane cleaning facility mentioned previously. Mr Palmer indicated that they were examining closely the use of wood from an exotic ‘weed’ tree that has established itself extensively in their area to the considerable detriment of the natural environment. Mr Goel, Indian Sugar and General Engineering Corporation, Uttar Pradesh, India presented the results of a survey in western India to quantify the extra trash fibre that would be available. Their survey indicated that the trash could supply an additional 60% dry fibre.

Factory changes to maximise cogeneration

The workshop session that attracted the most interest involved the discussion of changes that cogeneration suggests should be made to the factory process. A total of 14 speakers prepared discussion papers. In the limited space available in this paper, it is not possible to give them full justice.

The principal speaker for the session was Dr Ross Broadfoot, Sugar Research Institute, Australia. He pointed out that the changes that were theoretically and technically possible were very different from the changes to an existing factory that were economically justifiable. The thrust of the changes was always to reduce process steam use, and he questioned how low the steam use could economically be anticipated to go. This was a theme that many of the subsequent speakers addressed in one form or another. In particular, the delegates from Germany shared their knowledge in this area based on beet industry experience.

The main points raised during the session concerning the process changes that would reduce steam consumption were:

- vapour bleed to heaters and pans from as late in the evaporator set as possible;
- an increased number of evaporator stages to increase the efficiency of steam use;
- increased final vapour temperature so that the vapour from final vessels is still usable in juice heaters.

These changes have a significant impact on various aspects of factory operation and equipment usage.

- How to best use existing vessels. As the steam use efficiency demand changes, the existing evaporator vessels are likely to be of the wrong size and/or in the wrong place with doubtful ability to operate effectively at reduced driving temperature differences.
- Control difficulties are likely to arise as large pans go on and off line and require large changes in steam bleed rates.

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- Control difficulties are likely to arise as large pans go on and off line and require large changes in steam bleed rates.
The requirement for higher overall evaporator temperatures is likely to adversely affect sugar colour formation and scale formation in the calandrias. A potential consequence will be a requirement to change to evaporator designs that require reduced juice residence times and can operate at smaller temperature differences between the steam and juice. Falling film evaporators could be used for this duty. These changes were mentioned by Mr Boris Morgenroth, Balcke-Duerr and the recent installation at St Aubin factory on Mauritius of a falling film system was discussed in detail by Mr Rivalland. This installation was viewed by the delegates when they visited that mill. It was interesting to note that the falling film units were fitted inside the existing evaporator shells but were still able to provide increased evaporation capacity.

The changed vapour conditions will affect the juice heaters which may require changes to heater surface area and could result in higher scaling rates and more frequent need for scale removal.

The changes to the vapour fed to the pan stage is likely to affect productivity and control requirements as well as encourage the move towards the use of continuous pans. In particular Mr Theisen, Pro/Mtec, Germany stressed the need for improved evaporator and pan control, pointing out the reduction in steam consumption that could accrue.

Changes may well be required to reduce high-pressure steam use, to ensure the high pressure steam is used most efficiently, and to balance high pressure and low pressure steam consumption. In this regard during the mill visits delegates noted the changes that had been made from turbine to electric and/or hydraulic mill drives.

The session also touched on various other aspects of converting a factory to cogenerate electricity. Two papers from Andra Sugars, Andra Pradesh, India focussed on the use of existing pans, evaporators and heaters as means of condensing the steam from back pressure turbines so that the turbines could cogenerate electricity outside the harvest season.

In his opening remarks, Dr Broadfoot had stressed that the changes in a factory had to be constrained to those that could be economically justified. Mr Palmer, NSW Milling Cooperative, Australia enlarged on this point. He gave the results of their studies which indicated that it was reasonably cost effective to rework their factory to lower steam use to just above 40% steam on cane but, for levels below this, the cost rose very steeply. The capital expenditure to move from 50% steam on cane to 39% steam on cane was about six times greater than to only go to 42% steam on cane.

Boiler optimisation for cogeneration

In a cogeneration facility, it is necessary not only to consider the efficient use of steam but also the efficient generation of the steam in the first place. From this point of view, the boiler is a critical component in a cogeneration facility. In his initial overview of this topic, Dr Dixon, Sugar Research Institute, Australia touched on three aspects of boiler optimisation—design factors, maintenance techniques and practices, and operational practices.

