

**REPORT: ISSCT COPRODUCTS WORKSHOP 2009**

By

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and BRYAN P. LAVARACK<sup>3</sup>*ISSCT Coproducts*<sup>1</sup> *Section Chairman,* <sup>2,3</sup> *Section Members*[avram@ipro-bs.de](mailto:avram@ipro-bs.de)[mike.i@sucrose.com](mailto:mike.i@sucrose.com)[B.Lavarack@mkysugar.com.au](mailto:B.Lavarack@mkysugar.com.au)**KEYWORDS: Cogeneration, Boilers, Bagasse and Trash Handling, Cellulosic Ethanol, Vinasse, Biocomposting, Biofermentation, Molasses.****Abstract**

THE ISSCT Coproducts Workshop 2009 was held in Coimbatore, India from 15-19 March 2009 and attracted 41 participants from 8 countries. There were two main themes: Monday was termed the 'Energy day' and dealt with liquid and solid energy production from coproducts, as well as cogeneration of electrical power from bagasse and cane trash. Very good audience participation and lively debate was prevalent. On Tuesday, 2 sugar mills were visited (Sakhti Sugars and Bannari Aman), which had high pressure boilers. Sakhti Sugars also has equipment for vinasse concentration and incineration, while Bannari Aman has a plant for biocomposting of vinasse mixed with filter cake. Wednesday was the 'Derivatives day' where issues such as Biofermentation of sugar into high-value chemicals, pulp and paper production from bagasse and addition of molasses to animal feed were debated in a smaller circle. On Thursday we visited an impressive printing and industrial paper production plant (SPB) and an adjacent sugar factory (Ponni Sugars) that provides bagasse for the paper plant as well as a very efficient common treatment of waste water. The Workshop was hosted and graciously sponsored by Ponni Sugars (Erode) Ltd. as well as by SPB – Seshasyee Paper and Boards Ltd. Erode. All papers were well presented and generated discussion and interaction among the participants. The main conclusions of the Workshop were: In view of the necessity to reduce greenhouse gas emissions, the importance of cogeneration from bagasse and other biomass as well as the production of bioethanol from molasses and cane juice will continue to increase; High pressure boilers and efficient power generation cycles (110 bar, 540°C) are well established and investment costs are coming down; Practical alternatives to deal with the large volumes of vinasse arising during the production of bioethanol are available, but optimisation of the technologies and investment volumes is still required; To adequately cover promising subjects, the division into 2 sections (Energy and Derivatives) should be kept for future workshops. The actual emphasis on either one of these could vary according to the amount of contributions received. To encourage better participation for participants with limited time, there should be 2 days of consecutive presentation sessions followed by 2 days of plant visits for the next workshop. Many papers were considered suitable for submitting to the ISSCT Congress in Mexico in March 2010.

## Introduction

The ISSCT Coproducts Workshop 2009 was held at the Residency Hotel, Coimbatore, Tamil Nadu (South India) from 16–19 March 2009 and was hosted by Ponni Sugars (Erode) Ltd. and SPB- Seshasayee Paper and Boards Ltd, who were in charge of the local organisation of the venue and site visits. The Sugar Technologists' Association of India (STAI) helped generate interest amongst its members in attending the workshop.

The overall theme of the workshop was 'After the Oil has gone: Utilisation of Sugar Cane Coproducts'. Two main theme blocks were chosen: Energy and Derivatives. The first two days of the workshop were dedicated to Energy related themes and plant visits, whereas the third and fourth days were dedicated to Derivatives and related plant visits.

The workshop was attended by 41 participants from 8 countries (30 from India and 11 from Australia, Germany, Mauritius, Reunion, Sweden, Thailand, Uganda and the United Kingdom). Some Coproducts Section Members and sugar technologists from Brazil and other Latin American countries, who had initially expressed interest, were prevented from participating due to the economic crisis.

Financial support as well as great personal input was provided by the top management of Ponni Sugars Ltd and SPB, without which this workshop would not have been possible. Hospitality at the three sugar mills visited (Sakhti Sugars, Bannari Aman and Ponni Sugars) and especially at the paper plant (SPB) was very warm and generous.

## Technical sessions

### Session A – Overview speeches

*After the oil has gone: potential for coproducts of the cane sugar industry (P. Avram, IPRO Industrieprojekt GmbH, Braunschweig, Germany)*

There is a wide range of coproducts available from sugarcane, respectively 'downstream' products derived from bagasse and molasses. Most of these, however, have not reached particular economic significance or are 'niche products' that have only a limited market. The two currently most economically significant coproducts are bagasse as a fuel and molasses for ethanol production.

Worldwide cogeneration potentials for bagasse-based cogeneration are about 100 kWh per tonne of cane export power from sugar mills. This figure is already being attained in the more efficient sugar factories in Brazil, Guatemala, Reunion, Mauritius, India, etc, where the price being paid for electrical power from sugar mills is economically attractive. If the major cane producing countries could fully realise this potential, the sugar mills could cover an average of 7.5% of their total national electricity demand.

The results of an earlier case study for a 20 000 t/d fully electrified sugar mill employing 65 bar steam boilers, condensing-extraction turbines and additionally dried bagasse show that 112 kWh/t can be sold to the grid. With higher pressure boilers (110 bar, 540°C) available today, this figure can be raised additionally by about 13% due to the higher thermodynamic cycle efficiency.

