Factory Commission workshops, August 2014

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Abstract The Factory Commission conducted co-located workshops for the Engineering and Processing sections at the Protea Hotel Hluhluwe, South Africa on 24-28 August 2014. There were 83 delegates from 16 countries registered for the workshops. The Process Section theme of Meeting performance and efficiency targets for the evaporator and pan stations included formal workshop sessions over the first two days. The first day discussed energy issues, vacuum pan design and boiling, and the development of colour and its elimination. The second day was a combined Engineering and Process sections session which focused only on evaporation issues including designs, heat transfer performance, circulation paths, computer modelling and scale removal. Included in the program for day 2 was an interactive session to compare the design and performance of the different types of evaporators that are currently being used in sugar factories. The Engineering workshop theme of Maintenance Best Practices, dealt with the topics material selection, design for low maintenance/preventive maintenance and maintenance management. Thirteen presentations were made with a lot of interactive discussion about the relevant topics during the first day of the workshop. It was concluded that there is a wide scope for optimization of maintenance practises and the delegates were very interested to follow up the raised aspects in more detail in future workshops and at the next Congress. It was not easy to motivate enough presenters and to find some delegates from the beet industry presenting maintenance experiences and practises proofed as a basis for very lively discussions. Several delegates took the opportunity of the co-location arrangement to participate in selected topics from both the Engineering and Processing sections programmes on day one. Site visits to Umfolozi sugar mill and to the nearby Hluhluwe Game Park followed on the third day. On the fourth day some delegates took the opportunity to visit the Bell Equipment manufacturing facility on the way back to Durban.

Key words Efficiency, evaporator design, vacuum pan design, heat transfer, maintenance, preventive maintenance

INTRODUCTION

The ISSCT factory Commission workshops for the Engineering and Processing sections were held in South Africa on 24-28 August 2014. It was very well attended by 83 delegates from 16 countries. The Process Section theme of Meeting performance and efficiency targets for the evaporator and pan stations included formal workshop sessions over the first two days. The first day discussed energy issues, vacuum pan design and boiling, and the development of colour and its elimination.

The Engineering workshop theme of Maintenance Best Practices dealt with the topics of material selection, design for low maintenance/preventive maintenance and maintenance management. Thirteen presentations were made with a lot of interactive discussion about the relevant topics during the first day of the workshop. It was concluded that there was a wide scope for optimization of maintenance practises and the delegates were very interested to follow up the raised aspects in more detail in future workshops and at the next Congress. The Engineering Section had some difficulty in motivating enough presenters to fill the one-day programme.

The second day was a combined Engineering and Process sections session that focused only on evaporation issues including designs, heat transfer performance, circulation paths, computer modelling and scale removal. Included in the program for day 2 was an interactive session to compare the design and performance of the different types of evaporators that are currently being used in sugar factories.
PROCESSING WORKSHOP

Day 1, Session 1, Energy

After a brief introduction to the sugar industry on Réunion Island and the role that the eRcane research centre plays, Arnaud Petit discussed the program initiated in 2006 by the two factories (Bois-Rouge and Le Gol) to reduce steam consumption in order to export more power to the grid. Indeed, with high pressure condensing and extraction steam turbine systems, the export capacity became highly dependent on the energy balance of the sugar factory. To lower exhaust steam consumption, the sugar factories needed to update their process with a six-effect evaporation station, new steam bleeding arrangements and highly efficient heaters to use lower pressure steam or vapour. The two sugar factories installed falling-film evaporators working at a low temperature differences and with a small impact on exhaust steam temperature. The presentation and subsequent discussion looked at a number of issues that needed to be addressed to optimize the energy balance of the factories to maximise the benefits.

Dr Andreas Lehnberger provided updated experiences following modifications to the evaporator section at the ICPL factory in India. The #4 FFE of 1000 m² was replaced with a FFE of 4000 m². The modifications provided spare bodies of 4000 m² and 1000 m² to use when other bodies were taken off-line for cleaning. Additional measures for the pan station included agitators for the A pans, a syrup concentrator using #4 vapour and venting of non-condensable gases from the calandrias to the condensers. All these measures allowed the plant to operate at an impressive 28 % steam on cane (excluding stoppages) while producing plantation white sugar. A number of key points arose including the need for the vacuum pans to operate at low heating temperatures and the evaporators must provide sufficient heating surface area to sustain the required vapour flows for bleeding to other consumers such as the pan station.

