The VKT Continuous Vacuum Pan
- More than 20 Years of Experience -
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1. Introduction

Today more than 75 units of the BMA vertical continuous vacuum pans are in operation or under construction, for the beet and the cane sugar industry and for refineries. A brief history provides an overview on important steps during the development:

- - 1983 - First VKT installation
- - 1985 - First white sugar VKT in operation
- - 1994 - First VKT for refined sugar
- - 1995 - First VKT for cane sugar (B product)

The VKT system is ideally suited for energy savings and, consequently, environment-conscious operation. The introduction of mechanical vapour recompression and double-effect evaporation in crystallization were further essential measures for further reductions in energy consumption [1].

2. VKT / VKH concept

When the development of the vertical continuous vacuum pan was initiated it was obvious to choose vertical superimposed chambers in analogy with the proven conventional pan design (Fig. 1).

It allows the use of mechanical agitators ensuring excellent circulation and mixing of the massecuite

Fig. 1: VKT – concept
The preferred installation consists of 4 chamber units with throughputs of up to 190t/h for refined massecuites. It can be employed for all sugar varieties in beet and cane factories as well as refineries. The design of the 4-chamber pan can be such to permit retrofitting a 5th chamber to increase its capacity. Low grade and raw sugar VKTs have an external overflow system.

If the space occupied by an existing station equipped with modern, well-preserved batch pans shall be utilized for continuous operation, a horizontally cascaded unit (VKH) can also be used (Fig.2). All batch pans used should be similar in design and should have stirrers installed.

Fig. 2: Horizontal vacuum system (VKH)

The operation of both systems – VKT and VKH – is similar. A high quality seed is fed into the first crystallization chamber. Feed solution is continuously fed into all chambers, intermixing between the chambers being excluded. The dry substance content and, consequently the crystal content of the massecuite increases from chamber to chamber and reaches its maximum in the final chamber.

Efficient crystallization is reflected, in particular, by the centrifugal yield; it is closely linked with the crystal quality and the crystal content achieved during crystallization. Mechanical circulation of the massecuite in streamline-flow crystallizers provides for a high crystal content, which can be as high as 55% for white massecuite, entailing a centrifugal yield of approx. 50%(on MC).

Due to the residence behaviour in continuous crystallization, the crystal size distribution is slightly wider in the course crystal range. In actual practice the coefficients of variation are therefore somewhat inferior to those achieved in batch operation. However, the decisive
The control system of the VKT uses fixed setpoints only (Fig. 3). The essential parameters to be controlled are:

- Heating steam pressure
- Vapour pressure
- Condition of massecuite (dry substance content)
- Feed solution flow rate
- Seed/feed solution ratio
- Massecuite level (white sugar only)

The condition of the massecuite in all four chambers is controlled by way of the feed solution. The measuring system preferable used for this purpose is the microwave measuring system. The sum of measured feed solution is used to add a quantity of seed in a defined proportion to the total feed solution. Heating steam and vapour pressure are controlled in each chamber, allowing optimum operation and disconnection of a chamber for cleaning purposes. The throughput of the VKT is determined by adjusting the heating steam pressure setpoints for all chambers. The massecuite level is kept constant by control valves and in the last chamber by the speed of the massecuite discharge pump.
It is a well-known fact that incrustations cannot be fully avoided in continuous crystallization systems – especially where high-purity massecuites are involved. The vertical (and also the horizontal) cascaded design of the VKT allows cleaning without the need to interrupt the crystallization process. One chamber can be bypassed and disconnected from the process, while the other ones continue to operate. The typical cleaning process for a white sugar VKT is shown in Fig. 4.

![Diagram of VKT cleaning process](image)

Fig. 4: Schematic view of the cleaning process

The working cycle of a VKT, i.e. four-chamber operation before it needs cleaning, is 15 to 20 days for white sugar units, 20 to 30 days for raw-sugar units and 45 to 60 days for low-grade units.

### 3. Installations and experience

The specific design of the VKT crystallization chambers, a low massecuite level above the calendria, and the use of mechanical stirrers in each chamber allow the VKT to be reliably operated at a very small heating-steam-to-massecuite temperature difference and at heating steam temperatures far below 1 bar. As a result, optimum operation of the VKTs opens up numerous energy saving prospects [1].

One example for an optimised installation of 3 VKTS is shown in Fig. 5 for a beet sugar factory. The last effect evaporator provides nearly the complete required heating steam for the VKTs. As a result the dry substance content of the thick juice in the last effect increases by 28% resulting in very low colour formation in the evaporation station.
Fig. 5: Optimised installation with 3 VKTs

Fig. 6 gives an example of a high-raw VKT utilizing the steam from a standard-liquor concentrator. Standard liquor evaporation benefits from the low pressure of 0.5 bar, as it keeps down the temperature of the solution and the heating area of the concentrator. In addition, the concentrator vapour can be fully utilized as heating steam, which means direct savings of steam in comparison with condensation.