The design factors include the basic issues such as steam pressure, furnace size and the inclusion of an air heater and/or economiser but also extend to other more intricate issues that can affect operation. Dr Dixon briefly touched on aspects such as under grate air distribution, bagasse spreader capability, secondary air quantity and placement, gas flow geometry around the superheaters, convection bank, air heater and economiser to maximise thermodynamic effectiveness and minimise the tube erosion and corrosion.

Maintenance techniques and practices are more critical on a cogeneration boiler than on a normal sugar mill boiler because of the potentially large financial penalties associated with unscheduled down time, particularly if cogeneration is to take place for most of the year. Mr Jaques Albert-Thanet, Booker Tate, UK outlined the requirements for boiler reliability. Operational inefficiencies can also result in a direct financial penalty on a cogeneration boiler because those inefficiencies are directly associated with loss of income. The need to constantly monitor the level of excess air and distribution of bagasse on the boiler grate was particularly stressed.

Dr Dixon also stressed the importance of a highly reliable fuel supply. The other speakers in this session, Dr Mike Inkson, Biotherm Ltd, UK, Mr Hans Verbanck, John Thompson Africa, South Africa and Mr D.K. Goel, Indian Sugar and General Engineering Corp. addressed different aspects of this topic.

There was discussion of the use of coal as a fuel in a boiler designed also to fire bagasse. Potential problems associated with the interaction between grate design parameters for bagasse and coal were outlined, noting that the combustion characteristics of coal could vary over a much wider range than bagasse. It was noted that sluggish problems could be much more severe if a mixture of bagasse and coal was fired compared to firing either fuel on its own. Delegates were provided with detailed chemical analyses of bagasse and coal and the ash they produced.

Mr M. Narendranath, Andra Sugars Ltd, Andra Pradesh, India wanted to benefit from improved boiler operation as bagasse moisture content decreased. His company had installed a simple cyclonic flue gas bagasse dryer (see Figure 2). Delegates were much taken by the concept. Mr Narendranath pointed out that the system would not dry the bagasse to a very low level; it simply took advantage of what heat happened to be left in the flue gas to dry the bagasse as much as possible. At his factory, with a flue gas initially at 180°C, the bagasse moisture fell to 42% from about 50%.
Chimney

Fig. 2—A cost-effective bagasse dryer installed at The Andra Sugars Ltd, Andhra Pradesh, India.

Bagasse gasification

The thermodynamic cycle involved in burning a fuel, converting the heat energy to steam and then using the steam to generate electricity has inherent and fundamental limits on overall conversion efficiency. These limits can be relaxed if the gasification process is employed because it removes the steam generation component from the energy conversion process. It involves processing the fuel (gasifying) to produce a combustible gas that can be cleaned up and burnt directly in a gas turbine that drives an alternator to produce electricity. In many instances, the use of gasification can approximately double the amount of electricity produced per tonne of fuel. Gasification of bagasse is an option being examined in several sugar growing countries.

Mr Lars Waldheim, TPS Termiska Processer AB, Sweden was invited to address the workshop on this topic. He explained that a practical system cannot be effective if it uses gasification alone. In practice, the gasification process must be used in conjunction with conventional steam generation in a heat recovery boiler in order to recover heat from the gas turbine that would otherwise be wasted. The combined process therefore involves Integrated Gasification-Gas Turbine (IG-GT) operation. When Biomass such as bagasse is used as fuel the acronym becomes BIG-GT.

Gasification is, in effect, a carefully controlled partial combustion process that stops the combustion at the stage at which combustible gases are produced from the fuel. The complete BIG-GT process as applied to bagasse would then involve gasification of the bagasse, cleanup of the gas to remove particles and tars and make it suitable for combustion in a gas turbine. The turbine would power an alternator to generate electricity. The waste heat (exhaust gas) from the turbine would then pass to a heat recovery boiler. The steam generated there would provide process steam for a sugar factory and additional power by means of a steam turbine generation.

Mr Waldheim outlined the various options for gasification (e.g. the pressure at which the gasification takes place) and the gasification units that are currently operating or under consideration. He explained that his company was working closely with Brazil to integrate the gasification process into sugar mill operations. Initial tests with bagasse as a fuel are continuing. He outlined several options for installation at a 7000 tonne per day factory to produce between 29 and 59 MW of export to the grid. One such configuration suggested by Mr Waldheim that would result in 43 MW export is shown in Figure 3.
Interaction between the sugar mill and the power utility

Power utilities are charged with providing a reliable electricity supply to consumers. Until recently those utilities have had all components of the electricity generation and supply chain under their control. The introduction of independent power producers such as sugar mills therefore provides the power utility with concern for reliability of supply at the same time as it provides the sugar mill with a challenge to meet the required reliability standards.

