Challenges by transferring proven efficient design from beet to cane based on practical experience*

Abstract

In the past, developments in beet and cane sugar factories took place separately. Both industries used to rely on their local sugar institutes and technologists, who were best aware of the local economic conditions. One major difference between the cane and beet sugar industries is the energy supply issue: Cane sugar factories are self-sufficient in energy by burning bagasse, whereas beet sugar factories need to buy their primary energy. As a result, the beet sugar industry has been striving to improve energy efficiency. Nowadays cane sugar factories are keen on improving their energy efficiency, to maximise sell of surplus power to national grid. With reference to case studies, efficient designs proven in the beet sugar industry have been successfully applied to cane sugar factories. The challenges in designing efficient sugar mills, particularly in evaporator and sugar boiling houses, are explained especially.

Keywords: beet sugar processing, cane sugar processing, energy efficiency, evaporators, crystallisation

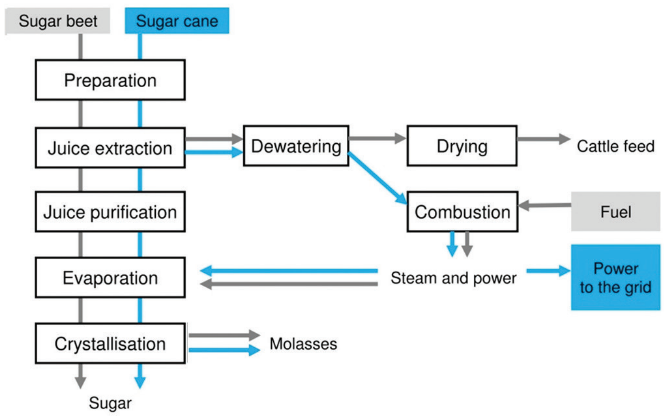
Can beet and cane sugar factories be compared?

Sugar is produced from both sugar cane and sugar beet. When taking a look at a rough classification into process steps, the applied production processes seem to be quite similar. General observations, on the other hand, only show little common ground between beet sugar factories and cane sugar factories.

Figure 1 shows the process steps for producing sugar from H beet and H cane. It is apparent that the process steps are fairly identical for both crops: both beet and cane are conditioned, then a solution is extracted that contains sugar, the juice is purified and concentrated and finally crystallised, and the sugar crystals are eventually separated. What remains is molasses. The residues produced during the juice extraction process are dewatered. But now we have to turn to some differences: beet pulp is dried and used as animal feed. The bagasse that is left after extraction in the cane processing is normally burned and used for generating steam and electric power for use in the cane sugar factory.

Cane sugar factories are located in tropical regions of the world, often with a poorly developed infrastructure. In most cases, the plants have been operating at the same location for decades, with the bagasse used as the energy source for the production of cane sugar. The capital invested in equipment and plant maintenance is kept at a low level. A factor that tends to favour this approach is the low labour costs. With few exceptions, cane sugar factories are typically operated with a large work force. The use of processing aids, i.e. chemical is relatively low He. Equipment is made from low-cost carbon steel.

Figure 1: **Common and disjoint process steps at beet sugar factory (grey) and cane sugar factory (blue)**



Andreas Lehnberger

BMA Braunschweigische Maschinenbauanstalt AG, Am Alten Bahnhof 5, 38122 Braunschweig, Germany

Email:
engineering@bma-de.com

Comparatively, beet sugar factories in Europe source all their energy requirements from fossil energy, and they constantly strive to upgrade their plants and make them more energy efficient. Production of high quality white sugar and refined sugar H is an essential criterion. Factories place their running costs under close scrutiny, and always try to find low-cost yet reliable solutions. Altogether, the staffing level in beet sugar factories is much lower than in cane sugar factories; at the same time, the processes are highly automated, and more and efficient use is made of additives. In recent past, the factories have increasingly turned to stainless steel.

