tech-info

► ***Crystallization plants***

BMA pan seeding systems,

batch pans, vertical

continuous pans (VKT) and

cooling crystallizers serve

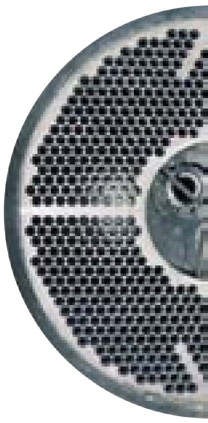
for efficient and optimum

crystallization of sugar

at beet and cane sugar factories

and sugar refineries

worldwide.



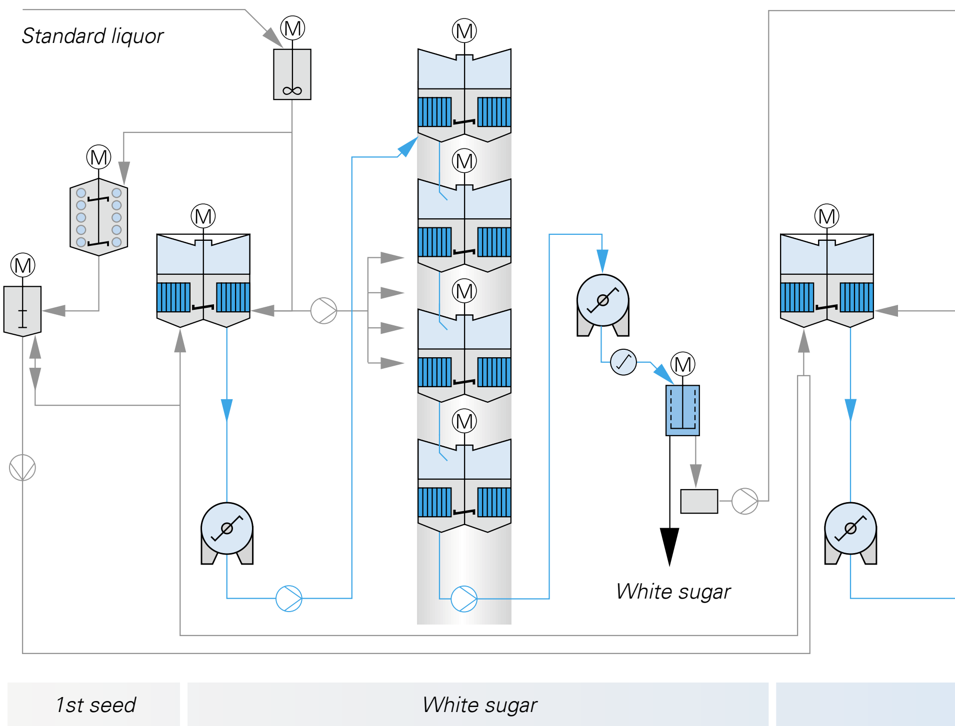
BMA

In the lead by know-how

"L' Art de Rafiner le Sucre" is the title of a textbook M. Duhamel du Monceau wrote in 1764 about refining and crystallization of sugar.

BMA has mastered this "art" for more than 100 years and during this time has played a prominent part in the development and introduction of novel crystallization equipment and technologies.

Today BMA is the leading manufacturer of plants and equipment for pan boiling and cooling crystallization of sugar. For example, the vertical continuous vacuum pan (VKT) is presently the only plant for unproblematic continuous crystallization of 1st-white (refined) sugar.



Crystallization of sugar

Fundamentals

Crystallization of the sugar is the decisive technological step to recover the sucrose dissolved in the thick juice. In a crystallization step, the crystal content of the massecuite limits the technically achievable degree of desugarization of a solution, which means that several crystallization stages are necessary. The sugar yield is determined in the first place by the molasses purity, which in turn is subject to the quality of crystallization (pan boiling) work, in the final stage in particular, and to saturation.