In recent years, fuel ethanol produced mostly from either sugarcane or corn (maize) has reached levels of over 40 ML annually and continues to rise. The worldwide cost situation of various biofuels shows that cane-based bioethanol in Brazil has an average production cost of €0.24 per litre, ethanol from corn in the US €0.42 per litre and gasoline costs wholesale an average of €0.54 per litre. The cost advantage of cane-based ethanol lies in its higher yield per ha (6000 L/ha vs. 3000 L/ha from corn) and easier conversion via direct fermentation of molasses from cane juice. Also the fossil energy balance of ethanol from sugarcane is approx 8:1, compared to only 1.5:1 for corn and 0.80:1 for gasoline from crude oil.

In the future, ethanol from cellulose crops appears to have great potential regarding an even better fossil energy balance than ethanol from sugarcane. Also synthetic gasoline from gasification of agricultural wastes / biomass has shown good potential but, in both cases, production costs are still far from being competitive. The greenhouse gas emissions of these alternatives appear to be somewhat better when considering all sources of greenhouse gases emitted during cultivation, transport and production / conversion.

An overview was also given of a very energy efficient beet-juice and syrup-based ethanol plant designed by IPRO that went on stream in 2008 in Germany. By employing a double-effect distillation scheme, the process steam demand has been reduced to 1.7 kg/L anhydrous ethanol. Further, the residual vinasse is concentrated in a six-effect evaporation plant to 60° Brix and sold as a fodder additive. The applied technologies can be easily transferred to cane-juice or molasses-based distilleries.

***Overview of the Indian Coproducts situation (R. Chandramouli, Ponni Sugars Ltd., Erode, India)***

The sugar industry is the second largest agro-based industry (after Textiles) in India. There are about 500 sugar mills operating, out of which 41% are in private hands and 59% are cooperatives or belong to the public sector. Each mill employs directly 300–500 persons and indirectly another 200–300 persons. Total annual cane production in the last 3 years has exceeded 300 Mt. About 70% of this amount is processed in the sugar factories, while the balance is employed for jaggery and khandsari (artisan sugar) and for seed planting.

Total sugar production has reached 28.2 Mt in 2006–07 and 25.5 Mt in 2007–08. Per capita consumption of sugar in India is 19–20 kg/annum with a current population of 1130 million. The area under sugarcane varies between 3.5 and 4.5 Mha, depending strongly on the price paid to farmers and competition from other cash crops as well as on drought or pest attacks.

The most important coproduct is bagasse, with an annual production of 60 to 75 Mt. Its main use is for power and energy production in the sugar factories. Currently there is installed electrical generation capacity of 1280 MW, from which 847 MW are exported to the grid. Potentially up to 10 500 MW of power could be produced, out of which 6270 MW could be additionally exported once all mills have high pressure boilers and fully electrified factory drives. Sugarcane trash has also been recognised in India as a valuable source of additional fuel, because of its much higher calorific value than bagasse. Several schemes of trash utilisation in the boilers are being tested with good results.

A smaller user for excess bagasse is the pulp and paper industry. The overall demand for paper in India is currently 6.6 Mt per annum and rising rapidly. Currently about 32% of the raw material employed for pulp and paper making is agricultural wastes, out of which a good part is bagasse. It is estimated that potentially 6–10 Mt of bagasse could be used by the paper industry. The particle board industry is another smaller user for excess bagasse, accounting for about 375 000 t per annum.

Final molasses production has varied between 8.5 and 13 Mt during the past 3 years. Over 70% of this amount is diverted to alcohol distilleries. The balance is employed in oil mills, cattle feed, poultry units and chemical derivatives. The total installed distillation capacity in India is currently 2900 ML per annum, out of which 1300 ML are adjunct to sugar mills. Of the total annual demand of 2069 ML, about 29% is ethanol for fuel blending, 37% for potable uses and 34% for industrial uses. There is a severe shortage of ethanol for fuel blending.

Filter cake with an annual production of 6.5 Mt is next in order of importance. Over 60% is employed for biocomposting (increasingly together with vinasse from alcohol

distillation) and the balance is sold to farmers as manure. Lastly, M. Chandramouli referred to the lift irrigation scheme devised at Ponni Sugars for jointly treating the waste water emanating from the adjacent SPB paper mill and employing it for irrigating the cane fields. Also, the treated waste water from the sugarcane process is recirculated, thus reducing the fresh water consumption for the process to zero.

***Greenhouse gas abatement policy initiatives (Dr Bryan Lavarack, Mackay Sugar Ltd., Queensland, Australia)***

olicies developed at an international scale to mitigate the effects of climate change were briefly reviewed. The Kyoto Protocol sets binding targets for 37 industrialised countries and the European community for reducing greenhouse gas emissions. A total of 186 parties of the Convention on Climate Change have ratified the Protocol to date. The targets amount to an average of 5% against 1990 levels over the 5-year period 2008–2012. The majority of the industrialised countries, i.e. the European Union and the UK, have established targets for 2020 of 20–32% reduction below 1990 levels. The new US Administration is proposing to achieve a per capita reduction of 25% below 1990 levels by 2020.

