OPTIMISATION OF SALT SEPARATION ON PUSHER CENTRIFUGES

By: N. Keller Tel. 514 Date: 16.04.2009
Pusher centrifuges, cake washing, centrifuge rinsing, special screens

Summary

Every salt production plant needs a centrifuge to separate the salt produced in the evaporator/crystalliser by centrifugal force. In this way, the salt can be recovered in a ready to use form and with low residual humidity. This is what the pusher centrifuges of Ferrum and previously Escher Wyss have been doing worldwide for decades. Thanks to further advances, further improvements have been introduced that can have positive effects within the entire plant. When the solids cake is washed in the centrifuge, clean salt can be obtained or elutriation can be reduced. As centrifuges are always subject to a certain amount of contamination (crystallisation on the outside, slots blocking, solids deposits in the discharge area), they need to be cleaned periodically. Appropriate changes to apparatus and equipment allow the time needed for this step to be optimised and work for the operator simplified. Screen clogging occurs due to the product after several hours through crystallisation, which results in increased residual humidity. This process can be slowed down substantially by using modified screens.

Introduction

In salt recovery by evaporation, separation of the salt crystals from the mother liquor is an essential step. This step ensures that the crystals are maintained in their form as far as possible and no agglomerates are formed during the subsequent drying process. The centrifuges of Ferrum have demonstrated their reliability in this application worldwide. Their uniform cake formation ensures vibration-free operation while the method of product delivery allows for minimal crystal reduction. Despite these excellent attributes, further endeavours have enabled the mode of operation to be further improved, resulting in optimised use of energy and raw materials. Reference is made to these points in the following.

Product washing in the pusher centrifuge

Crystallisation is also a cleaning process. The valuable products crystallise pure; the impurities are concentrated in the mother liquor. When this process is carried out over any length of time, the impurity content in the mother liquor increases over time. Only when the amount of impurities introduced into the process with the brine is equal to the amount removed with the residual humidity on salt, is equilibrium achieved (working without purge). This condition can be undesired from two aspects:

- When the impurity content in the crystallization plant causes problems, e.g. due to boiling point rises or encrustations, operation obviously is not possible.

- When the purity of the salt is insufficient for the specific purpose, the plant can also obviously not be operated.

Where difficulties are encountered due to the aforementioned processes, purge is necessary by means of which the impurity content can be maintained at the required level depending on the purge volume and the purity of the salt can also be influenced.

For maximum salt purities, high elutriation volumes are necessary in this case, resulting in energy and product loss; while hot brine is removed, in addition to the impurities (desired), valuable product (sodium chloride) is also lost.

A distinct improvement can now be achieved here by cake washing on the pusher centrifuge. By means of appropriately arranged washing pipes, the cake is impinged with washing water; this water flows in a film over the surface of the cake pores and removes the mother liquor partly by displacement, partly by dilution.
Exceptional washing effects with corresponding economical operating conditions can be achieved by the selection of a suitable feeder and optimal positioning of the washing liquid feeding zone. The advantages of the multi-stage pusher centrifuge are clearly demonstrated in this area:

- The cake formation as a thick layer results in a regular cake of uniform thickness, so that each cake segment is evenly circulated by the washing water. There is also the fact that the liquid applied to the top of the cake can act as a plug, thus greatly improving the washing efficiency compared to thin film machines, where only a type of dilution wash is generally possible.

- The component-free design of the machine enables the washing devices to easily be integrated in the product space.

- The washing pipes can be freely adjusted in both axial and circumferential direction using simple fastening devices.

- In the case of sodium chloride, this washing device is arranged so that 3 pipes are each provided at the end with a flat jet nozzle. This arrangement allows the nozzles to be aligned so that the liquid jet strikes the cake slightly in tangential direction, so that splashing is avoided.

No statements on the achievable washing effect can generally be made according to experience. Important above all is the fact that by washing the cake, only the impurities contained in the mother liquor can be influenced. Embedded impurities, impurities adhering to the surface and impurities present in the form of solid matter cannot be removed by this method.
Shown on the following page is a measuring result as can be found in practice. The washing effect is defined as the ratio between the washed out impurities and the impurities contained in the mother liquor. Defined as the washing ratio is: Washing liquid volume in relation to the dry solids after centrifugation. To be taken into account is that the residual humidity only corresponds to the water content; however, also dissolved solids are present in the adhering liquid. For the sake of simplicity, it is assumed that this value is the same with and without washing; this approximation should be correct as long as the impurity content is not very high (approximately less than 10% of the valuable product).