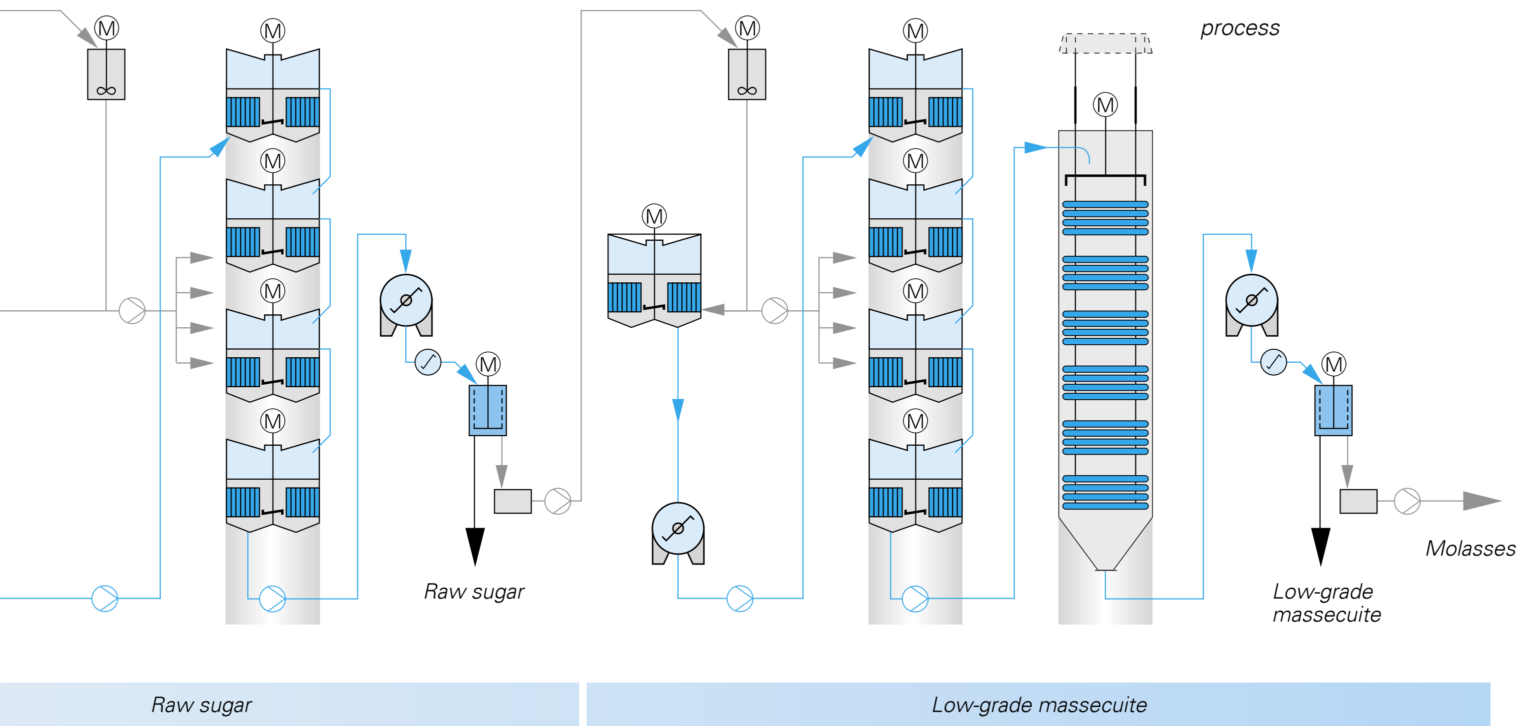
The physical process of crystallization allows an excellent separation of sugar from nonsugars. However, this requires optimum crystallization work producing crystallizate with a low percentage of aggregates and fine crystals. This ensures high yields in every stage of crystallization.

Into the eighties of the 20th century, evaporative crystallization of sugar took place almost exclusively in discontinuously operating (batch) units. Certain improvements in terms of both sugar quality and reduced energy requirements for crystallization were brought about by mechanical stirrers used in batch pans. However, crystallization undergoes several different process stages. Actually, the crystal formation phase requires a crystallizer with a small heating surface, as in this phase the evaporating capacity must be conformed to the crystallizing capacity. Towards the end of the process, the available heating surface is not sufficient for the required evaporation in many cases. A discontinuous unit, however, is designed for average conditions.

The introduction of the seeding technique using special pan seeding systems was the decisive step forward towards the production of uniform, low-aggregate crystallizate. Crystal formation was separated from the normal process and included in the seed production process.

However, the essential technological advance in the crystallization of sugar was the introduction of continuous pan boiling, because it allowed novel heat economy and plant concepts in the sugar house, along with substantial reductions of primary energy consumption.

The continuous crystallization process



Batch pans

Standard sizes of batch pans

Diameter	mm	3,200	3,600	4,000	4,400	4,800	5,200	5,600	6,000
Net volume, approx.	m^3	25.6	32.7	40.9	49.9	60	70.9	82.9	96.2
Heating surface	m^2	193	247	319	385	468	546	636	745

Experience gathered in more than one hundred years in the design and construction of batch pans and know-how acquired from BMA's vertical continuous vacuum pans now determine the design of modern BMA pans.

***Advantages and features*:**

- Central downtake
- Welded heating tubes with a tube-to-tube distance <10 mm (providing larger heating surfaces)
- Optimal calandria deaeration and condensate removal
- Mechanical stirrers conformed to calandria, downtake, shape of pan bottom and application
- Pan bottom designed for optimum flow (no dead corners)
- Starting volume <30%
- Low massecuite level above the calandria
- Excellent crystal quality even in large units (CV 25 to 30%)
- Efficient separation of juice from vapour

BMA designs and constructs batch pans for all crystallization products in the beet and cane sugar industry and for refineries. They are made in mild steel, or in stainless steel (in whole or in part).

Even though the sugar industry increasingly changes to continuous pan boiling, batch pans are still required, e.g. for the production of seed.