The allowed emissions are divided into ‘assigned amount units’. As per the Kyoto Protocol, a trading mechanism allows countries that have emission units to spare—emissions permitted to them but not used—to sell this excess capacity to countries that are over their targets. Emitters of greenhouse gases (industrial production units) need to acquire a permit for all greenhouse gases they emit. The number of permits issued by the Government in each year will be limited. Firms will compete to purchase the number of permits they require. The ones that value them most highly will pay more for them, either at auction or at a secondary trading market. For a number of firms it will be cheaper to reduce emissions than to buy permits. Therefore, the marketplace will help to reduce CO<sub>2</sub>-emissions on a global scale.

Most sugarcane producing countries are not liable to achieve this target for the short term since these countries are regarded as developing. The Government of Australia accepted the requirements for the Kyoto Protocol in December 2007 and has committed the country to achieving these targets. Under current accounting rules, carbon dioxide emissions from the combustion of biofuels and biomass are zero-rated, because these emissions are equivalent to carbon sequestering through growth of these feedstocks. Therefore a major opportunity is developing for sugarcane coproducts as biofuels and biomass.

**Session B – Liquid energy**

***Late technology in vinasse evaporation (C Stoffers, Alfa Laval, Sweden)***

This presentation reported on the lessons learned from concentrating vinasse up to 60% solids with plate heat transfer equipment. The properties of the vinasse, in particular propensity to scaling, raw material quality and treatment and viscosity all influence the design. Rising film plate evaporators are suitable for concentrating up to 40% solids. Forced circulation through plate heat exchangers with flashing in a separate vessel is required to achieve higher concentrations. A three effect system with thermal vapour recompression is suggested to achieve solids levels up to 60%. Some of the vapour from the first effect is recycled through thermal vapour recompression (TVR). An installation capable of concentrating up to 52% solids for a distillery in Colombia was reported during the presentation. The presentation noted that support fuel is required for boilers that are fired with the concentrated vinasse.

***Evaporation system for molasses-based distillery effluent: a successful leap towards zero discharge (S. Chaudhari, Praj Industries, India)***

This presentation described several options for processing the effluent from distilleries with close examination of the option for evaporation and incineration. The main concerns for

evaporators concentrating spent wash (vinasse) are scaling, plugging, foaming and requirement for CIP (clean-in-place). The design for CIP should focus on the cost of chemicals, shut-down frequency for cleaning and methods for disposal of spent cleaning chemicals. The concentration of solids in the spent wash is directly proportional to the viscosity which in turn is proportional to (i) higher capital costs requirement for additional heat transfer area and (ii) increased operating costs from higher power consumption in pumps because of higher pressure drops. The higher the requirement for solids in the concentrated spent wash (exiting the evaporators), the higher are the capital and operating costs.

Conventional falling film, forced falling film, forced circulation and fluidised bed types of evaporators are suggested as solutions for the evaporation of spent wash. A system has been designed for Bannari Amman in India. The evaporator station is designed to produce 58–60% solids for a distillery rated at 60 kL/d. The incineration boiler can provide all the requirements of high pressure steam for power generation and of exhaust steam for process heating in the distillery and evaporators. Other evaporator installations were briefly reported.

***Zero liquid discharge through spent wash incineration (R. Rajesh, Thermax Boilers, India)***

The policy of zero liquid discharge being implemented in India at present requires that ethanol plants adopt new technologies for effluent discharge. The production of biocompost from filter mud and spent wash is not viable for new stand-alone distilleries and another solution is required. This presentation described the requirements for a boiler incinerating concentrated vinasse (spent wash) for Bannari Amman in India. Brief details of three similar boilers presently under construction are also given.

For the boiler at Bannari Amman, the firing rate of concentrated spent wash is 8.8 t/h and steam generation capacity is 23.4 t/h of which about 16.6 t/h is required for process heating. About 1.6 MW of power is generated. The incineration boiler can provide the entire needs for power and steam for the stand-alone distillery. The boiler is a fluidised bed design which requires concentrated vinasse at 55–60% solids and 10–15% support fuel. Coal is the support fuel in the application described. The boiler assembly is a gas tight design. Total combustion is ensured through adequate residence time in the combustion chamber.

The high alkali content in ash from incinerating concentrated spent wash fouls the heat transfer surfaces. This is minimised through multi-pass design and provision of mechanical rappers for soot removal. The presence of chlorides leads to high temperature corrosion of the superheater. The boiler is reported to have operated successfully for more than 45 days without cleaning.

***Vinasse as a fuel – practical results (Dr N. Schopf, Saacke, Germany)***

This presentation focussed on the application of burners to incinerate vinasse and similar materials. Two case studies are presented for factories incinerating vinasse-like material at Araucaria and Cambé, both in the Parana state of Brazil. Both boilers are 42 bar boilers with 40 t/h and 60 t/h steam capacities. The main design issues for the burners for these boilers are high ash content, low calorific value (resulting from high water content) and conditioning system required for atomisation of the fuel.

The design for the boiler requires a support fuel to bring the boiler up to temperature and to ensure the flame is stable in the burner. The requirements for the support fuel are low once the boiler is at temperature. Typical support fuels required are natural gas, heavy fuel oils and animal fats.

Detailed descriptions of the burners required for the boilers were given in the presentation. The typical characteristics of the feed materials and the combustion products were presented and comparisons between vinasse and the vinasse-like material were given.