Sanjay Awasthi discussed the selection and installation of process house equipment for maximum energy saving for an integrated sugar and co-generation plant using the KPR sugar mill in Karnataka State as an example. The installed designs included FFE and Robert evaporators, extensive vapour bleeding to heaters, CVPs and batch pans. Various electrical energy saving systems in the process house provided an additional power saving of 3 kW/t of cane and included:

- Use of energy efficient motors (EEC II);
- AC VFD drives for high grade centrifugal machines;
- Decanter system for two stage mud filtration;
- Planetary gear boxes for magma mixers, pug-mills, crystallizers, all stirrer drives;
- VFD on injection pump, juice and massecuite duty, air blower at sulphur burner; and
- Closed loop gravity system for cooling and condensing system to avoid double pumping of injection water.

The Mauritius Sugarcane Research Institute (MSIRI) has, through a project funded by the European Union under the ACP Sugar Research Programme, carried out an audit in 11 ACP countries since 2011 to investigate the use of energy in sugar cane processing. Altogether 26 sugar factories were visited to raise awareness on the benefits of efficient use of energy and for capacity building. Participants from 10 ACP countries then followed a 3-week training session in Mauritius, where they had the opportunity to visit sugar factories and power plants, exporting a surplus of up to 130 kWh/t of cane to the grid.

To further reinforce capacity building, software was being developed to assist the ACP sugar factories. It was meant primarily for training purposes, but could also be used for energy optimization by sugar technologists and engineers. Factory layout can be redesigned to optimize energy use, ensuring self-sufficiency or maximize surplus electricity production for those exporting to the grid. The software ‘Acp-Energy’ calculates specific steam consumption (kg/t cane) using the Rillieux principle as well as by enthalpy balance across 4, 5 or 6 effect evaporator stations with or without flashing. Bleedings for heaters and vacuum pans are calculated by mass and energy balances. The layout of the selected equipment including evaporators, flash tanks, heaters and pans can be graphically displayed to facilitate use.

Day 1, Session 2, Pan boiling

Unstable low grade massecuite boiling is associated with a hydrodynamic instability and unsteady boiling according to Peter Rein. The process appears to be similar to geysering, associated with low heat transfer rates. Measurements of this phenomenon were presented and suggested that a closer study of this phenomenon could identify conditions under which non-steady boiling occurs and assist in optimizing designs.
Bruce Moor discussed a recent energy balance for a typical three-boiling cane sugar factory which showed that, of the factory’s total energy requirement for producing sugar from the input cane, some 30% was needed for boiling and crystallising in the pans. This high percentage is because the pans boil in single effect, with large losses to their condensers.

Energy efficiency criteria needed to be considered in the design of both batch pans and CVPs. Such criteria included:

- Maximising the proportion of crystallisation done in continuous (as opposed to batch) pans;
- Designing pans capable of operating at low ΔT values in order to use the lowest possible grade of vapour;
- Designing pans for strong natural circulation, aided where necessary by incondensable gas jiggers to avoid energy-intensive mechanical stirrers;
- Maximising A and B pan exhaustions to minimise the overall amount of pan boiling;
- Producing uniform-sized crystals to minimise re-boiling of sucrose lost in centrifugation and in refinery affination; and
- Maximising the intervals between CVP boil-outs.

Sanaullah Arain described the enhancement from 9,000 to 11,000 tcd and simultaneous reduction in steam demand at Mehran Sugar Mills Limited, Pakistan which also included the automation of refinery pans. The 4 refinery pans each had 60 t strike capacity and 242 m² heating. The floating calandrias with central and lateral down takes were a disadvantage. The typical refinery pan design includes a fixed calandria with central down take with a mechanical stirrer fitted inside the down take. For automation, getting a representative and accurate measurement of brix of the massecuite is one of the prime parameters. This was difficult to achieve with the floating calandria design with no mechanical agitation.

It was considered that fitting mechanical agitators to the floating calandrias was not possible and substantial cost would be involved to replace the floating calandrias with fixed calandrias having central down takes and mechanical circulators. It was decided to automate the existing pans by:

- Relocation of the brix probes;
- Introduction of jigger steam;
- Even distribution of molasses feed; and
- Maintaining a higher vapour pressure.