Batch pans for 1st and 2nd white massecuite

Pan seeding systems

When slurry is used as seed for pan boiling, the technological and economic demand that the product crystallizate be low in aggregates and free of fine crystals cannot be met. As the total surface of the slurry crystals is too small, the supersaturation increases during the crystal formation phase beyond the metastable region, because in this phase crystal growth cannot cope with the concentration of the solution.

Secondary nucleation, but formation of aggregates in the first place, deteriorates the product quality. In addition, a large percentage of the slurry crystals added are remelted due to the uneven supersaturation profile in a conventional pan. However, this (from a crystallization technology point of view) difficult seeding phase decisively influences the quality of the final product. To make this phase easier to control, it proved to be good to separate it from the boiling process, in terms of both time and space.

Standard 1st-seed cooling crystallizers

Net volume	m^3	2.1	4.2	5.0	6.8	10.0	15.0
Diameter	m	1.4	1.8	2.0	2.0	2.4	2.6
Max. total height*	m	4.4	5.3	6.0	6.0	6.3	7.2
Cooling surface	m^2	11.3	19.0	21.0	27.0	44.0	61.0

**incl. stirrer*

Production of 1st seed

The first step of seeding proceeds in a cooling crystallizer which is equipped with a stirrer specifically designed for a high shear rate. The low temperature and the clearly defined supersaturation ensure uniform growth of the added slurry seed crystals, avoiding the formation of aggregates.

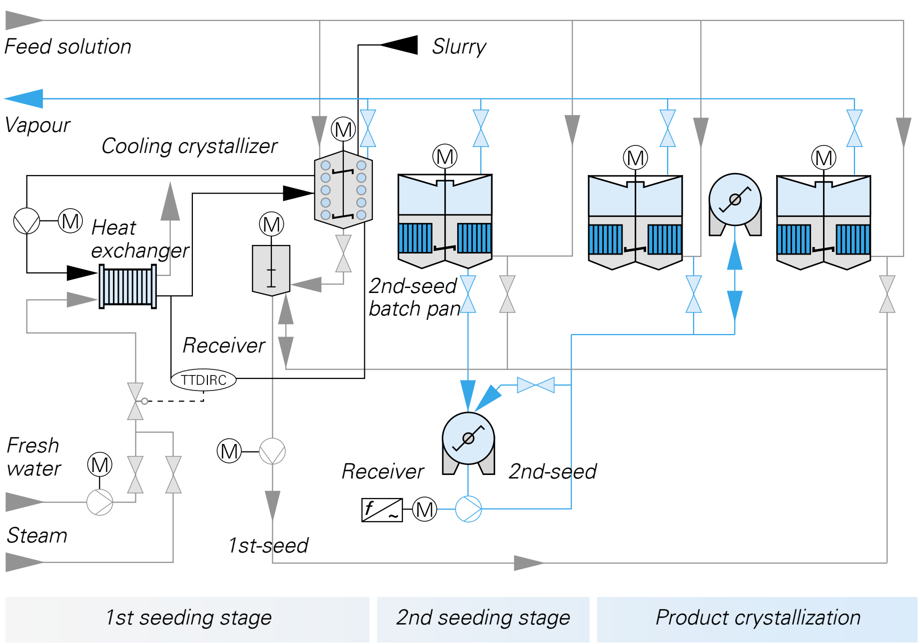
The syrup used (preferably thick juice) is subjected in the cooling crystallizer to evaporation to the required dry substance content, and the concentrated syrup is then cooled. When a supersaturation of 1.1 has been reached, it is seeded with the required quantity of slurry. Thereafter, the suspension is further cooled (slowly) to approx. 30°C. The massecuite-to-cooling-water temperature difference serves to control the cooling gradient and, consequently, to adapt the supersaturation to be maintained during the cooling crystallization process.

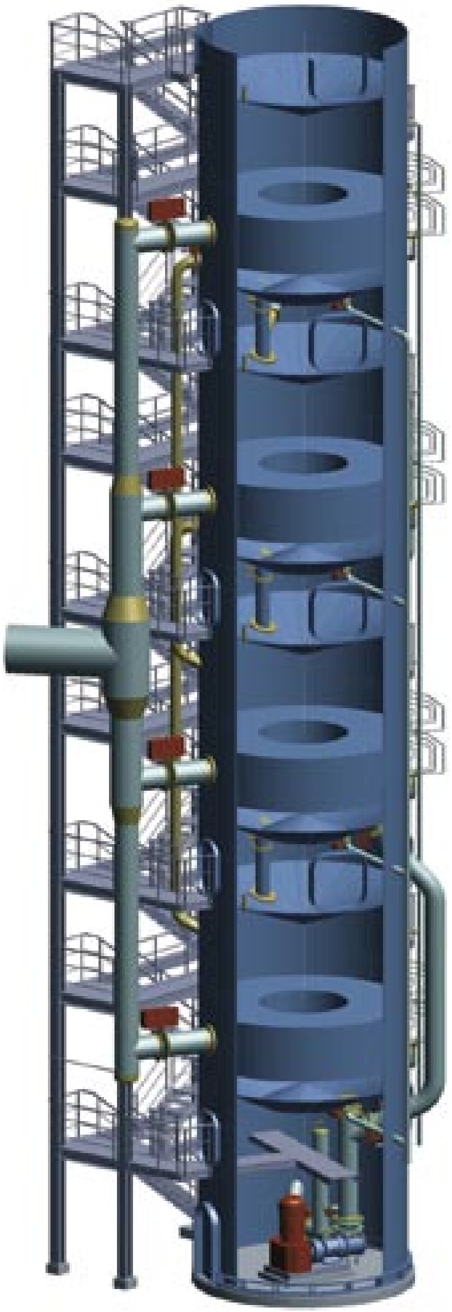
After the crystals have grown to a mean size of approx. 0.08 to 0.11mm (subject to requirements) at a crystal content of approx. 20% at the end of the cooling phase, the 1st-seed massecuite is dropped into a receiver.