***Technology to reduce, re-use and recycle spent wash from ethanol production  
(A. Vadanagekar, KBK Renuka, India)***

This presentation described proprietary designs for ethanol plants in India, Thailand and Africa.

reduction of low volumes of concentrated spent wash is achieved by recycling a certain proportion of spent wash to fermentation. A typical production value of 3 volumes of concentrated effluent per volume of ethanol (or 3:1) is claimed for the 160 kL/d ethanol plant at Athani, Karnataka State. The typical value for the industry in India is about 8:1. 12% alcohol concentration is being achieved in the fermenters. Excess spent wash is concentrated to 30% solids content and sent to biocomposting.

***Developments in cellulosic ethanol – Australian perspective (B P Lavarack)***

The main technologies to produce ethanol from bagasse and other cellulosic materials were reviewed in this presentation. The review only included information on major technological developments that have been published in the open literature. The two main pathways for the production of ethanol from bagasse were described; namely biochemical and thermochemical technologies. In the biochemical pathway, the DHR, Iogen, Lignol, Arkenol, Verenium and permutations of the technologies were discussed. The thermochemical pathway of gasification was reviewed and some recent developments in North America were described.

For cellulosic ethanol to be successful, it should be more competitive than existing ethanol production technologies based on starch (e.g. corn) or sugar (e.g. cane molasses) feedstocks. A target minimum selling price of US\$1.07/US gal (at 2002 pricing) has been set by the USA Government agency (NREL) for the development of cellulosic ethanol. At time of presentation, it was apparent that cellulosic ethanol is not competitive, but this situation is changing rapidly, as the cost for the necessary enzymes has come down significantly in recent years.

**Introduction to Sessions C and D**

The Monday afternoon session was dedicated to solid fuels, recognising the direct energy value of sugarcane fibre: primarily bagasse but also trash. Economics dictated that most of the topics were commercial scale but there was some domestic scale as well.

Fundamentally, cane fibre has a bone dry GCV of almost 20 000 kJ/kg [not far from coal at perhaps 26 000], but it is a carbohydrate so has a higher wet gas loss than coal, more akin to gas or oil. The problems are that it is never bone dry – more like 50% moisture – it has an erosive ash content and it has a low bulk density plus difficult mechanical handling properties. It turned out that there were three natural divisions to the proceedings: solid fuels, trash utilisation and export cogeneration.

**Solid fuels**

***Handling and storage of solid fuels) (Dr Bryan Lavarack, Mackay Sugar Ltd., Queensland, Australia)***

The large scale storage of bagasse is essential for the more industrial uses of bagasse and it is its physical characteristics which dictate how this can be done: low bulk density; mat forming; high moisture content; subject to decomposition [and hence possible spontaneous combustion]; potential for environmental issues [dust, water run-off, odour]

Storage options range from low technology [and high use of mobile equipment] open piling through open air linear piling with units similar to wood chip pilers to high technology storage sheds which can be either circular [Australia] or linear [Southern Africa]. Several countries have also tried baling in one form or another but without too much success.

The solution adopted depends primarily on local conditions for operations but it will become more important in the future as nations seek to reduce greenhouse gas emissions. Innovative answers will be required which are safe, economic and environmentally friendly.

***Bagasse briquettes and pellets (Dr M.B. Inkson, TSE, U.K.)***

The low bulk density of bagasse [125 to 150 kg/m<sup>3</sup>] is a serious drawback to its use, except when it comes to suspension firing. Techniques are required to increase the density for large-scale transport and/or storage or to create a solid fuel for domestic or small-scale industrial use.

The issue is economics: the cost of plant and energy to compress the bagasse and again to decompress it. Low pressure baling to something closer to 1000 kg/m<sup>3</sup> is, therefore, probably the answer, a technique which also reduces the oxygen content in the pile and reduces the fire risk of bagasse storage.

Pelletising [to make 8–15 mm extrusions] and briquetting [to make >50 mm extrusions] are techniques for making solid fuel. Typically they rely on the natural components of the biomass – waxes and the like – to bind the pellet or briquette. Unfortunately, bagasse is highly abrasive so the dies in the machines do not last long and are expensive to replace so that the economics at an industrial scale do not add up. There is also the issue of moisture: pre-drying is required and, if that was easy, it would be routine for all boiler fuel.

However, the desire for ‘green fuels’ is distorting economics and bagasse pellets are being made at industrial scale and shipped across oceans so maybe the future holds promise.

**Trash utilisation**

***Cane trash as boiler fuel (N.Prabhakar, Nava Bharat Sugar, India)***

Trash, up to 15–20% of the clean cane mass and with only about 30% moisture has about one quarter of the crop’s total energy content. There is the potential to produce an additional 730 kWh per tonne of trash – which would, if fully utilised, increase the industry’s power export by 87% in India and reduce the country’s annual energy deficit by 28%.

Another reason for investigating trash as a fuel is that, in India, at least, newer cane varieties have lower fibre contents. The average has decreased from 14 to 12.64% in this decade alone.

The higher cost of separate handling for trash and the impact of the high alkali metal content on the boiler led Nava Bharat to try whole-cane processing. The benefits were as expected with no serious impact on boiler operations, although bagasse moisture and ash contents were higher. There was a slight increase in cost of transportation and a reduction in sugar recovery due to pol loss through increased bagasse and juice purity.

***Cane field residues as boiler fuel (K N Nibe, Pandurang Sugar, India and D K Goel, STM, India)***

The very recent results of separate harvesting and burning trash at a mill in Maharashtra were reported.

