TECHNOLOGY TRANSFER BETWEEN BEET AND CANE SUGAR INDUSTRIES  
- Possibilities for Energy Savings including Cogeneration -

Hansjoachim Wunsch and Pedro Avram-Waganoff
IPRO Industrieprojekt GmbH
Celler Straße 67, D-38114 Braunschweig, Germany

ABSTRACT

The distribution of steam consuming stations in the beet and cane sugar industries are compared and defined according to their importance. The "state of technology" in the beet sugar industry regarding energy consumption as realized in the Klein Wanzleben sugar factory in Germany is shown. An analysis is made of sugar house work, showing technologies (e.g. seed magma system, optimized pan configuration, continuous boiling, low temperature boiling) which can be easily applied in the cane sugar industry with a view to reduce steam consumption in a significant way. As a consequence, efficient evaporator stations operating with low temperature differences are required. Another consequence is the requirement of higher pressure steam boilers in order to secure the required prime mover energy and electricity generation. Three examples how this could be realized in the cane industry are shown. The net result of the measures described is an appreciable increase in the capacity of the factories to "cogenerate", i.e. sell surplus energy to the public grid.

INTRODUCTION

The distribution of steam in a beet sugar factory is shown in Figure 1 in a very simplified way. The generated steam is used for electrical power generation and the exhaust steam is used in the evaporation plant where it is only transformed without condenser losses to a lower thermodynamic condition and from there distributed to the actual consumers. The biggest consumer is the sugar boiling house followed by juice purification, juice extraction and others.

![Steam distribution in a beet sugar factory](image-url)
In comparison to the beet sugar industry Figure 2 shows an optimized scheme for a cane sugar factory. Actually, we think that most cane factories need more steam especially in the sugar boiling house and for the evaporation plant. The condenser losses are mostly much higher than 0.5 % on cane. Also in cane sugar factories the sugar boiling house is the biggest consumer.

In the sections below we want to explain how to reach this first target of 27% steam on cane. Therefore, we want to concentrate on the sugar house and evaporation work.

**Fig.2 :** Optimized steam distribution for a cane sugar factory

"State of technology" in the beet sugar industry

First in order to show the latest development in the beet sugar industry we want to mention the steam distribution of Klein Wanzleben sugar factory in Germany which is probably the most modern beet sugar plant. A well performing West European beet sugar factory needs for electric power generation and process the shown figure of 22% steam on beet. This corresponds to about 2% fuel on beet and in addition 1% fuel on beet for pulp drying i.e. all together 3% fuel on beet. Klein Wanzleben sugar factory needs all together with the integrated steam drier for beet pulp 17% steam on beet (Figure 3). This corresponds to about 1.7% fuel on beet, and is a reduction to nearly half of the fuel consumption (Fig. 4). In this case we want to point out that steam demand of the sugar boiling house is also reduced from 12 to 6.5% steam on beet because we installed continuous vacuum pans where the vapour from the second and third products are used to heat the white sugar pan (Fig. 5).
Fig. 3: Basic steam usage scheme in the Klein Wanzleben sugar factory

CONVENTIONAL SUGAR FACTORY WITH POWER STATION AND DRUM DRIER
TOTAL = 272 kWh/t beet 100%

STEAM BOILER
DRIER

PARAMETERS:
Process steam demand = 22 kg/dt beet
Spec. el. power requirement = 25 kWh/t beet
Dry substance of pressed pulp = 32%
Usage of boiler flue gases in drum drier

SUGAR FACTORY "KLEIN WANZLEBEN"
TOTAL = 147 kWh/t beet 54%

STEAM BOILER
DRIER
GAS TURBINE

PARAMETERS:
Process steam demand = 16 kg/dt beet
Spec. el. power requirement = 25 kWh/t beet
Dry substance of pressed pulp = 32%

Fig. 4: Comparison of energy requirements
Fig. 5: Klein Wanzleben Sugar Factory Process Flow Diagram

Fig. 6: A picture of the outdoor-evaporation and continuous boiling pan installation in Klein Wanzleben sugar factory.
IMPROVEMENTS IN SUGAR HOUSE WORK

In the beet sugar industry we very often use the 3 product-sugar boiling scheme where thick juice and remelt second product sugar and affinated third product sugar is mixed to standard liquor. First product massetcuite has a purity of about 94 % and we are directly producing white sugar between 8 and 10 EEC points. This is possible because we are using today in nearly all factories a magma seed-scheme (Figure 7) i. e. we are producing a defined crystal magma in a special seed magma pan where the crystal size is exactly controlled.