In batch operation, 1st-seed massecuite can be directly used as seed in the product pans for a mean product crystal size of approx. 0.5mm.

For mean product crystals larger than 0.5mm, and for continuous operation in general, 2nd-seed massecuite is produced in a second step in batch pans.

One-/two-stage pan seeding system





VKT

Production of 2nd seed

In a second seed production step, batch pans produce crystallizate with a mean crystal size of approx. 0.3 to 0.5mm. Optimum plants use stirrers providing a high shear rate. New batch pans are optimally designed for the production of 2nd seed.

The feed solution is concentrated until the seeding point is reached at a supersaturation of approx. 1.1 and the 1st-seed massecuite is drawn in as quickly as possible. After a short phase of homogenization and temperature equalization, growing can start immediately. After growth, the resultant 2nd-seed magma containing approx. 45% to 50% crystals is dropped into the receiver. In batch boiling, the 2nd-seed magma is pumped past the units into a second elevated receiver, allowing the required quantity of 2nd-seed magma to be quickly drawn into the product pans. In continuous operation, the required quantity of 2nd-seed magma is fed into the respective continuous pans.

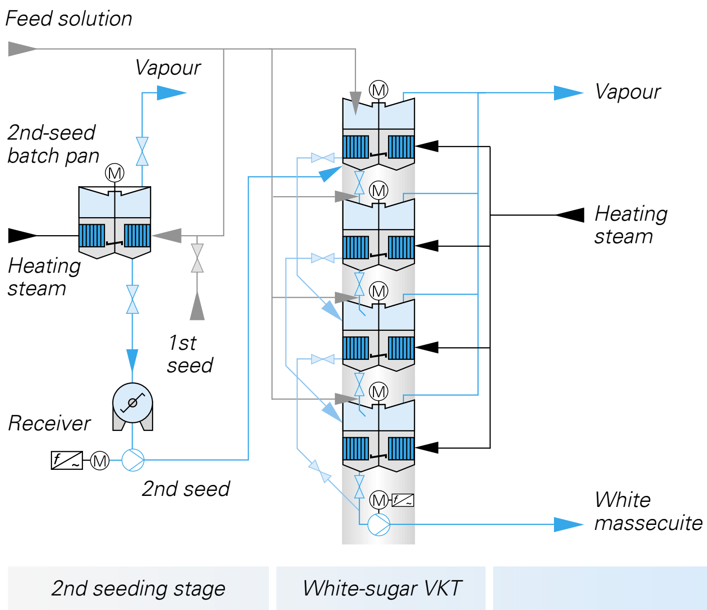
By adjusting the quantities of slurry and seed, the mean crystal size of white sugar can be varied within a range of approx. 0.5 to 1mm. For raw sugar, the product crystal size usually is 0.4 to 0.5mm, and for low-grade sugar approx. 0.3 to 0.35mm.

Advantages:

- Simple process control due to crystallization being limited to the growing and tightening phases
- Excellent product crystal quality along with good centrifuging ability of massecuite
- Use of high dry substance feed solutions without addition of water, even for high-purity solutions
- Optimum syrup washing and reduced wash water consumption by centrifugals
- Reduced sugar house steam requirements
- Flexibility of installation of 1st-seed system
- Optimum adaptation to product requirements

White-sugar VKT

with production of seed



Continuous boiling

BMA's vertical continuous vacuum pan "VKT" (Verdampfungs-Kristallisations-Turm) is based on a proved design principle: the vertical cylindrical crystallization chamber of the batch pan. It allows the use of mechanical circulators ensuring excellent circulation and mixing of the massecuite. The VKT consists of superimposed crystallization chambers, i.e. it is a cascade of stirring vessels, where the massecuite flows from top to bottom under its own gravity. The forced circulation practised, in conjunction with constantly low massecuite levels, allows the use of low-pressure heating steam, as the hydrostatic pressure of the massecuite column in a continuously operating unit is much lower than in a conventional pan.