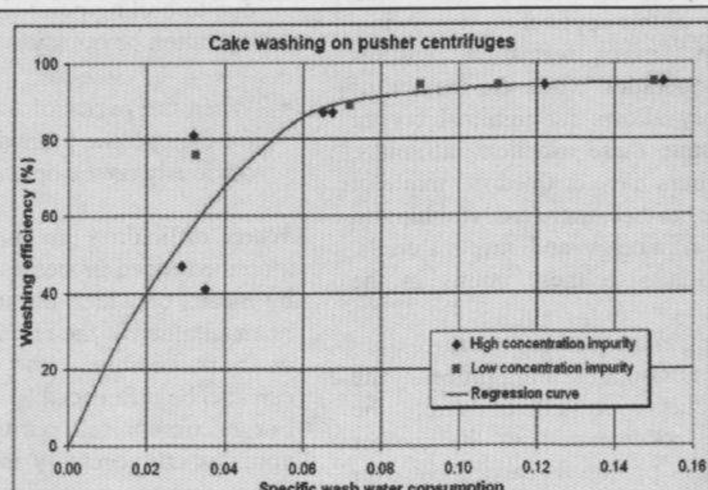


Fig. 1: Cake washing on pusher centrifuge, washing efficiency

If the cake is cleaned in this way, this has the following effects for the entire plant:

- The purity of the salt is achieved without the need for significant elutriation. A correspondingly smaller amount of valuable product is lost; in this case, sodium chloride.

- By washing the cake with unsaturated water, a specific amount of salt goes into solution; the solution is returned to the process without losses, however the water must be re-evaporated within the plant. This effect can be prevented when washing with brine; the washing effects in this case are less significant however.

- To be taken into account in the determination of the elutriation volume is also the influence of the increased contamination of the entire plant.

- It is conceivable that the methods used in the brine cleaning plant can be less effective, i.e. the use of precipitating chemicals can be reduced in any event, so that optimisation is possible from this aspect.

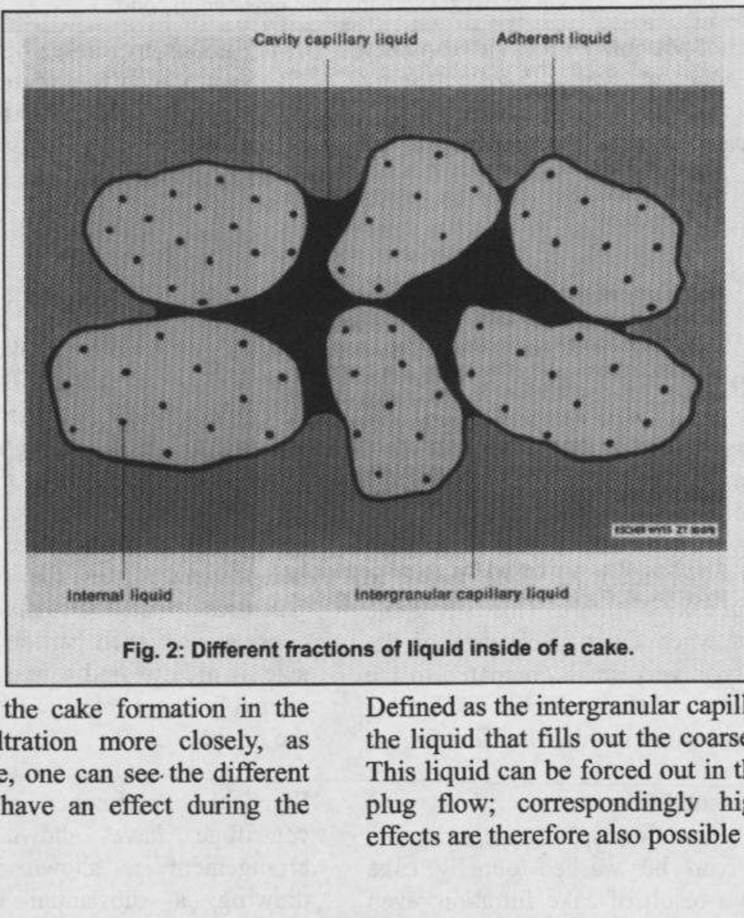


Fig. 2: Different fractions of liquid inside of a cake.

When looking at the cake formation in the area of cake filtration more closely, as illustrated opposite, one can see the different mechanisms that have an effect during the washing process.

Defined as the intergranular capillary liquid is the liquid that fills out the coarse capillaries. This liquid can be forced out in the form of a plug flow; correspondingly high washing effects are therefore also possible here.