Fig. 6: Vapour from standard liquor concentrator for high-raw VKT

The principle of continuous crystallization of high-quality white sugar, in conjunction with mechanical vapour compression, was practised for the first time in the Aarberg sugar factory [5, 6]. The compression ratio of the new vapour compressor could thus be reduced from 6:1 to 3:1, and the electric energy requirements for compression were reduced from 3.6 MW to 1.9 MW (see Fig. 7).
Consistent development of this concept led to the so-called “double-effect evaporation” [2,3], which is the first real multi-effect evaporation process as part of crystallization that does without any additional vapour compression. In the 1994 and 1995 campaigns, this principle was introduced in the Güstrow and Klein Wanzleben sugar factories, which today belong to Nordzucker AG. Fig 8 is a basic flow chart for this operation principle.

The two VKTs for raw sugar and low-raw sugar use a vapour pressure (vacuum) of 0.29 bar, while the white-sugar VKT operates on a vacuum of 0.1 bar. This allows the vapour of the raw sugar and low-raw sugar VKTs to be used as heating steam for the white-sugar VKT. The condensation system is designed for both pressures. The low vacuum can be produced
either directly by means of adequately dimensioned vacuum pumps, or it may be compressed to the 0.18-bar level in a thermal vapour compressor, as shown in Fig. 8.

Another important step (in parallel with the introduction of double-effect evaporation) was the installation of two VKTs for refined sugar (R1) in the new refinery of Al Kahleej Sugar Co. in Dubai. The plant had originally also been designed for mechanical vapour compression, but for local reasons this system was not installed immediately. In the meantime, the concept was subjected to a number of modifications, which were not least due to the much higher quality of the raw sugar processed. The details of these developments have been reported and discussed on several occasions [7, 8]. The essential step forward was the employment of the VKT for continuous crystallization at a purity of approx. 99%. One special feature is that the refined sugar (today: R3, R4 and R5) is magmatized with fine liquor and is then used as crystal seed for the final refined sugar product (R1 and R2).

Another example for the application of double-effect evaporation in conjunction with thermal vapour compression is a VKT installed for the Malayan Sugar Manufacturing Co. Bhd. (MSM), Malaysia in 1997 [9], which is to crystallize very coarse refined sugar. The energy saving concept practised in this case uses vapour from the batch pans as heating steam for the R-VKT (Fig. 9). A controllable thermo-compressor increases this vapour from 0.2 bar to 0.3 bar. In addition, vapour from the liquor concentrator is supplied at a pressure of approx. 0.35 bar (abs), and this reduces the heating steam requirements of the pan vapour/thermo-compressor line to 75% of the total requirements.

![Fig. 9: Process scheme of the MSM VKT](image-url)

A specifically developed program determines the pans that can provide the appropriate vapour which is fed into the manifold (thermo-compressor inlet) for pressure control. If this pressure setpoint should be less than in the VKT heating steam manifold (thermo-
compressor outlet), the thermo-compressor comes on stream automatically. The steam used for pan vapour recompression is exhaust steam at 3.0 bar (abs).

At the moment, another application of double-effect evaporation is being put into practice. The Nakashari factory of Hokuren/Japan will get two new VKTs (Fig. 10). These are to produce a particularly pure white sugar. The operating principle will have a VKT produce A-sugar, which will be remelted to yield a very pure liquor. The B-sugar will be produced in the second VKT. The heating steam for the A-VKT will be vapour obtained from the B-VKT. Any additionally required steam will be supplied from the evaporator station at 1.4 bar (abs) and will at the same time serve as motive steam for the thermo-compressor. This compressor increases the pressure of the vapour coming from the B-VKT from 0.24 bar to 0.33 bar. In this way, both VKTs can be designed with a smaller heating surface.

![Diagram of double-effect evaporation with A- and B-VKT (Nakashari / Japan)](image)

Fig. 10: Double-effect evaporation with A- and B-VKT (Nakashari / Japan)

Systems using double-effect evaporation primarily differ from other systems in their much lower crystallization temperature of approx. 53 °C, at a vapour pressure of 0.1 bar. The following differences should be noted:

- Reduced crystallization speed at decreasing temperature
- Lower saturation concentration (approx. 72 - 73 %)
- Twice the specific volume of heating steam and vapour because of the lower density

This means that for safe operation, the following measures have to be taken:

- Feed solution conditioning (concentration and temperature)
- Crystal seed made available at the required temperature
- Minimizing of air in VKT heating steam and vapour system.
Continuous crystallization in cane sugar factories mainly takes place today in simple horizontal systems due to the lower investment costs and the available amount of steam. The increasing demand on high quality raw sugar and the installation of more efficient co-generation plants are requesting solutions as presented in this presentation.

4. Conclusions

Continuous crystallization of also very pure products has become state-of-the-art technology. The quality of the crystals produced can be controlled. The examples presented illustrate that different solutions are available for specific requirements. When designing new factories the examples discussed point to a number of possible energy saving options. In connection with factory expansion programmes, outdoor installation of a VKT will also go along with significant cost benefits.

At an international scale, energy as a cost factor will become a major criterion in a competitive situation.

References:

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