One way these challenges are being met is for the cogeneration facility to be operated or directly controlled by the power utility. This is the situation in Mauritius and on Reunion Island and is likely to be the approach used in Australia. This does not absolve the sugar mill from reliability requirements, because the cogeneration boiler will still require reliability of supply of make-up boiler feed water and bagasse (to the same extent as the mill will want reliability of electricity and process steam from the cogeneration facility).

Mr H. Fakim, Central Electricity Board, Mauritius outlined these aspects from the utility’s point of view while Mr Jonathon de Jager, Tongaat-Hulett, South Africa discussed aspects of the electrical interconnection from the sugar mill’s point of view. From the mill’s viewpoint, communication with the electricity utility was a problem. The utility’s electricity supply is never perfect and there is a need to protect the mill from the vagaries of the utility’s actions. The utility is generally so big that it could destroy the electrical system in a sugar factory if protection is inadequate. The sugar mill’s power to disturb the utility is by comparison very much less.

Mr Albert-Thenet discussed the interconnection from the point of view of the power purchase agreement (PPA) that a sugar mill must inevitably have with the utility. Under these circumstances, the factory shares the responsibility for a satisfactory power supply with the utility. The power purchase agreement sets out those shared responsibilities and the basis on which they operate. Like Mr de Jager, he concluded that communication was the basis for an effective working relationship. That cooperation should include sharing of technical resources and training.

Financial incentives for cogeneration by sugar mills

Two papers were delivered that outlined the processes that have encouraged sugar mills to cogenerate electricity. The first was presented by Dr Kassiap Deepshand, Mauritius Sugar Authority, who outlined the history of the development of cogeneration in Mauritius and the role the government played. The development was focussed on either producing agreed levels of export power during the crushing season alone or producing power all year round using coal as the fuel outside the harvest season.

Between 1985 and 1997, a series of Acts of parliament or other government initiatives were used to promote cogeneration in Mauritius. Those initiatives involved:

- rebates and taxation incentives, in some instances tied to the pressure of the boiler used in the cogeneration plant and other equipment installed;
- specific financial disincentives for the production of export electricity on a casual basis
- agreed pricing for export electricity and pre-determined basis for future price increases.

These incentives are linked to the associated process for reducing the number of mills in Mauritius as part of the process of ensuring their long-term viability. The long gestation period for cogeneration in Mauritius appears to be caused by the difficulty the government and mills had in developing effective incentives.

A second paper was presented on the situation in Guatemala by Mr Sergio Guzman, Pantaleon Mill. Their sugar and power industries were, until relatively recently, under direct government control. Again, government initiatives were required to enable cogeneration to proceed. During the 1990s, power generation was gradually allowed to operate in a free market and the market was allowed to find its own financial level with a minimum of government interference. Comments from the customers with regard to aspects like the reliability of supply became an important feedback mechanism. The result is that cogeneration by sugar factories has increased from 16 GWh in 1994 to more than 250 GWh in 1998 and 1999.

In both cases, government action was required to initiate the expansion of cogeneration by sugar mills, although the form of that government action was very different in the two countries. Discussion amongst delegates after these two presentations indicated that in every country where cogeneration was under serious consideration, government initiative of some sort has been or will be required.

Final technical session to review the workshop

At the final technical session, workshop delegates were asked to assess the value of the workshop and to indicate the conclusions they drew from its deliberations. Delegates agreed that the workshop had been beneficial. The discussion eventually revolved around two issues.

Gasification: The technology was new to some delegates but all understood the potential of the BIG-GT approach whilst realising that effective commercialisation was at least ten years away. They urged the completion of the Brazilian and Australian research projects and wondered whether some form of effective international collaboration should be arranged.

Minimum effective steam use in a cane sugar factory: Delegates had heard much discussion about the reduction in process steam use but were unable to come to any conclusion about the effective minimum steam consumption that would be acceptable in a cane sugar factory. The estimates of practical limits ranged from about 35% to 20%. Colour formation at higher temperatures in cane sugars was recognised as a
potential problem but the extent to which it is determined by the lower steam use limit was undetermined.

Factory visits

The workshop delegates made visits to four factories on Mauritius and some delegates visited the two mills on Reunion. These visits allowed delegates to see the practical implementation of the sugar mill cogeneration concept. Various aspects that were not brought out in the technical discussions became apparent.