Typically, 100 t of clean cane is harvested per hectare with green tops going for animal feed, leaving 8–10 t of trash. The trash is baled with commercially available units and delivered to the factory at a cost of US\$16 per tonne. The trash has a GCV of almost 16 000 kJ/kg, two thirds more than that of the factory’s bagasse so the price is equivalent to about US\$10/t.

The bales are shredded again in specially made, electrically driven units and fed to the boilers at a rate of about 5% of the bagasse feed rate. No adverse impact on the boiler operation has been observed in the first 60 days of the trial.

## Export cogeneration

### *Overview of modern bagasse power stations (Dr M.B. Inkson, TSE, U.K.)*

Export cogeneration involves a series of steps, each of which reduces the overall efficiency of the process. The boiler contributes the highest apparent loss but the hidden and sometimes highest loss lies in the overall time efficiency of the factory: those periods when not crushing and therefore not making boiler fuel but still consuming steam.

Over 90% of boiler losses are stack losses so boiler efficiency can be optimised by minimising excess air and the flue gas exit temperature. However, the first focus should be on minimising bagasse moisture in the factory [or by drying – a topic sadly missing from the workshop] as the greatest by far of the stack losses is the wet gas loss.

Although turbine efficiency is important to the work recovered [and hence the station's export capability], it contributes little to energy loss as the un-recovered energy appears in the exhaust steam. It is worth noting, however, that the efficiency can be optimised by selecting high speed machines and considering twin shaft units if a lot of condensing is involved. Condensing, however, should be considered with care: cogeneration is more efficient than condensing and it is only the 'free' fuel that permits competition with a utility.

The HP steam condition is the final point for efficiency discussion: thermodynamics dictate that higher conditions deliver a higher efficiency. However, when economics are considered the return on investment at higher conditions seems to fall.

### *Experience with bagasse-based cogeneration (G.V. Raman, Avantgarde, India)*

There has been a steady increase in HP steam conditions in India with several stations at or about 110 bar/540°C and now one at 125 bar/540°C, although how the two different pressures with one temperature can both be optimal was challenged. There is an 8% improvement in work recovered when going from 67 bar/485°C to 87 bar/515°C and another 7% in going from there to 110 bar/540°C. The capital cost increase from the lowest condition to the highest is 25%.

The most important points during conceptual design are to take the OTE (overall time efficiency) into account and to downsize the station to ensure a good load factor. Other factors presented also reinforced those made in the previous paper and then focused on the steam % cane ratio.

Mills in India are now achieving 36% steam % cane: a value which delivers 10.7% more electricity than 50% steam on cane on a gross basis. The point was also made that re-injecting medium pressure bleed from the turbine into the boiler, whilst counter-intuitive, is a valuable way of improving cycle efficiency.

On the turbine side, the issue of silica solubility in steam was highlighted which leads naturally to the need for considerable attention to be paid to boiler feedwater and boiler water qualities. Membrane technologies have mainly been adopted for water treatment in India and membrane costs have come down considerably.

Operating costs are more favourable than ion exchange technologies too, although they do start to converge at low raw water dissolved solids levels.

The final point addressed was the question of the station's parasitic power. In the early 1990s, the parasitic power of a typical station was about 12% of gross. Ten years later it had dropped to about 8%, just by using VFDs instead of dampers and valves to control flows and pressures.

### *High pressure multi-fuel boilers (A.K. Subramanian, ISGEC John Thpmson, India)*

This paper examined the features of a typical modern Indian boiler firing bagasse, other fibrous fuel and Indian coal. The HP conditions were 105 bar/540°C.

It is a single drum unit rather than bi-drum but otherwise much like similar boilers operating at lower conditions. It did, however, receive much hotter feedwater because of the two-stage BFW heating in the thermodynamic cycle. That is possible because of the higher saturation temperature at which the boiler operates.

The single drum can be much thinner walled as there are few penetrations and it also allows for non-heated downcomer tubes so circulation is improved. The separate steam generation bank eliminates tube expansion and the associated issues. The particular design adopted the so called flag concept with the tubes at the top of the heat recovery tower.

Higher HP conditions do require careful attention to be paid to materials of construction, as was evident in this boiler.

***Advanced bagasse boilers (E. Browne, Cethar Vessels, India)***

The paper also examined the features of a typical modern Indian boiler firing bagasse, this time generating at 107 bar/545°C. The unit, however, was a conventional bi-drum design.

This particular company is currently building the boiler for the highest HP conditions in India: 135 bar/545°C

***Power generation efficiency of Greenfield Sugar Plants (D K Goel, STM, India)***

This important paper compared the results from six Indian export cogeneration factories as being typical of 36 surveyed in total. Brief cycle characteristics were:

A:45 bar/430°C	back pressure power cycle without HP heater.
B:45 bar/430°C	extraction condensing power cycle without HP heater.
C:67 bar/500°C	back pressure power cycle without HP heater.
D:87 bar/515°C	back pressure power cycle without HP heater.
E:87 bar/515°C	extraction condensing power cycle without HP heater.
F:87 bar/515°C	extraction condensing power cycle with HP heater.

The survey confirmed that higher HP conditions and using the boiler as part of the cogeneration are both beneficial. The station efficiency of the six examples was presented as the net electrical export MW per MW available in the fuel bagasse expressed as percent:

	A	B	C	D	E	F
Station efficiency	9.00%	12.94%	12.30%	13.68%	14.58%	15.34%

Extrapolating the data, an efficiency of 16% was predicted for a 110 bar/540°C cycle and, if bagasse drying is adopted, an efficiency of about 17% might be expected.