At the outset, sugar production from cane and beet does not seem to have much in common: there are few links between the networks of technical and technological advisors: you either work for "beet sugar" or for "cane sugar". Important sugar industry conferences, too, fall into the categories "cane" and "beet". There is no immediate exchange of cane and beet sugar factory know-how, or of their experience and solutions. Specialist institutes tend to address country- or region-specific problems. Since beet and cane cultivation areas overlap in only very few regions (e.g. Japan, Iran, Morocco), activities have traditionally specialised in either beet or cane processing problems. There is a similarly high level of distinction among equipment suppliers. Even if they may not specialise as exclusive suppliers of equipment for beet or cane sugar factories, they normally clearly tend to either of the two source materials.

Energy efficiency – a new requirement for cane sugar factories

The conditions under which cane sugar factories are operated are changing on a global scale and to an extent that allows the production concept to be subjected to a fundamental review. In some countries, generating electric power from bagasse and feeding it into the local grid promises considerable economic benefits (figure 1). So much so that the production of sugar becomes a secondary objective, while the new focus is on maximised power generation and reduced process steam consumption.

Reducing steam consumption has been a key interest of developments in the beet sugar industry. How these developments in the beet sugar sector can be applied to the cane sugar sector will be dealt in the following section.

Potential technology transfer from beet to cane ready to use?

System analysis offers insight into the extent to which cane sugar and beet sugar production can share certain processes. As regards juice extraction and juice purification, the two systems have to deal with raw materials that clearly differ in their characteristics (table 1): With H cane, a mechanical process has to be used to decompose the cells and thus tap the sugar source, while with H beet, cell decomposition is the result of a heating (scalding) process. The applied extraction methods must consequently also differ. Juice purification also involves different physico-chemical processes, because the juices differ in their composition. No common ground can therefore be found or implemented for these diverse mechanical and physico-chemical processes.

The situation is different with juice concentration in evaporators and with crystallisation: In these two cases, the basic process operations in both beet sugar and cane sugar factories are identical (table 2). The heat transfer from the heating steam to the juice in evaporators is always the result of a temperature difference. And the driving force utilised for crystallisation is the supersaturation of the mother solution. There is evidently a basis for "beet" and "cane" to share the same process technology and concepts.

With the processes crystal separation from massecuite, and drying off the crystals there are so many similarities that the same centrifugals and sugar dryers are nowadays used for the production of both cane sugar and beet sugar.

Table 1: **Differences in juice extraction and juice purification**

	Cane 	Beet 
Morphology of raw material	Mechanical cell opening	Cell opening by scalding
Equipment for extraction	Diffuser or mills	Extraction tower
Juice characteristics	Reduced sugars	Bad tasting components
Juice purification	Liming, sulfitation, clarifying	Liming, carbonation, filtration
Properties of the juice	Saturated with carbonates, sulfates, phosphates High amount of reduced sugars Low pH	Low hardness No suspended solids Thermostable

Table 2: **Common basic process operations at evaporation and pan boiling**

	Cane	Beet
Evaporation 	Heat transfer Temperature difference is the driving force	
Pan boiling 	Crystallisation Supersaturation is the driving force	

Challenges in the evaporation station

Evaporators

The falling-film evaporators that are in operation in beet sugar factories are state-of-the-art technology. Cane sugar factories have considerable reservations about using falling-film evaporators that are widely used in the beet sugar industry, primarily because of the problem of fouling and scaling requiring the necessary cleaning measures, while Robert evaporators traditionally only require manual cleaning. Beet sugar factories apply scaling inhibitors to counteract the formation of encrustations, or the thin juice is softened.

In cane sugar factories, the formation of encrustations cannot be prevented with conventional juice purification methods. The necessary cleaning operations have to be carried out at certain intervals. Cleaning can both be done mechanically, using a high-pressure water jet, or with chemicals, or even with a process in which primary chemical cleaning is combined with final mechanical cleaning. For such regular cleaning, falling-film evaporators have to undergo some structural modification, so cleaning can be easily and quickly carried out as both chemically and mechanically.

When planning evaporators for use in the cane sugar industry, another difference needs to be accounted for: more non-condensable gases are produced with cane sugar juice than with beet sugar juice. These gases must be removed in sufficient quantities and at adequate points. Experience has shown that it is particularly important to ensure that vapour pipes and valves are vacuum sealed, in order to limit the amount of non-condensable gases in the evaporator calandrias. However, it is also evident from practice that there are reliable solutions.