Versions

The preferred VKT version has four superimposed chambers. It can be employed for all sugar varieties such as 1st and 2nd white (refined and basic), raw and low-grade, at beet and cane sugar factories and in refineries. For cleaning purposes, one chamber each of the white and raw sugar units can be bypassed via appropriate pipelines. 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.

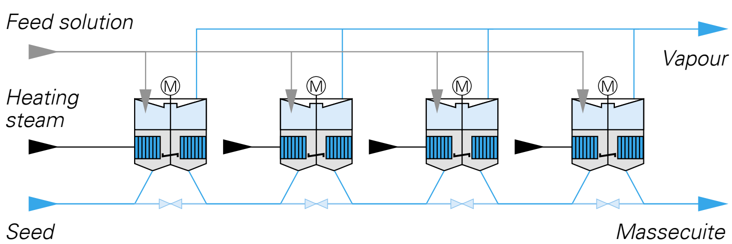
If the space occupied by an existing station equipped with modern, well-preserved batch pans shall be utilized for continuous operation, a horizontally cascaded unit (VKH) can also be used. All batch pans used should be similar in design and should have stirrers installed.

Operation

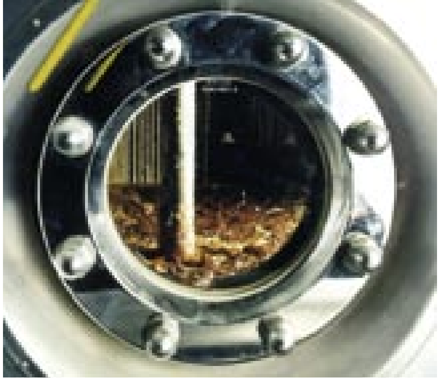
The seed produced in a special pan seeding unit as described above is fed into the first crystallization chamber. Feed solution is continuously fed into all chambers, intermixing between the chambers being excluded. The dry substance content and, consequently, the crystal content of the massecuite increases from chamber to chamber and reaches its maximum in the final chamber. Where a low-grade VKT is concerned, the optimum nonsugar/water ratio for subsequent cooling crystallization can be set in the final chamber.

Each VKT chamber can be adjusted separately, a fact which ensures safe and continuous operation and brings about technological advantages such as

- uniform tapping of heating steam from evaporators,
- uniform tapping of feed solution,
- uniform vapour tapping and condenser loading,
- uniform massecuite discharge.



Horizontal vacuum pan system (VKH)



View of a VKT 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 helps produce crystallizate which is characterized by a low percentage of fine and aggregate crystals. The crystal content of white massecuite can be as high as 55%, entailing a centrifugal yield of approx. 50%. Without mechanical circulation, such figures even cannot be achieved by steam injection frequently used as a circulation aid.

Due to the residence time behaviour in continuous crystallization, the crystal size distribution is slightly wider in the coarse crystal range. In actual practice the coefficients of variation are therefore somewhat inferior to those achieved in batch operation. However, the decisive criterion influencing the quality of the product is the quality and quantity of seed added in relation to the product.

Control

The control system a continuous vacuum pan requires is much less sophisticated than that of a batch pan, as it uses fixed setpoints only. The essential parameters to be controlled are:

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

White VKT control philosophy

The condition, i.e. the dry substance content, of the massecuite in all four chambers is controlled by way of the feed solution. The measuring system preferably used is the microwave measuring system, but also radiometric density measurements are still being applied. Inductive flowmeters serve to measure the feed solution flow rate which is then adjusted to the setpoint required by the massecuite control system (cascaded control).

The sum of measured feed solution quantities is used to add a quantity of seed in a defined proportion to the feed solution.

Heating steam and vapour pressure for all four chambers are under separate control, allowing optimum operation and disconnection of a chamber from the system for cleaning purposes. To adjust the VKT throughput, it is only necessary to change the heating steam pressure setpoints.

The massecuite level in each chamber is measured and kept constant by varying the massecuite discharge via the massecuite valves in the overflow pipes and, for chamber 4, by the speed of the massecuite pump.

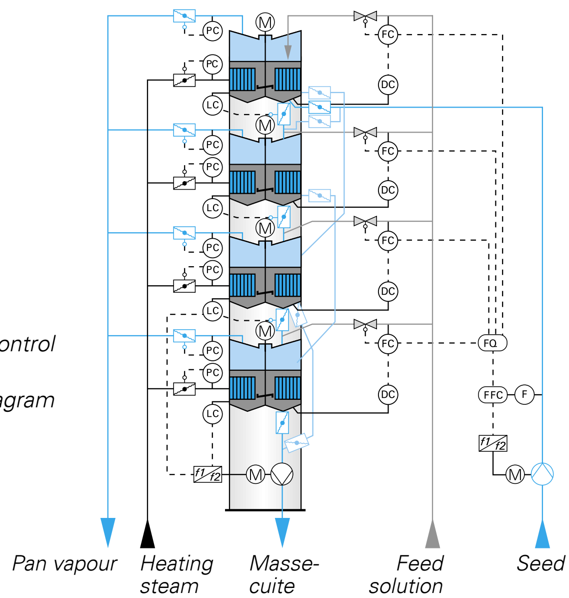
Raw or low-grade VKT control philosophy

Due to their negligible inclination towards incrustation, chambers 1 to 3 of a raw or low-grade VKT can use an external massecuite overflow, eliminating the need for level control systems.