Fig.7 : Magma Seed Scheme

Depending on the different sizes or types of the boiling pans resp. the crystal foot volume and calandria, the quantity of seed magma is calculated for every strike. The use of seed magma systems guarantees a high uniformity of all crystals and it is also possible to reach a bigger final crystal size of up to 0.8 mm. The bigger size of the crystals corresponds with the lower total surface of all crystals, leading to a very effective reduction of wash water in the centrifugals. The washing process is also optimized by using first syrup or run-off before using hot water. As you know 11 of hot water dissolves about 4 kg sugar. Another advantage is the fact that the "sugar dust" percentage (crystals smaller than 0.2 mm) can be reduced effectively.

Figure 8 shows the water mass balance in the sugar boiling house. To reduce the steam demand to 10.5% it is necessary to concentrate the thick juice up to 75° brix. The remelt has also a dry substance of 72° brix and other water supply is strictly controlled like wash water in the centrifugals, screen washing, steaming out and cleaning water. All different streams are controlled and measured. Additional steam demand besides the boiling station is necessary for melt liquor heating, melt station, for first and second boiling run-off pre-heaters and sugar drying (Figure 9).
Fig. 8: Water Mass Balance in the Sugar Boiling Home

1) Vacuum Pan Station
2) Melt Liquor Heating 70 - 80 °C
3) Melt Station
4) I. Boiling Run-off 70 - 88 °C
5) II. Boiling Run-off 70 - 88 °C
6) Sugar Drying

by means of V. Vapours
by means of V. Vapours
by means of III. Vapours
by means of IV. Vapours
by means of IV. Vapours
by means of IV. Vapours

10.50% on Beet
0.28% on Beet
0.40% on Beet
0.32% on Beet
0.12% on Beet
3.38% on Beet

TOTAL 12.00% on Beet

Fig. 9: Steam Consumers in the Sugar Boiling Station
Otherwise, the results are influenced by the installed boiling pans. Figure 10 shows a discontinuous boiling pan with stirrer in the central tube. Central tube diameter should be at least 40\% of the pan diameter. Tube length should be as short as possible and the conical space/volume under the calandria should be as small as possible.

This type of pan should be used for seed magma and batch boiling pans when new installations are planned. With existing pans, where very often the geometric parameters are not optimal you have the possibility to connect them in a cascade system (Figure 11). This allows for a continuous operation.
Otherwise, there are 3 different types of continuous vacuum pans commonly in use. The two horizontal types of Tongaat-Hulett and FCB and the vertical type of BMA ("VKT"). The VKT-type is the consequent further development of the just shown cascade-system.

Especially in Germany we are using "VKTs" and also the cascade system with great success. The advantage of the VKT-system is shown in Figure 12 and is realized in two of the new East German factories. In this 3 product-scheme VKTs are used for all products and you see that for each product a seed magma pan is installed. The raw sugar and after-product VKT is heated with vapour from the evaporation stage VII-a with a temperature of 98.5°C. The vapour of these both continuous pans is used to heat the white sugar-VKT. For this reason, the heating surface of all three continuous pans had to be increased in comparison to normal use because the temperature difference had to be split and the vacuum in the condenser had to be increased, respectively a 2-stage barometric condenser is applied.
Unfortunately, this sophisticated technology can only be installed with high investment costs in existing factories. On the other hand, the great advantage of the crystal seed magma scheme and also the cascade system using the existing pans represents a relatively easy step to optimize sugar house work.

MODERN EVAPORATOR PLANTS

Now let's have a look on the evaporation plant. Juice evaporation being the heart of the sugar factory has a central influence on a well performing continuous process. The quantity of the produced raw juice flowing through juice purification has to correspond with the process speed in the sugar boiling house in relation to the evaporation process. In the beet sugar industry, this is realized on a high level because all steps of production beginning with beet preparation up to sugar drying are automated.