Steam savings with new heat systems

It is possible to use heat systems employed in beet sugar factories for application in the cane sugar industry. This can produce substantial steam savings.

Cane sugar factories commonly use 4-effect evaporation plants that are equipped with Robert evaporators. The vacuum pans are often operated with 2nd vapour. The steam consumption in the evaporation plant is therefore about 43% steam on cane (figure 2).

A modern juice concentration concept is with 5-effect evaporation in falling-film evaporators that can be operated with lower temperature differences in the different effects. Since this allows the vacuum pans to be converted to operation with 3rd vapour,

Figure 2: **Conventional evaporation system with typical operating figures**

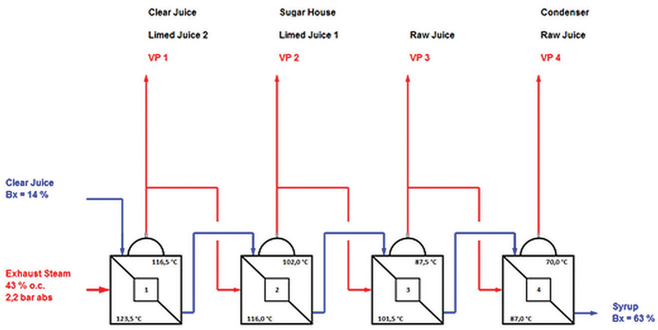
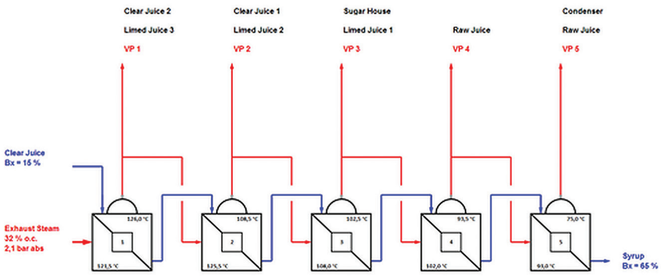


Figure 3: **New evaporation system with typical operating figures**



the steam consumption can be reduced to about 32% steam on cane (figure 3).

Case study of a cane sugar factory using falling-film evaporators

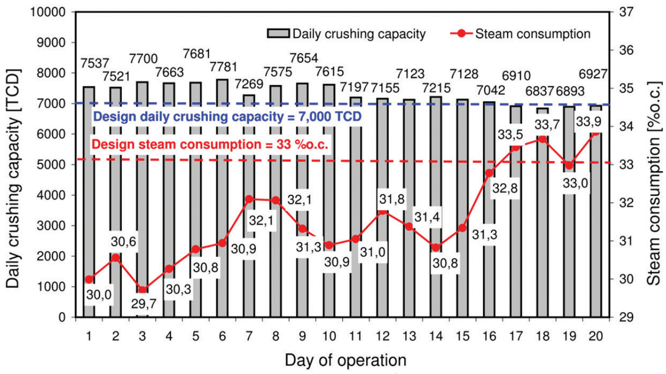
In the ICPL cane sugar factory in India [1], the 5-effect evaporation plant has been equipped with new falling-film evaporators (figure 4). The factory uses double sulphitation and produces plantation white sugar. Heat system details are shown in figure 3.

Figure 4: **Falling-film evaporators at ICPL / India (3x 4000 m² and 2x 1000 m²)**

When the heating surfaces were clean, the throughput was more than 7,500 tcd, at a specific steam consumption of around 30% o.c. Because of the encrustations that formed during a 21-day operation period without cleaning, the throughput had to be cut to 7,000 tcd, which automatically made the specific steam consumption go up to more than 33% o.c (figure 5).

When the plant was operated continuously, the first three evaporator effects were cleaned after about 3 weeks each; because the encrustations contained high levels of sulphate, effects 4 and 5 had to be cleaned after about 10 days each. Important for proper cleaning of the evaporators is that the heating tubes can be easily accessed, so the encrustations can be mechanically removed with a high-pressure water jet.