The great influence the purity has on the boiling point rise allows a low-grade VKT to use a temperature measuring system to determine the condition of the massecuite, provided the vacuum is a stable and exactly controlled one and the purity of the feed solution is constant.

Cleaning

A fundamental demand made on a continuously operating vacuum pan is that it is available throughout the campaign without any total plant standstills. It is a well-known fact that incrustations cannot be fully avoided – especially where high-purity massecuites are involved.

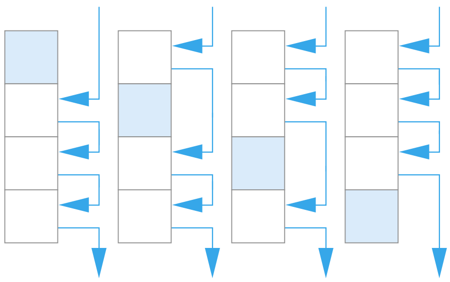


White VKT control diagram

Many mechanical precautionary measures have been devised to prevent incrustations, i.e. lining the massecuite-contacted walls of high-purity massecuite pans with thin stainless-steel membranes. These membranes vibrate slightly and so automatically repel incrustations forming thereon. Crystallization chamber cleaning requires a system which allows cleaning without the need to interrupt the crystallization process.

The vertical cascaded design of the VKT meets this requirement ideally. The fact that a chamber can be bypassed, allows it to be disconnected from the process, while the other ones continue to operate.

This means the VKT is available through the whole campaign, which is of major importance especially with massecuites with a purity over 94%. The working cycle of a VKT, i.e. continuous 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.



Schematic view of the cleaning process

Low-grade VKT

Advantages and features:

- Suited for all crystallization stages of beet and cane sugar factories and sugar refineries
- Optimum circulation of massecuite by mechanical stirrers in vertical cylindrical vessels, based on proved batch pans
- Uniform operation by continuous feed and removal of masses
- Optimum adaptation of crystallization chambers and stirrers to process conditions
- Reliable operation and easy process monitoring by fixed setpoint control
- High crystal content and, consequently, high yields
- Minimized incrustations due to specific know-how of design and manufacture of crystallization chambers, long operating cycles even with high-purity massecuites
- Permanent availability of VKT throughout the campaign due to special cleaning concept
- Use of low-pressure heating steam
- Special energy-saving configurations such as double evaporation and vapour compression in crystallization

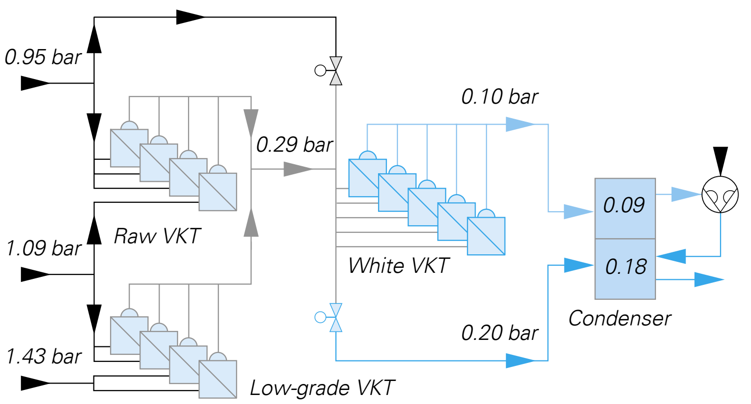
Standard vertical continuous vacuum pans (VKT)

Diameter	mm	3,200	3,600	4,000	4,400	4,800	5,200	5,600	6,000
Net volume, approx.	m^3	62.1	79.7	101	124	150	178	208	243
Heating area	m^2	772	988	1,276	1,540	1,872	2,184	2,544	2,980

- Easy startup and shutdown
- Quick and easy adaptation of throughput to changing factory conditions
- Chambers need not be cleared of massecuite for longer standstills even with high-purity massecuites
- Easy and simple increase in capacity by retrofitting an additional crystallization chamber
- Space-saving indoor or outdoor installation
- Simple foundations without steel structure

Advanced energy concepts

The specific design of the VKT crystallization chambers, a low massecuite level above the calandria, 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 pressures far below 1 bar. As a result, optimum operation of VKTs opens up numerous energy saving prospects. Among these is the double evaporation technology in crystallization, reducing the steam requirements in the sugar house and, consequently, of the whole factory by 3% to 4% o.b. The principle underlying double evaporation is to use part of the pan vapour to heat a VKT (e.g. for white sugar) and thus save the heating steam otherwise required by the evaporator station. Optimum adjustment of the condensation system still leaves enough heat to heat the raw juice, which is normally done with part of the pan vapour.