The results were very encouraging and the desired and anticipated results were achieved.

Michael Getaz challenged the perception that vigorous boiling demonstrated that a continuous vacuum pan was well designed and operating efficiently. He contended that the true efficiency of a CVP design is demonstrated by it being able to operate well at low evaporation rates when the boiling action is perceived as just simmering. Continuous vacuum pans operate at a great variety of conditions and a study of their specific evaporation rates related to the temperature difference between steam and vapour gives some interesting results which he presented and discussed.

Day 1 Session 3, Pans, colour development and elimination

In Australian factories it is common for one operator to manage the pan stage and for one operator to manage the high grade and low grade fugal stations. Operators are required to take on greater responsibility in making decisions on the respective stages.

Broadfoot and researchers from the Central Queensland University developed a supervisory/advisory system to manipulate available data from other stations such as cane receiveal and the laboratory, as well as the control signals from the DCS system on the pan and fugal stations to assist the operators in decision making. The objectives for the stations of throughput rate, sugar quality, sugar recovery and steam consumption are considered in determining the appropriate advice for the operators.

Mesmacque provided a history of the development of the FCB CVPs from the initial installations in the late 1960s, through recent changes to the current designs. Changes through the last decades included several modifications that improved the overall efficiency of the vacuum pan. These modifications were mostly based on experiences, trials and modelling and concerned both the design and the control of the CVP. They led to a higher quality of the final product, an increased capacity as well as better energy efficiency.

Crystallization is the most efficient process for elimination of colour. Observations by Rein indicate that the ratio of colour in the massecuite to that in the sugar increases as the colour of the massecuite increases, but it varies widely, depending
on a number of other factors. Those factors include the spectrum of non-sugar species in the massecuite, the crystallization conditions and the size of the crystals and colour formation during boiling. Data available shows wide variations in the colour ratio, e.g. 15 for raw sugar through to about 110 for plantation white sugar in India and beet sugar production. He discussed some of the factors that contribute to the wide variation in the colour ratio.

Tarique and Khan of Mirpur Khas Sugar Mills, Pakistan provided a brief synopsis of sugar colorants and their origins. They then outlined steps they have taken to monitor and minimise colour formation in their factory.

Investigations being undertaken in Argentina by Saska and others highlighted the benefits in reduced colour being achieved by limiting the amount of process stream recycle, particularly filtrate and A and B molasses. Data were presented which showed just how much colour was being generated by long residence times in the juice clarifiers. Interestingly, the data also showed that the colour of the juice in the clarifier underflow was much lower than the colour of the clarified juice.

Narendra Mullapudi of The Andhra Sugars, India described how they replaced their conventional sulphitation system with a more energy efficient system that requires less than half the floor area. The new system was based on using induced air flow through a rotary sulphur burner and an eductor to introduce the sulphur dioxide into the juice.

Day 2 Evaporation

The first session was devoted to a comparison between Robert, Kestner and falling film evaporators. Broadfoot gave a detailed analysis of the design and performance of the current design of radial flow Robert evaporators with significantly higher HTC than previously reported. Schorn provided details of a typical evaporator station in South African factories with Kestners in #1 and #2 positions and Robert design vessels in the following stages. Unfortunately, his performance comparison between Kestners and Roberts designs included out of date data for Roberts designs. Morgenroth discussed performance comparisons between rising film plate and tube evaporators against falling film tube and plate designs. He emphasised the benefits of FFEs for lower steam on cane and operation at lower ΔT. However he stressed the importance of the three factors that have contributed to poor performance in some installations including operator training, control systems and a good CIP setup.

Wright supplied information on refinements to the radial flow evaporator that included a mix of downcomers and underflow offtakes, removal of steam lanes and a modified removal system for non-condensables. HTC of almost 1.4 times that of a typical Robert design operating in an Australian factory have been recorded supporting the previous performance data provided by Broadfoot.

Further investigations are continuing at QUT to determine optimum tube dimensions for the Robert design. Variations in both the tube diameter and length exist in Robert installations in different countries and the investigations will look at the full range of options for Robert designs in each position in the set.