The process steam demand was reduced to the figure of 22% shown earlier whereby the electrical power purchased from outside increased. This led to an increase in evaporation stages up to 6 to 8. This was only possible by using evaporators, which can work with low temperature differences. Contrary to the Robert-type where the effective temperature difference rises from the first stage to the last, the use of falling-film evaporators allows evaporation work with a defined temperature difference of down to 3°C.
Figure 13 shows different falling film evaporator types, which are in use. In most of the new Greenfield sugar factories the type which is shown on the extreme right hand side has been installed.

The vapour space of this type has a larger cross section than the calandria, making an additional entrainment separator unnecessary.

In our opinion, standard plate evaporators are only useful when they are installed as a “booster”. Technologically, they are an obsolete way to follow because juice has to rise like a Robert-evaporator. A technological alternative to falling film tube evaporators is the falling film plate evaporator, which has been in operation since 1992 with increasing success.

Fig.14 : Evaporation Station Klein Wanzleben Sugar Factory
The scheme of the Klein Wanzleben evaporation station with 7 stages (Figure 14) shows that we are using vapour VII-a for a sugar boiling. The stage VII-a is the first in the juice flow i.e. we are starting thin juice concentration in this stage. The advantage is that the boiling point elevation is still low and because the juice is thin evaporation speed and quantity is high. This will allow smaller peaks in vapour demand from the boiling station without disturbing the evaporation process.

Another advantage of this working method is the fact that the vapour temperature used in the vacuum pans is lower than in former times. Many cane sugar factories are still using today vapours or steam in the sugar boiling house with too high temperatures. This leads to high evaporation speed in the boiling pans and uncontrolled oversaturation. The result is false grain formation with all negative effects. By using vapour of about 100°C for crystallization the process can be controlled much better and the effect on steam demand is also very significant.

The reduction of steam demand also has an influence on the power station. Increasing electrical demand and decreasing process steam demand lead to boiler and electrical turbine installations with higher pressure because the specific steam demand of the turbine must decrease. Today we are using boiler and turbine pressures up to 85 bar at 525°C in the beet sugar industry. This is the critical limit because higher pressures and temperatures are only reachable with uneconomically expensive material alloys in steam boilers.

**IMPROVED HEAT BALANCES FOR THE CANE SUGAR INDUSTRY**

Now we want to explain how existing cane sugar factories can reduce their steam demand down to 27% steam on cane. In the first proposal (Figure 15) we are using the first three existing Robert-stages and adding 2 falling film evaporators as 4th and 5th stage. The sugar boiling house is heated with 3rd and 4th vapours. The calculation shows that in this case only 55% of the bagasse is necessary for steam generation but over 45% can be saved and used for other purposes.

---

**Fig.15**: Improved Heat Balance / Evaporation Cane Sugar Factory
The example shown is related to a typical plantation white factory with turbine driven cane mills and preparation equipment of 3000 t/d capacity.

For improving the thermodynamic cycle a new steam boiler rated at 50 t/h with 85 bar and 525°C has been foreseen, whereby feedwater quality and treatment have higher requirements than what is typical in the cane industry. For maximum power generation a multi-stage turbine with 85 bar/520°C inlet conditions and 2.7 bar exhaust pressure would normally deliver 6.1 MW. This would be sufficient for driving all equipment in the factory with electric motors and leaving approx 1 MW for power export. However we have assumed that part of the turbine drives of the mills/cane preparation would remain. These turbines typically have an inlet pressure rating of 21 bar/320°C.

Fig.15 shows the main turbine driving the generator as a back-pressure/extraction turbine. With the quantities shown of 17/10% on cane (21.3/12.5 t/h at 3000 t.c.d) this turbine will generate 4.9 MW. The steam extraction quantity of 10% on cane (21 t/h) will enable existing turbine drive power of approx 1 MW at 21 bar inlet pressure. If the existing turbines have a higher rating (say 30 bar/440°C) up to 1.6 MW drive power could be obtained. In this case however the main turbine would generate less (approx 3.5 MW). Therefore the best compromise will have to found, depending on local conditions.

Summarizing, the scheme shown in Fig.15 shows how to balance the factory steam and power balance, producing a significant bagasse surplus at the same time. Several alternatives are possible to employ this bagasse surplus. One would be to store it and employ it in a cogeneration plant during the off-season.