- In general, the cogeneration facilities were entirely separate from the sugar factory with the interconnection of steam, water, bagasse and electrical power quite obvious. The staffing and management of the cogeneration plant was also generally quite separate from that of the mills.
- The provision of acceptable feed water by the mill for the cogeneration boiler was of critical concern to the boiler operators. Generally the make-up water came as condensate from the first evaporator vessel although, in some cases, the condensate from the second vessel was accepted. The greatest degree of quality assurance for this make-up water was exhibited at Le Gol factory on Reunion. Here the condensate from the factory did not directly enter the cogeneration water. Rather the condensate was evaporated in a Kestner evaporator using low-pressure (pass-out) steam from the turbo-alternator system and it was this evaporated condensate that was fed back to the sugar mill.
- None of the cogeneration facilities visited had any provision for long term bagasse storage to enable generation outside the harvest season. No reason was given for this but presumably long-term bagasse storage was found to be uneconomic.
- Other changes within the factory to accommodate cogeneration were noted. Mention has already been made of the installation of falling film evaporators to replace Roberts vessels and the use of hydraulic and electric drives on milling units to replace steam turbines or steam engines. Another system of interest was a very neat Barriquand juice heater at Union St Aubin mill in Mauritius in which three stages of juice heating took place within a single heater installation using three different vapours.

Acknowledgments

The workshop organisation by the Director and staff of the Mauritius Sugar Industry Research Institute was excellent and greatly appreciated by all delegates. Their efforts are gratefully acknowledged. The delegates also greatly appreciated the hospitality shown by the management and staff of Belle Vue, FUEL, St Aubin and Beau Champ factories on Mauritius and Le Gol and Bois Rouge factories on Reunion for welcoming delegates to visit the cogeneration plants at their factories. The author also appreciates the efforts made by all presenters at the workshop in the preparation of their talks.

COGÉNÉRATION EN SUCRERIE DE CANNE—DÉBATS DE L’ATELIER ISSCT

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Résumé

En Octobre 2000, 90 délégués de 16 pays, se sont rencontrés à Maurice pour un atelier ISSCT sur la cogénération. Le papier présente les débats de cet atelier, qui a compris 3 jours de présentations techniques et 2 jours de visites au sucreries Mauritiennes. Les délégués ont aussi visité deux sucreries Réunionaises qui produisent de l’électricité.

La biomasse, les chaudières, la gazéification de la bagasse, les procédés et les interactions entre la sucrerie et le réseau ont été discutés. On s’est aussi penché sur les avantages économiques nécessaires pour encourager la cogénération. Le plus grand potentiel reste la gazéification de la bagasse.

Du côté de la sucrerie une connaissance détaillée de la quantité minimale de vapeur nécessaire pour le process n’a pas été bien établie jusqu’à présent.

Mots clefs: Atelier ISSCT, cogénération, électricité.
COGENERACION DE ELECTRICIDAD EN FABRIZAS DE CANA DE AZUCAR—
EL RESULTADO DE UN ISSCT SESION

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Resumen
En la tarde parte de Octubre 2000, 90 delegados de 16 países tuvieron reunión en Mauritius para el
ISSCT Ingeniería de Fabrica y Energía sesión sobre cogeneración de electricidad por las fábricas de
cana de azúcar. Este artículo hace revisión y resumen de aquel sesión. La sesión fue constituido de
tres días de presentaciones técnicas y discusión más dos días de visitas a las instalaciones de
cogeneración en cuatro fábricas en Mauritius. Unos delegados también se aprovecharon de la
oportunidad de visitar los instalaciones de cogeneración en las dos fábricas en Reunión. Las
presentaciones técnicas examinaron colección de biomasa, cambios de proceso en la fábrica,
optimización de calefacción, gasificación de bagazo, el interacción entre la fábrica de caña y la empresa
de producción de energía eléctrica y los incentivos que se necesitan para permitir fábricas de caña a
convertir económicamente a generar energía eléctrica para exportación. En la última presentación
técnica los delegados pensaron que el efectivo desarrollo de la tecnología de gasificación tenía el
mejor potencial de largo plazo beneficio mientras el más grande desconocido era el límite bajo
práctico de el uso del vapor de proceso en una fábrica de caña (en contrario a una fábrica de azúcar
de remolacha).

Palabras claves: ISSCT sesión, cogeneración, electricidad, eficiencia de energía.