Figure 5: **Daily crushing capacity and specific steam consumption [1]**



To allow the evaporators to be operated reliably, discharging of the non-condensable gases from the evaporator calandrias was adjusted while plant commissioning. These gases are discharged through the vent pipe in a concentrated form. The heating steam can easily condense, when the mass concentration of non-condensable gases remains below 1%, or the temperature rise at condensation remains below 0.25 K.

Sugar boiling equipment

Batch pans and continuous boiling with VKT

From a process engineering point of view, a vacuum pan is first of all an evaporator and only secondly a crystalliser. The principles of heat transfer and crystallisation are the same for beet sugar and cane sugar applications. Heat cannot be transferred without a temperature difference, and crystallisation takes place when supersaturation conditions are maintained.

When the focus is on the specific steam consumption of a sugar factory, the vacuum pans must be operated at a low heating steam temperature, which implies that the temperature difference between the heating steam and the massecuite is also low. The decisive measure is using powerful stirrers, which are standard equipment in beet sugar factories, because they provide for excellent circulation. This enhances the vacuum pans to operate easily on 3rd vapour, and under certain conditions also on 4th vapour.

The consistent development from batch crystallisation to continuous crystallisation for beet sugar production is installing stirred vacuum pans that are connected in a cascaded control loop. The best known version of these vacuum pans is the vertical continuous vacuum pan (VKT).

The experience gained with an A-product VKT at the ICPL sugar factory confirms that the basic process operations for beet sugar production can be applied to cane sugar production without any reservations. In the ICPL factory, the A-product VKT is operated with 4th vapour (H 84°C) at a low water evaporation rate. At higher water evaporation rates, 3rd vapour (H 91°C) is used.

Continuous crystallisation produces constant operating results, such as throughput and crystal quality, only in connection with a sophisticated control system and VKT control. For cane sugar factories, this can be a first step towards complete automation of sugar production, which has already become state-of-the-art technology in beet sugar factories.

In addition to installing batch and continuous vacuum pans, measures were taken to ensure that

- the non-condensable gases are only passed on to the condenser,
- the entire heating-steam and vapour system is operated under vacuum conditions and is designed accordingly,
- the addition of water for crystallisation is minimised or eliminated altogether, and
- continuous crystallisation is operated steadily.

As a result, a cane sugar factory with an A-product VKT only consumes 28 % of exhaust turbine steam on cane at a pressure of 1.7 bar abs. (115°C).

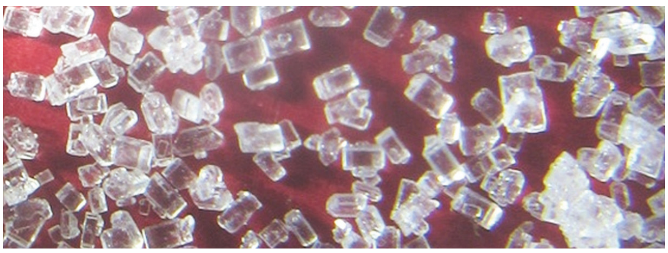
Seeding procedure

Controlled crystal growth is the real challenge with crystallisation. In particular at the beginning of the process, when the crystals are still very small and have a low volume concentration in the vacuum pan, undesired secondary nucleation can take place and is regularly observed in sugar factory practice. The normal countermeasure that is taken in this case is applying water in the vacuum pans, so these crystals are re-dissolved. As a consequence, the steam consumption in the sugar factory goes up.

With beet sugar production, pan seeding is an established method that helps to considerably reduce the risk of secondary nucleation. An approach that is successfully taken in beet sugar factories is cooling crystallisation in order to produce sugar crystals with a size of 100 µm from slurry [2]. This provides for excellent control of the crystal growth from the slurry up to a stable intermediate size.

In the cane sugar industry, crystal seed cooling crystallisation has recently been installed for the first time; this was in a sugar factory in Honduras [3]. Fully automatic crystal seed production from slurry has improved the crystal size distribution in the refined sugar (figure 6), has considerably reduced the application of wash water in the crystallisation process, and has improved separation

Figure 6: **Refined sugar crystals produced with crystal seed from cooling crystallisation**



in the centrifugals. Additional benefits are a higher throughput and a higher sugar yield, while the steam consumption has been reduced. The pan seeding unit commissioned in the cane sugar factory in Honduras clearly shows that the process in the cane sugar factory is the same as that in the beet sugar factory. The technology known from beet sugar production can be applied to cane sugar production without any modifications.