Circulation within a pan or evaporator affects the rate of heat transfer within the vessel as well as the capacity of the vessel or even the factory as a whole. Whilst the circulation ratio determines the downtake diameter, there are additional factors within our control that can be modified to optimise circulation. Research by Shah and others has shown that circulation is largely dependent on the down-take design, feed design and positioning of jigger steam inlets. The design of each of these systems is often carried out ad hoc or in isolation; however, in order to achieve optimum performance, all systems must work together. Evaporator design research has shown that a minimum recirculation rate of 1.2 kg/min/tube is recommended for all evaporators and can be achieved in Kestner-type evaporators with the installation of an external recycle line. For the Robert-type vessel, a semi-sealed downtake allows for optimum performance and an optimum wetting rate can be determined more accurately according to the correlations developed by Shah and Peacock. Circulation in a batch pan is aided by the correct feed location, effective feed distribution as well as the positioning and sizing of the jigger steam pipes.

Retrofitting plate packs into a Robert vessel to increase evaporation capacity has been suggested for many years. Belzen described a stepwise process that has been followed to retrofit plate evaporator packs into Robert bodies in the beet sugar industry.

After a rationalisation at Maidstone Mill because of a reduction in cane supply it was found that the evaporator station could not achieve the design performance criteria, i.e. syrup brix and steam consumption. A technical audit of the station highlighted design problems with the feed distribution, the incondensable gas removal and the entrainment arrestors. The operating philosophy, in place to compensate for the design problems, was also not ideal. Sharma highlighted some of the
remedial steps that were taken to improve the performance of the station and discussed the modifications made to the equipment design and operating philosophy.

Rodriguez discussed two approaches that have been implemented in Colombian sugar factories to increase or manage the performance of evaporation stations. The first one was applied in a sugar mill with physical space limitations, which intended to increase its processing capacity by 50%. An experimental evaporator vessel was designed, instrumented and tested in parallel with the third and fourth effects. It was found that increasing the length of the tubes by 100% for the third effect and by 67% for the fourth effect maintained controllability and improved heat transfer coefficient. From these results, the effects were modified and performance results showed good agreement with those found with the pilot evaporator.

The second approach was an Evaporation Energetic Performance Index that allowed assessing the energy performance of evaporation station configurations to determine equipment cleaning schedules and operation efficiency. Calculations from historical data from a Colombian sugar mill showed good agreement with the operational conditions of the evaporation station and allowed its real time implementation, from which the cleaning schedule for the vessels was validated.

Process modelling programs are commercially available, however due to the upfront cost they are not widely used with many engineers using computer spread sheets to provide solutions. Watson presented an example of evaporator station modelling using free open source software. The advantage is that open source software can be freely used, changed, and shared by anyone. For process systems engineering a software standard known as CAPE-OPEN is widely used to provide interoperability between different pieces of open source software.

The workshop presentation used COCO, which is a CAPE-OPEN compatible simulation environment, to provide a steady state model of a multiple effect evaporation system. The three parts of COCO used are flow-sheeting, thermodynamics and unit operations. Through a combination of simple unit operations a sophisticated steady state model is developed for a quintuple effect with pre-evaporator where the vapour is used for juice heating and vacuum pans. The model can be used to explore the steam requirements for different vapour heating options.

The cane sugar industry is experiencing lot of changes over the last years. Worldwide demand for sugar is increasing and thus sugar mills might have a brilliant future if they manage to prepare themselves. Implementing state of the art technologies, increasing productivity at lower production costs are key success factors. This goes along with concentration on sugar mills with higher production capacities.

Hessler spoke about an optimized energy balance to reach production and energy targets and how plate heat exchangers could be used successfully to achieve those targets. Plate heat exchanger technology has been used successfully for process stream heating and evaporation, either through the retrofit of plate packs in both rising film and falling film configurations and as a booster to existing Robert vessels. Plate heat exchangers were the superior heat exchanger type for most heat transfer tasks within a sugar mill by providing higher turbulences, better heat transfer efficiency enabling closer temperature approaches and thus higher heat recovery.

The final presentation at the workshop was given by Grossmann who gave an interesting talk about the chemical composition of the different scales found in evaporators and the options for chemical removal. Because chemical cleaning of evaporators is more effective and less dangerous for workers than mechanical cleaning, for each type of scale a method for the removal, proven by laboratory studies and experience gained in the factories was presented.