In Fig. 16 we have shown such a scheme, which includes a high-pressure boiler feeding an extracting/condensing turbine rated at 10 MW. The existing amorphous sugar and liquid sugar plant has a year-round requirement of 13 t/h of steam at 11 bar and 1.3 MW of electric power.
Assuming an off-season of 150 days (3600 h) and an excess bagasse production of 70,000 t, the maximum possible steam production is 43 t/h. The scheme shown allows to produce an amount of 7.9 MW of export power, which generates an income of USD 1,140,000 in 150 days based on a selling price of 40 USD/MWh. The return on investment here depends on several factors. The boiler and water demineralization plant would be employed during the crop season also but it has to be examined whether the turbine can be employed there too, for example.
Lastly we have examined the case of a new 3000 t/d raw sugar factory with an integrated refinery, designed for good heat economy and maximum cogeneration and working 300 days per year. As you can see in Fig. 17, the high pressure steam boiler will generate 60% on cane (corresponding to 75 t/h) employing practically all the bagasse available.

The process part of the new factory requires only 25.14% on cane (31.4 t/h) of exhaust steam at 2.7 bar going to the first body of the evaporation station. All process consumers except for the last stage of clarified juice heating are heated with vapours from the different bodies. The vacuum pan station is fed entirely from the pre-evaporator operating in parallel with the 3rd body. Thick juice leaves the evaporator station at 72°Cx to the pan station.

The annexed refinery of 500 t/d capacity requires 18.4% on cane (23 t/h) of exhaust steam, and 2.5 MW of electrical power.

The balance of the high-pressure steam (15.2% cane = 19 t/h) is expanded to an absolute pressure of 0.12 bar in an extraction/condensing turbine rated for 15 MW of electrical power generation. The new factory and refinery require approx 7.5 MW together, so that a surplus of 7.5 MW can be exported to the public grid.

Based on 300 d/a and a price of 40 USD/MWh, this represents an annual income of 2,160,000 USD. Here the return on investment is more attractive than in the previous examples.

We hope the above has shown some possibilities to improve energy usage in the cane sugar industry and IPRO stands ready to help you implement any of them.

INTERCAMBIO DE TECNOLOGÍA ENTRE LAS INDUSTRIAS DE AZÚCAR DE CAÑA Y DE REMOLACHA
Posibilidad de Ahorro de Energía, Incluyendo Cogeneracion-

Hansjoachim Wunsch y Pedro Avram -Waganoff
IPRO Industrieprojekt GmbH
Celler Straße 67, D-38114 Braunschweig, Germany

RESUMEN

La distribución de estaciones consumidoras de vapor en las industrias de azúcar y de remolacha son comparadas y definidas de acuerdo a su importancia. Se mostró el "estado de tecnología" en la industria de azúcar de remolacha con respecto a consumo de energía, tal y como lo visualizó la factoría Klein Wanzleben en Alemania. Se realizó un análisis del trabajo en una fábrica azucarera, mostrando tecnologías (ejemplo, sistema de semilla, configuración optimizada de tachos, cocimiento continuo, cocimiento a baja temperatura) el cual puede ser aplicado a la industria azucarera con el objetivo de reducir consumo de vapor en forma significante. Como consecuencia, se requieren estaciones de evaporadores eficientes cuando operan con diferencias de temperaturas bajas. Otra consecuencia es el requerimiento de calderas de vapor a alta presión para asegurar el suministro de energía primaria y generación de electricidad. Se presentaron tres ejemplos acerca de cómo esto es obtenible en la industria azucarera. El resultado neto de las medidas descritas es un aumento considerable en la capacidad de las fábricas para "cogenerar", ejemplo, vendiendo energía extra al público.
LE TRANSFERT DE TECHNOLOGIES ENTRE LA BETTERAVE ET LA CANNE

H Wunsch et P Avram-Waganoff

RESUMÉ

On compare et discute les ateliers consommateurs de vapeur en sucreries de betterave et de canne. Le savoir faire le plus récent, de l'énergie en betterave, à Klein Wanzleben en Allemagne, est décrit. On montre les technologies nouvelles, telles que le système magma, la configuration des cuites, les cuites continues et la cristallisation à basse température, qui pourraient être transférées vers la canne pour réduire la demande d'énergie. Il faut un atelier d'évaporation efficient, avec des différences de température assez basses. Il faut aussi avoir des chaudières hautes pressions pour optimiser la demande d'énergie. On donne trois exemples pour décrire comment cela se ferraît en canne. Comme résultat ces (sucreries) pourraient alors produire de l'énergie pour le réseau.