Crystallization and

double evaporation

Double evaporation:

a modern

energy concept

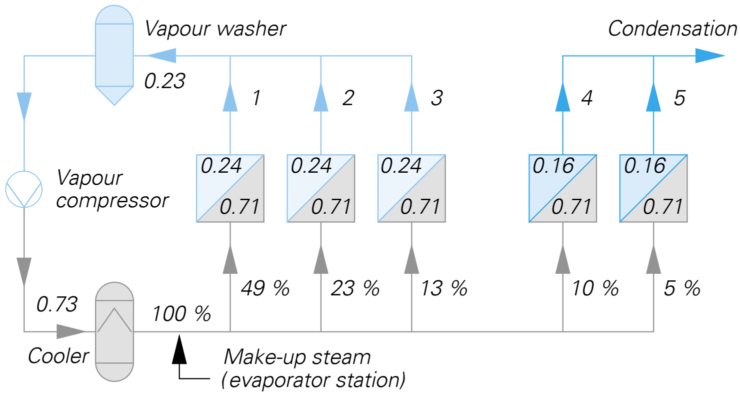
VKTs using low-pressure heating steam also allow economical employment of mechanical vapour compressors. Crystallization in conventional batch pans requiring a high heating steam pressure calls for a vapour compressor operating at a compression of 6:1 and a high power consumption. On the other hand, a VKT operating at a heating steam and vapour pressure of 0.71 and 0.24 bar, respectively, manages with a compression ratio of 3:1 to 2.5:1 and a correspondingly less costly compressor.

Refineries in particular have the possibility of practising thermal vapour compression, where a thermo-compressor compresses the batch pan vapours from 0.2 to approx. 0.3 bar. The motive steam used can be turbine exhaust steam. The compressed vapour serves as heating steam for a BMA refined sugar VKT operating at 0.1 bar vapour pressure.

Compound operation of VKT

and batch pans, practising

vapour compression



1 White VKT
2 Raw VKT
3 Seed pan
4 Low-grade VKT
5 Raw and low-grade seed pan

Vertical cooling crystallizers equipped with oscillating cooling tube banks

Crystallization and, as a result, desugarization of the mother syrup of low-grade syrup proceeds in two successive steps. The first step is evaporative crystallization, providing for a mother syrup purity drop of approx. 15 points and producing approx. 85% of the low-grade sugar crystal mass. Then, the low-grade massecuite is cooled down, maintaining an almost constant nonsugar/water ratio. The objective is to extract from the mother syrup as much sucrose as possible by continued crystallization of the existing crystals. This being the final stage of desugarization in the sugar production process, cooling crystallization is of great importance, since process control errors have an irreversible effect on the sugar lost to the molasses.

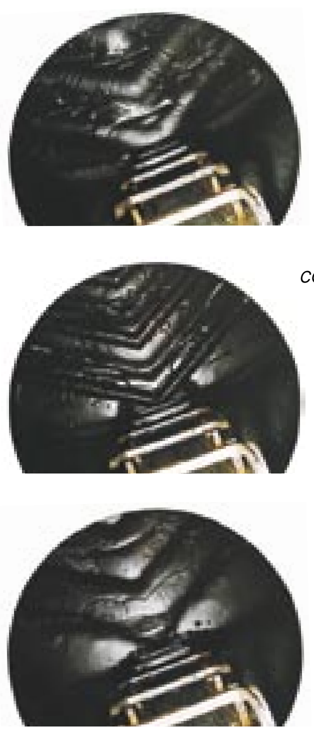
The cooling crystallization process must be optimized with regard to the parameters chosen. The rate of crystallization at which sucrose can be withdrawn from mother syrup largely depends on the supersaturation and the temperature of the mother syrup. However, the sucrose mass crystallized per unit of time results from the product of crystal surface and rate of crystal growth. The crystal surface is defined by the crystal content and the crystal size. The crystal content is limited by the maximum viscosity, and the crystal size has an essential influence on the centrifuging process. The absolute degree of desugarization that can be achieved at the same final temperature depends on the specific supersaturation; it increases with increasing nonsugar/water ratios and decreasing residual supersaturation. In actual practice, however, a higher nonsugar/water ratio leads to an increasing residual supersaturation, unless the residence time is extended at the same time.

Experience gathered with modern low-grade stations and studies made at the chair for Technologie der Kohlenhydrate at the Institut für Technische Chemie of the Braunschweig Technical University show that in beet processing, the optimum nonsugar/water ratio ranges from 3.8 to 4.0. However, under these conditions the viscosities rise so much that it is advisable to check the total equipment of the station concerned.

Temperature profile, residence time and residence time spectrum are parameters which can be influenced by the design. The massecuite temperature must only drop as quickly as allowed by the crystal growth rate. Otherwise the supersaturation of the mother syrup is liable to increase too much, leading to formation of fine crystals. In actual operation, a cooling rate of approx. 1 K/h is a good design figure.