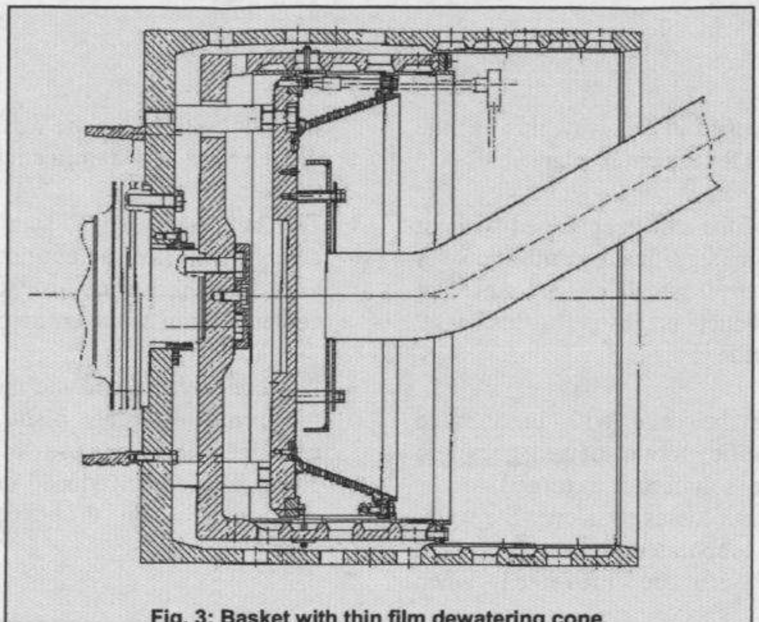


Fig. 3: Basket with thin film dewatering cone.

Plug flow is not possible with cavity capillary liquid and adherent liquid; here, cleaning takes place in the form of a film flow, a type of dilution wash.

It is difficult to foresee how the above liquid fractions mutually influence each other in relation to washing, so that more accurate statements are only possible by experimentation.

However, it can be said in general that according to the above curve, a washing effect of 90 to 95% is possible when the crystals are similar in terms of size like sodium chloride, i.e. 400 – 500 µm average particle size and a fairly smooth surface. Important is that the impurities are present only in the mother liquor as solids cannot be washed out in cake filtration. This is possible in any event when the particle size of the solid impurity is very small compared to the valuable product; cleaning is possible in this case via classification in thin film filtration.

Impurities in solid form

As previously mentioned, only impurities in liquid form can be washed out by cake washing. As a result of cake filtration, even very fine solids are embedded in the cake; this has a similar effect to filter-medium filtration. Extensive experiments both in the laboratory and on industrial machines have confirmed this effect.

The separation of these undesired solids is possible by classification however as they are much finer than the sodium chloride crystals.

Such classification can take place in thin film filtration, where the size of the filter opening determines whether a particle is retained or allowed to pass through. This thin film filtration is achieved in that the mixture is made to flow over a cone. The cone angle is selected so that the crystals glide independently over the screen due to the grade resistance and as no cake can form as a consequence, each particle, depending on its size, is able to find a free opening and glide over it or enter into the filtrate together with the liquid.

Practical experiments on a P80 pusher centrifuge have shown that with an arrangement as shown in the following drawing, a substantial reduction of the impurity content can be achieved.

- In the case of a standard machine with two-stage basket, the impurity content of the relevant materials is about 5 ppm.
- If the conical screen is installed in the inlet area, the impurity content can be reduced to about 2-3 ppm.

- This makes identical purities possible as on old machines where a massive counter-cone was installed in the inlet area as a type of thin film classification.

Periodic cleaning of centrifuges
Apparatus operated with solids or suspensions behaves completely differently to impurities than equipment operating with liquids (e.g. pumps). Solids can remain behind anywhere and if the liquid is a solution, then there is the risk of the particles adhering through drying of solution. The solution itself can also partially evaporate in cases of fine dusts, which in turn gives rise to the occurrence of solids that adhere easily to metallic surfaces.

The two following processes are illustrative examples for different cases:

- A Ferrum P80 pusher centrifuge can achieve with sodium chloride a throughput of about 50-55 t/h. If we assume that only one gramme of solids per second remains in the machine, this is in one hour 3.6 kg or in eight hours (which is a normal cleaning interval) 28.8 kg. Based on the total amount that passes through the centrifuge, this is however only 0.01%, i.e. almost nothing. But, 30 kg of salt in the solids casing of the centrifuge is a comparatively large amount, where there is a risk of the casing becoming clogged.

- When the liquid side is observed as in the above example, this is as follows: At a solids concentration of 50 per cent by weight in the feed, the filtrate quantity is also about 50-55 t/h. At a solubility of 26%, this corresponds to a salt volume of 13 t/h. For clogging screen slots in the case of a P80 pusher centrifuge on the second stage, a solids volume of about 0.5–1 kg is required (volume approximately 0.4 l). If this occurs within 8 hours, this is for the total filtrate salt volume 1 kg salt per 104 t dissolved salt, or in other words 0.001%. This means that a relatively small filtrate quantity must evaporate in order to close the screens by crystallization.