ENGINEERING WORKSHOP

Session 1, Material selection

In the first session, Kent set out to generically define wear and corrosion and the types of wear and corrosion that may be experienced in a sugar factory. As an example, he used an intermediate carrier chain pin. It was suggested that the wear experienced by the pin could be classified as:

- Severe sliding wear with some grinding abrasion;
- Mild sliding wear away from working faces; and
- Pitting or crevice corrosion if juice ingress occurred.

Skinner compared the corrosion effects of rust, stress corrosion cracking, galvanic corrosion, hydrogen sulphide and oxidizing agents. He then discussed the use of volatile phase corrosion inhibitors, their different forms and how the different forms can be used to protect a full range of plant items from printed circuit boards through to boilers and pressure vessels.
Geyer compared the criteria applied to material selection decades ago with the additional criteria being applied today to address issues such as food safety, duty specific materials, operational reliability, maintenance requirements and the increasing demand of government regulations. Geyer then used vacuum pans, centrifugals and drum dryers to highlight the changes that have evolved over recent times in the materials selected.

Inappropriate material selection was highlighted by Broadfoot when relating the experiences at one factory in Australia where significant corrosion has been experienced in condensate systems.

Plant design is very important when considering maintenance best practice. Morgenroth spoke about a number of issues that must be considered when designing a new plant to reduce the costs associated with maintenance activities. These included:

- Realistic consideration of the life time cost of plant maintenance;
- Use of galvanized or stainless steels rather than painted carbon steels;
- The use of sensors for condition monitoring;
- Installing single large units rather than multiple small units;
- Standardised equipment;
- Piping design;
- Easy access to high maintenance plant; and
- The use location of compensators.

The benefit of CFD modelling of boilers was highlighted by van der Merwe. He indicated that, if applied correctly, the wear on critical components can be reduced significantly. However, he stressed that validation of the model predictions was of key importance.

Geyer presented information about what BMA has done to improve the productivity of their centrifugals as well as increasing the service life, reducing wear and tear of components and improving accessibility to components for maintenance.

Cenicaña (Colombian Sugar Cane Research Center) has recently begun a new project about maintenance management according to Cobo. The main objective is to propose the characteristics of a World Class Maintenance Management System that impacts favorably on the principal industry KPIs. Maintenance of plant in Colombian factories is a critical issue because the average grinding season extends for about 300 days and many factories aim for operational 330 days. This leaves little opportunity for maintenance of major plant items. The focus has been on the following key components:

Overall equipment efficiency (OEE) which measures the availability, performance and output quality of a machine, system or production line was developed out of the need for improvement groups to have a way of measuring and analyzing equipment problems as part of their Define, Measure, Analyze, Improve and Control cycle:

- Root cause analysis (RCA);
- Reliability Centered Maintenance (RCM) which is a structured, deductive and participative method which defines an appropriate maintenance strategy for each item of plant; and
- FMECA (Failure Mode, Effect and Criticality Analysis).

For examples Cobo described the review of some common failures including a tail drum shaft on an intermediate conveyor, the breakage of a gearbox shaft on a refinery batch pan circulator, roll shaft failures and cane transport equipment breakages and accidents.

Roukema presented details of a TPM system that has been adopted in their beet factories. It integrates eight pillars and involves all levels and all departments to achieve high productivity at reduced costs and includes all aspects of the value chain and the business processes around it. The eight pillars are:

- Focused improvement;
- Autonomous maintenance;
- Effective maintenance;
- Training and education;
- Early management;
- Quality management;
- TPM in administration; and
- Safety, health and environment.
Downtime is a significant cost to a factory. It extends the season length and requires additional installed capacity to maintain budgeted cane rates or a shorter season length. Kent described how downtime is defined and costed differently in various countries. Improved plant availability requires effective asset management strategies but can be constrained by available resources. He described algorithms that have been developed by QUT for reliability modelling, condition monitoring, operations and maintenance decision making and advanced data analysis.