Conclusions

In the cane sugar industry, H generating surplus energy in a co-generation system for selling to H local grid is gaining significant interest. Cane sugar factories therefore demand H improved energy efficiency for their sugar production. The experience and concepts from H beet sugar industry, where the emphasis by necessity has been on energy efficiency because the factories solely rely on fossil energy, provides useful insight into technology transfer from "beet" to "cane".

Common ground can, in particular, be found with evaporation and crystallisation, even though minor adaptations have to be made when using established falling-film evaporators in cane sugar factories, so the unavoidable formation of scaling and its removal H, and also the higher percentage of non-condensable gases are adequately accounted for.

For sugar crystallisation, vacuum pans with powerful stirrers are a must, to be able to use 3rd and 4th vapours for crystallisation. A vacuum-sealed system is required for unhindered heat transfer in the crystallisation process.

Continuous crystallisation in a VKT and the use of a pan seeding system in the cooling crystalliser offer special advantages. Both methods are common practice in H beet sugar industry and produce the same results also in cane sugar factories. They offer a substantial energy savings potential, while providing for a very good crystal quality and excellent sugar yield.

Automated crystallisation makes production more uniform at a reproducible sugar quality. At the same time, less water is consumed; this, too, is a must in a factory with optimised energy consumption [4].

There is a compelling case for H exchange of knowledge, experience and technology between the beet and the cane sugar sector, and there is a sound basis for doing so. Opportunities can be seized for implementing known methods in order to make production processes more efficient and cost competitive.

** The paper was presented at the AVH Symposium 2015, Mauritius and at the ASSCT Conference 2015, New Orleans*

References

[1] Lehnberger, A.; Brahim, F.; Mallikarjun, S. S.: (2013), Falling film evaporation plant for a cane sugar factory: Presentation of the concept and operating results. *Proc. Int. Soc. Sugar Cane Technol*., Vol. 28, FE 22

[2] Ruytings, D.: (2005), Equipment and factory experiences with seed magma production by cooling crystallization. *Proceedings AVH Association 12th Symposium* Reims: 33-41

[3] Hauck, W.; Solís, S.; Ayestas, R.; Ayala, R.; Lehnberger, A.; Frankenfeld, T.: (2015), Production of seed magma by cooling crystallization in the cane sugar industry. *Proceedings ASSCT*, New Orleans

[4] Morgenroth, B.; Max, H.; Mogalle, M.; Singh Bola, H.: (2014), Batch pan automation and its impact on energy conservation in cane sugar factories. *Int. Sugar Journal* 116: 892-900

AvH
Association Andrew van Hook
Pour l'avancement des connaissances sur les sucres

XXIIIRd Symposium A.V.H

7th April 2016

SUGAR SPECIALTIES: EVOLUTION OF CONSUMPTION AND TECHNICAL ASPECTS

Program:

9:00 -10:20 - Session I: History and evolution of consumption of sugar specialties .
10: 20 – Coffee break, Posters and Exhibitors
11:00 – 12:30 - Session II: Analytical aspects and Processing
12: 30 – Posters & Exhibitors
13:00 – Lunch
15:00 – 17:00 - Session III: Technological Aspects

Venue :
Maison des Agriculteurs
2, rue Léon Patoux
F - 51664 REIMS
www.associationavh.com

Registration : inscription@associationavh.com
Prof. M. Mathlouthi, Association AVH
2, rue Léon Patoux, F-51664 Reims Cedex2
Tel. +33 3 26 04 74 30- Fax +33 3 26 04 74 31
E-mail : mohamed.mathlouthi@associationavh.com

The Association Andrew Van Hook is a non profit association launched at Reims in 1992 with the following objectives:

- To lead R & D programs in the fields of sugar crystallization, quality of crystals and sugar-water interactions
- To set up a computerized database open to members of Association and help in solving sugar technology problems.
- To work at the increase of knowledge in the field of the physico-chemical properties of sugar solutions
- To propose training and consulting services to sugar producers and users in our fields of competence