***Overview of high efficiency turbines (Dr M.B. Inkson, TSE, U.K.)***

Little has changed fundamentally with steam turbines since Parsons hit upon the need to have many small let-down stages rather than a single large stage over a century ago. Higher-speed machines are more efficient than low-speed ones, but speed is limited by the need to keep the tip speed below the speed of sound. Every single shaft multi-wheel turbine is therefore a compromise and efficiency suffers. As we move to more stages – and particularly extraction condensing machines – the problem gets worse.

The other issue is that a condensing section requires typically at least 10% of the steam flow to pass through the back-end in order to keep it cool.

One solution is to install more than one turbine, using a back-pressure machine during crop and a condensing machine during off crop operation: an expensive approach. A better solution is to have twin shaft machines [on the basis that triple or more shafts are uneconomic] with each shaft at an optimum speed. It might then be possible to decouple the condensing section during crop.

***Overview on bagasse gasification (Dr B.P. Lavarack, Mackay Sugar Ltd. and Dr P.A. Hobson, Queensland University of Technology, Queensland, Australia)***

Ultimately, though, the way to improve the efficiency of electricity production from bagasse is to adopt bagasse gasification coupled to a combined cycle station: a gas turbine followed by an HRSG (heat recovery steam generator) and steam turbine. A doubling of the gross electrical production can be expected.

There are many types of gasifiers with much work on-going. A search in 2007 identified 13 'credible' technology suppliers using a range of technologies but none of them is yet able to offer anything over 5 MW-electrical and nothing has been achieved yet in the cane sugar industry. Of the work that has taken place in our industry, nothing has yet reached commercialisation and work seems to have more or less stopped for now.

Beyond gasification with combined cycle lies gasification to produce biofuels and hydrocarbons: essentially the Fischer Tropsch process. This lies still further in the future and it is unclear how it would be integrated into the sugar factory – one point which has at least been resolved with the combined cycle option.

**Sessions E and F – Biofermentation of sugar into chemicals**

***Biofermentation of sugar into high value chemicals and polymers (Prof. D. Jhurry, University of Mauritius, Réduit)***

This presentation discussed the option for Mauritius to produce products both from the sugar industry and the sea (the two main local resources available in the country). In particular they focus on (i) polymers for medicines and therapeutics, (ii) value added chemicals and (iii) green analytical procedures for quality control.

The concept of white biotechnology was explained: the application of nature's toolset (yeasts, mould, enzymes and plants) to synthesise products that are easily degradable, require less energy and produce less waste. An interdisciplinary approach is required.

Examples of the fermentation of sugars into sugar alcohols were discussed. The potential for application as low calorie sweeteners is large.

***Biobased polymers (Prof. D. Jhurry, University of Mauritius, Réduit)***

Microbiological produced polymers manufactured include polysaccharides (xanthan gum and hyaluronic acid) and polyesters (polyhydroxybutrate (PHB), Natureworks<sup>TM</sup> and Sorona®). The advantages of these biobased polymers are (i) they use renewable resources and up to 55% less fossil resources, (ii) they contribute to reducing greenhouse gas emissions and (iii) require cheap biological feedstocks. The basics for the production of PHB (biodegradable plastic) were discussed, including fermentation and chemical recovery.

***From sugar to lactic acid and polylactic acid (Prof. D. Jhurry, University of Mauritius, Réduit)***

The potential for lactic acid as an intermediate chemical for conversion to both esters and polylactic acid was described. Lactic acid esters are used in cosmetics and in the food industry. Polylactic acid (PLA) is a polymer with applications in the packaging industry and in the medical field.

Preliminary results were presented for the production of lactic acid from mixed juice and syrup feedstocks using a *Lactobacillus* strain. The steps for the recovery and purification of lactic acid were given. CMR (Carbon 13 magnetic resonance spectroscopy) and NMR (nuclear magnetic resonance spectroscopy) results were presented that indicate that the process is technically feasible. The initial laboratory work will transfer to pilot plant scale.

Market opportunities exist in India for lactic acid as well as for other fermentation products including L-lysine, gluconic acid, itaconic acid and glutamic acid (MSG).

## Session G – Pulp and Paper production

### *Pulp and paper manufacture from sugarcane bagasse (K. Viswanathan, SPB-Seshasayee Paper & Boards Ltd, Erode, India)*

SPB (Seshasayee Paper and Boards Ltd.) and TNPL (Tamil Nadu Newsprint and Papers Ltd) produce over 120 000 and 200 000 tonnes, respectively, per year of newsprint, as well as printing and writing paper from bagasse and wood. SPB was established in 1960 and TNPL in 1992 and both have achieved high productivity and ecologically friendly production methods. While raw materials for paper worldwide consist of 57% wood, 39% waste paper and only 4% agro residues (i.e. bagasse and others), in India the proportions are 37% for wood as a raw material, 32% waste paper and 31% of agro wastes (mostly bagasse).

Agro fibres require only 50% of chemicals when compared to wood. About 5.5 t of bagasse are required for producing 1 t of bagasse chemical pulp. By adding a minimum necessary amount of wood pulp (10–15%), the paper mill produces approx. 1.17 t of printing and writing paper from 1 t of bagasse chemical pulp.