Bester spoke about the development of an asset care strategy for Tongaat Hulett. A well-developed asset care strategy forms the foundation layer of an overall integrated plant reliability strategy and includes elements of Reliability Centred Maintenance (RCM), condition-based monitoring of assets and continuous improvement. The age of a large number of critical assets combined the continuous pursuit of minimizing maintenance related resources has necessitated a re-evaluation of the existing asset care strategy at Tongaat Hulett. The objective of the evaluation was to assess how successful the existing asset care strategy was in achieving optimum plant availability and safety at minimum cost. The evaluation led to the development of a modernized asset care strategy that relies to a large extent on condition-based monitoring of equipment.

Cobo provided a second presentation on the maintenance management project being undertaken by Cenicânia. Initially, an analysis of global maintenance management indicators for the Colombian sugar mills was conducted. A correlation of 70% between the OEE indicator and conventional lost time indicators was found, i.e. mills with less lost time have a higher OEE. Diagnostic activities have been developed and principal maintenance structures at Colombian sugar mills were identified. A solid strategy focused on equipment and process reliability has to be adopted by the mill to achieve world class maintenance indicators. In more technical areas, activities are oriented towards identifying research requirements related to critical maintenance areas and processes and to plan strategies that help to achieve objectives.

In the final presentation, Morgenroth conducted an interactive session in which he related IPRO’s experiences on plant reliability and maintenance.

MISCELLANEOUS

Delegates also enjoyed site visits to Umfolozi Sugar Mill and to the Bell Equipment manufacturing facility for heavy material handling machines. The social program included a braai in a traditional Boma area and a drive through the Hluhluwe Game Reserve.

The idea of joint workshops for Process and Engineering has proven to be beneficial to all delegates. There was general agreement that holding the two workshops at the same time and at the same venue allowed costs to be kept to a minimum for both the organising committee and for delegates.

Many delegates also attended the SASTA Congress which was held in the week preceding the workshops.

Atelier de Conseil: Fabrication, Août 2014


Mots-clés: Efficacité, design de l’évaporateur, conception de cuites, transfert de chaleur, entretien, maintenance préventive
Workshop de la Comision de Fabrica, Agosto 2014

Resumen. La Comision de Fabrica realizo un workshop conjunto para las Secciones de Ingenieria y de Proceso, en el Protea Hotel Hluhluwe, en Africa del Sur del 24 al 28 de Agosto de 2014. Se registraron y estuvieron presente 83 delegados de 16 paises. El tema de la seccion de Proceso “alcanzando metas de desempeño y eficiencia en las estaciones de evaporadores y tachos” incluyo sesiones formales del taller de trabajo en los primeros dos dias. En el primer dia se discutieron temas de energia, diseño de tachos al vacio y cocimiento, y el desarrollo del color y su eliminacion. El segundo dia fueron sesiones combinadas de las sesiones de Ingenieria y de Proceso que solo se enfocaron a temas de evaporacion incluyendo diseños, desempeño de la transferencia de calor, caminos de circulacion, modeling de computadora y eliminacion de incrustaciones. En el programa del dia 2 se incluyo una sesion interactiva para comparar el diseño y el desempeño de los diferentes tipos de evaporadores que existen actualmente en uso en los ingenios azucareros. El tema del workshop de Ingenieria “mejores practicas de mantenimiento” trabajo con material de topicos seleccionados, diseño para bajo mantenimiento/mantenimiento preventivo y administracion del mantenimiento. Trece presentaciones fueron realizadas con muchas discusiones interactivas en relacion a los topicos relevantes durante el primer dia del workshop. Se llego a la conclusion que hay un amplio espectro para la optimizacion de las practicas de mantenimiento y los delegados estuvieron muy interesados en darle seguimiento con mayor detalle a los aspectos resaltados en los futuros workshops y en el proximo Congreso. No fue facil motivar a suficientes participantes y encontrar algunos delegados de los mejores ingenios para que presentaran sus experiencia de mantenimiento y sus practicas ya probadas como base para un discusion animada. Varios delegados tomaron la oportunidad del workshop conjunto para participar en topicos seleccionados de ambas secciones, ingenieria y proceso, en el programa del dia uno. Las visitas al ingenio Umfolozi y a la cercana reserva de animales Hluhluwe se realizaron el tercer dia. El cuarto dia algunos delegados aprovecharon para visitar la compayia Bell Equipment en el camino de regreso a Durban.

Palabras clave: Eficiencia, diseño de evaporador, diseño de tacho al vacio, transferencia de calor, mantenimiento, mantenimiento preventivo