Versions

In the development of low-grade cooling crystallizers BMA attached great importance to the theoretical fundamentals outlined above and devised cooling crystallizers which can easily cool high-viscosity massecuites, even at a nonsugar/water ratio ≧ 4, to a final temperature of 40°C. BMA cooling crystallizers are successfully employed in both the beet and the cane sugar industry and are exclusively available as vertical units.



Photos showing vertical movement of cooling water tubes at massecuite surface prior to cooling (reduced level)

Cooling crystallizer with 600 m^3 net volume

Standard cooling crystallizers equipped with oscillating cooling tubes

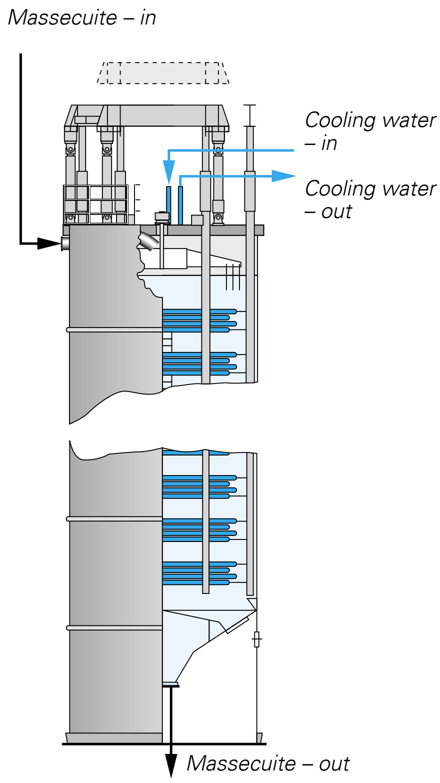
Net volume	m^3	220	300	340	400	467	533	600	667
Cylindr. height	m	15.5	19.5	21.5	24.7	27.5	30.1	33.5	36.4
Cooling surface min.	m^2	406	406	580	580	638	754	870	870
Cooling surface max.	m^2	406	580	638	754	870	986	1,102	1,218

The success of this cooling crystallizer version results from the following design principle: The cooling system consists of standardized block-type cooling elements, through which cooling water flows counter-current to the massecuite. The entire cooling system oscillates 1 m in vertical direction, and this movement, combined with the symmetrical arrangement of the cooling tubes, ensures an optimum massecuite residence time spectrum and cooling rate. The vertical movement of the cooling system can be varied in two steps, operated by six hydraulic cylinders symmetrically arranged on the crystallizer cover.

One half each of the cooling elements can be connected or disconnected, respectively. In this crystallizer version, the massecuite always flows from top to bottom. A low-speed distributor evenly spreads the massecuite over the cross-section of the unit. The cooling crystallizer has no massecuite-end antifriction bearings, plain bearings or stuffing boxes. The cooling water can be recooled in a separate cooling unit. Alternatively, it can be recooled by an air cooler mounted on the cooling system and following its oscillating movements, in which case the whole secondary cooling water system can be dispensed with.

Advantages and features:

- High yields due to defined residence time behaviour
- Excellent self-cleaning effect on oscillating cooling surfaces
- No problems encountered with high-viscosity massecuites
- Very large units, presently up to 1,000 t net volume and 1,200 m^2 cooling surface
- Small floor space requirements due to vertical design, suited for outdoor installation, avoiding building costs
- Excellent heat transfer between massecuite and cooling medium by uniform relative movement of massecuite on all cooling tubes
- Large specific cooling surface
- Hydraulic cylinders as a simple means for operation of the vertically oscillating cooling system
- Extremely silent internal-gear pumps providing high efficiency and low wear
- No overloading of plant by hydraulic pressure-limiting valve
- Low specific power requirements



Massecuite pumps

BMA massecuite pumps are best suited for realizing high throughputs with highly viscous massecuites. At maximum speeds below 40 rpm, delivery pressures of up to 10 bar can be reached. Owing to such low speeds, wear is minimized. The following BMA pump types are available:

Type	*Delivery* m^3/h
F 150	1 - 10
F 350	5 - 25
F 500	25 - 40
F 800	30 - 65
F 1000	65 - 100

Advantages and features:

- Extreme reliability
- High throughputs at low impeller speeds
- Leak-proof due to mechanical seal
- Clearance between seal and antifriction bearing housing protects the bearings and also facilitates inspection
- Easily accessible for maintenance
- Amply dimensioned connections reduce pressure losses
- Trouble-free pumping of high-viscosity massecuites
- Overhung impeller for free access to pump components
- Excellent price/performance ratio

Cooling crystallizer with oscillating cooling tube banks

Massecuite pump F 1000 F

© Braunschweigische
Maschinenbauanstalt AG
Postfach 32 25
D-38022 Braunschweig
Germany
Phone +49 531 · 804-0
Fax +49 531 · 804-216
www.bma-de.com
sales@bma-de.com