Bagasse as a fibre source for paper making has a number of advantages over other raw materials such as bamboo, soft or hard woods and wheat or rice straw:

- Lower alkyl-benzene extraction requirement (because of lower content of wax and resins)
- Higher pentosan content (good bonding characteristics)
- Lower lignin content and more open structure (easily pulpable with less chemicals)
- One disadvantage in relation to soft and hard woods is the higher 1% NaOH solubility, indicating potential deterioration during storage (this can be handled with adequate precautions)
- Lignin separated from the bagasse fibre is burnt in steam boilers, thus providing energy
- Lower tearing strength of bagasse pulp is due to short fibre length due to crushing in the sugar mill; this can be compensated by adding wood pulp with longer fibres

The presentation was complemented by a very well organised visit to the SPB plant and to the adjacent Ponni sugar mill.

### *Production of bagasse-based particle boards in India (V.S. Raju, Ecoboard Industries Ltd, Pune, India )*

India produces annually about 200 000 m<sup>3</sup> of bagasse-based particle board in 17 plants located in Maharashtra, Gujarat and Uttar Pradesh. These particle boards are employed for furnishing office, school and household furniture with good appearance and better mechanical properties than wood-based particle boards, thus saving an equivalent felling of trees. India's potential requirement of particle boards is assessed at 10 Mm<sup>3</sup> to meet increasing construction and housing activity; the same could be produced by establishing about 1000 similarly sized plants and by using pith-free fibre from bagasse produced by the existing 560 sugar mills and other agri-crop residues.

About 250 t of bagasse are required to produce 100 m<sup>3</sup> of particle board per day (typical size of the existing plants), respectively 3.5–4 t of sugar mill bagasse with 48% moisture are required to produce 1 t of particle boards.

Presently, however, bagasse is also in great demand for cogeneration purposes. Both uses contribute to the reduction of green-house emissions.

**Session H – Animal feed and others*****Addition of molasses to cattle feed (S. Ramamurthy, SKM Feeds, India)***

Compounded cattle feed is a concentrated feed i.e., high in nutrient content. It does contain a maximum of 11% moisture, minimum of 60% total digestible nutrients (TDN) and not more than 18% crude fibre (CF). The main raw materials for the compounded dairy cattle feed are maize or corn, sorghum, broken rice and ragi. That apart, some deoiled rice bran, wheat bran, maize bran and rice polish are also used as ingredients. Additionally, certain oil cakes such as cottonseed extraction, coconut extraction, soybean extraction and Gingelly oil cake are also used.

Molasses is another major component which is used in cattle feed manufacture. It has the unique advantage of stimulating the rumen activity, improves appetite, increases forage and dry matter intake and enhances digestion. Molasses as a byproduct of sugar manufacture is more attractive so that forage intake can be increased and is economically viable. The other ingredients used are salt, calcite, dicalcium phosphate, mineral supplement, vitamin AD3 supplement, etc.

***Sugar cane coproducts in Thailand (Dr P. Weerathaworn, Mitr- Phol Group, Thailand)***

The Thai sugar industry produces about 7 Mt of sugar yearly, from a cultivated cane area of about 1 Mha. There are 47 sugar mills with daily processing capacities ranging from 5000 to 40 000 t/d. One of the largest groups is Mitr Phol, which has five modern factories with crushing capacities of 14 000–31 000 t/d in Thailand and five factories in China ranging from 5000 to 15 000 t/d. Through close supervision, Mitr Phol accepts only properly cleaned and loaded green-cut cane. Cane is mostly hand-cut and trash is left on the fields as a protective blanket.

Mitr Phol has invested heavily in byproduct utilisation in recent years. At the Phu Khieo site ('Mitr Phol Park'), for example, it operates a biomass boiler utilising 85% bagasse and 15% rice husks and corn cobs as fuel and selling 65 MW to the grid. At the Dan Chang site 53 MW are sold.

At Phu Khieo there is also a distillery producing 200 000 L/day and a second distillery at the Kalasin site, both producing fuel-grade ethanol for blending with gasoline. Also at Phu Khieo, there is a particle board plant, already established in 1990 with a capacity of 90 000 m<sup>3</sup> per year. It uses more than 200 000 t of bagasse per year.

Finally, through adequate waste-water treatment and usage of excess condensate from the sugar production process, irrigation schemes have been implemented to irrigate cane fields during the dry months. Agricultural extension services and its own sugarcane research station round off a highly successful enterprise.

**RAPPORT: ATELIER DE TRAVAIL DE L'ISSCT  
SUR LES CO-PRODUITS 2009**

Par

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**MOTS-CLÉS: Cogénération, Chaudières, Manutention de la Bagasse et de la Paille, Éthanol Cellulosique, Vinsasse, Biocomposting, Biofermentation, Mélasse.**

**Résumé**

L'ATELIER de travail de l'ISSCT sur les Co-Produits s'est tenu à Coimbatore, Inde du 15 au 19 mars 2009 et a attiré 41 participants de huit pays. Il y avait deux thèmes principaux : le lundi fut appelé le 'Jour de l'énergie' et les communications traitaient de la production d'énergie sous forme liquide et solide émanant des coproduits, ainsi que de la cogénération d'énergie électrique de la bagasse et de la paille. La participation de l'audience fut très active et les discussions animées. Le mardi des visites furent effectuées à deux usines sucrières notamment Sakhti Sugars et Bannari Aman qui sont équipées de chaudières à haute pression. Sakhti Sugars dispose également d'équipements pour concentrer et incinérer la vinsasse alors que Bannari Aman a une unité de biocomposting à partir de la vinsasse et des écumes des moulins. Le mercredi a été consacré au 'Produits dérivés' et les questions telles que la production des produits chimiques à forte valeur ajoutée par biofermentation de sucre, la production de la pulpe et du papier à partir de la bagasse et l'incorporation de la mélasse pour l'alimentation animale, ont été débattues dans un cercle restreint. Le jeudi, une visite a été effectuée à un complexe industriel impressionnant (SPB – Seshasyee Paper and Boards Ltd. Erode) dédié à la production de papier d'impression et industriel en association avec une usine de sucre (Ponni Sugars) qui fournit de la bagasse à l'usine de papier. Une unité de traitement des eaux usées est commune aux deux activités. L'atelier était organisé et gracieusement sponsorisé par Ponni Sugars (Erode) Ltd., ainsi que par SPB. Tous les communications ont été bien présentées et ont généré des vives discussions et une bonne interaction entre les participants. Les principales conclusions de l'atelier étaient : Compte tenu de la nécessité de réduire les émissions de gaz à effet de serre, l'importance de la cogénération à partir de la bagasse et autre biomasse, ainsi que la production de bioéthanol de la mélasse et du jus de canne ne cessera d'augmenter. Des chaudières à haute pression et cycles efficaces (110 barres, 540°C) sont bien établies et les coûts d'investissements sont entrain de diminuer. Des solutions pratiques pour gérer de large volume de vinsasse émanant de la production de bioéthanol sont disponibles, mais ces technologies ainsi que les investissements requis doivent être optimisés. Pour couvrir adéquatement les sujets prometteurs, la division en deux sections (énergie et dérivés) doit être retenue pour les ateliers futurs. L'emphase sur l'un ou l'autre de ces thèmes pourrait varier selon le nombre de contributions reçues. Afin d'encourager une meilleure participation des technologistes avec des emplois de temps chargés, il devrait y avoir deux jours consécutifs de sessions qui seraient suivis de deux jours de visites à des unités industrielles pour le prochain atelier. De nombreuses communications ont été jugées aptes pour être présentées au Congrès de l'ISSCT au Mexique en mars 2010

## INFORME: TALLER DE COPRODUCTOS DE LA ISSCT, 2009

Por

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**PALABRAS CLAVE: Cogeneración, Calderas, Manipulación de Bagazo y Paja de Caña, Etanol Celulósico, Vinazas, Biocomposteo, Biofermentación, Mielles.**

### Resumen

EL TALLER de Coproducción de la ISSCT del 2009 se realizó en Coimbatore, India, del 15-19 de marzo del 2009 y contó con 41 participantes de 8 países. Se identificaron y consideraron dos Temas Principales: El Lunes se denominó 'Día de la Energía' y en él se abordó la producción de energía sólida y líquida a partir de los coproducidos, así como la cogeneración de energía eléctrica a partir del bagazo y la paja de la caña. Prevalcieron una muy buena participación de la audiencia y vivos debates. El Martes se visitaron dos ingenios azucareros (Sakhti Sugars y Bannan Aman), que tienen calderas de alta presión. Sakhti Sugars posee también equipos para la concentración e incineración de las vinazas, mientras Bannan Aman cuenta con una planta para compostear las vinazas mezcladas con las tortas de los filtros. El miércoles fue el 'Día de los Derivados', cuando se debatieron, en grupos más pequeños, aspectos como la biofermentación de azúcar para la obtención de productos químicos de alto valor, la producción de pulpa y papel de bagazo, la adición de mieles finales al alimento animal. El jueves visitamos una impresionante planta productora de papeles de imprenta e industriales (SPB) y un ingenio azucarero adyacente (Ponni Sugars) que provee de bagazo a la planta de papel, así como también un eficiente tratamiento conjunto de aguas residuales. El Taller fue acogido y gratamente patrocinado por Ponni Sugars (Erodes) Ltd., y por SPB-Seshasyee Paper and Board Ltd. Erodes. Todos los trabajos técnicos fueron bien presentados y generaron discusión e interacción entre los participantes. Las principales conclusiones del Taller fueron: En razón de la necesidad de reducir la emisión de gases de efecto invernadero, continuará incrementándose la importancia de la cogeneración con bagazo y otras biomásas, así como la producción de bioetanol a partir de las mieles y jugo de caña; La generación de vapor en calderas de alta presión y ciclos eficientes de generación de potencia (110 bar, 540°C) están bien establecidos y se reducen los costos de inversión; Están disponibles alternativas prácticas para manejar los grandes volúmenes de vinazas residuales de la producción de bioetanol, sin embargo, aún se requiere la optimización de las tecnologías y los volúmenes de las inversiones; Con el fin de cubrir adecuadamente aspectos promisorios, debe mantenerse en futuros Talleres la división en dos (2) Secciones (Energía y Derivados). El énfasis real sobre cualquiera de ellos variará en correspondencia con la cantidad de contribuciones que se reciban; Para promover, en el próximo Taller, una mayor participación de especialistas que disponen de tiempo limitado, deberán realizarse las presentaciones en dos (2) días consecutivos de sesiones, seguidos de dos (2) días de visitas a plantas; Muchos trabajos técnicos discutidos en el Taller se consideran con méritos suficientes para ser presentados en el Congreso de la ISSCT en México en Marzo del 2010.