- Note: The above values are purely model examples intended to give a better understanding of the processes.

The above examples clearly show that it is virtually impossible, in the case of salt-like substances, to operate centrifuges for any length of time without rinsing being necessary. This is mainly associated with the fact that the liquid in these cases is a saturated solution, which on evaporation or vaporisation, already has an adherent effect in small quantities.

The fact that this mechanism is responsible for the problem is demonstrated as a counter-example by a centrifuge that is operated with cellulose in acetic acid. An essential part of the project prior to contract conclusion was that the centrifuge can be operated for 40 days successively without the need for cleaning (cleaning in this case means complete stoppage of the centrifuge, manual clearing out of the solid matter and rinsing of the screens from the rear). Both extended tests on a pilot machine as well as experience with the P100 pusher centrifuge currently in use show that these values can easily be achieved and even exceeded. However, as previously stated, the liquid does not contain any dissolved substances liable to crystallize out when a small part of the liquid evaporates or vaporises.

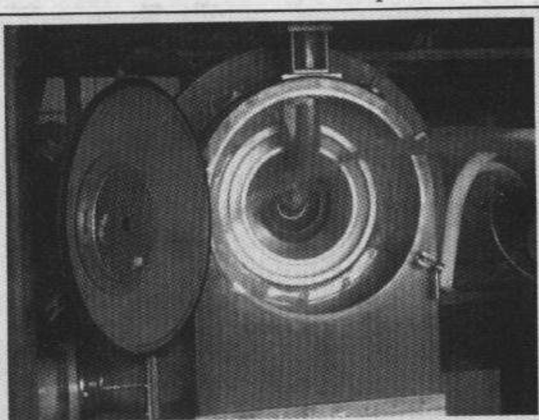


Fig. 4: Standard rinsing of pusher centrifuges.

Cleaning of a pusher centrifuge generally takes place in two steps:

- In the first and most important step, the inside of the drum is cleaned. The entire salt volume must be dissolved so that it can be removed via the filtrate. With reference again to the Ferrum P80, the minimum salt volume in the drum is 56 litres (resulting from a cake thickness of about 40 mm), corresponding to a salt volume of about 80 kg. Under the assumption of achieving a saturated solution during the cleaning process, a minimum of 240 kg of cleaning liquid is necessary for this stage. Realistic for a completely clean drum are about 300 – 400 l of water.
- In the second step, the outside of the drum, labyrinth and also the solids casing are cleaned. It is highly probable that the first two points (drum outside and labyrinth) in particular will only be achieved with a fixed installation.

Previous procedure

The procedure for cleaning a centrifuge in earlier times takes place as follows: The supply to the centrifuge is initially stopped. This should preferably not take place abruptly, but gradually so that the cake height in the drum is able to reduce to the possible minimum, so that the necessary cleaning liquid volume, respectively the time involved is reduced and optimised.

Since liquid also escapes on the solids side during the cleaning process, the solids outlet must be brought into the cleaning position as a next step. For this purpose, diverse variants are conceivable – from purely manual installation of a hopper over the plant-sided solids transport pipe through to a pneumatically driven swivel pipe, etc.

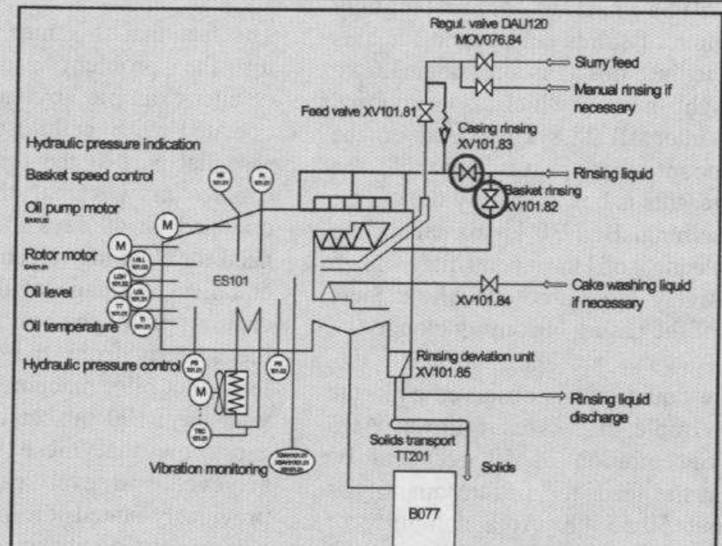


Fig. 5: General PID pusher centrifuge with rinsing

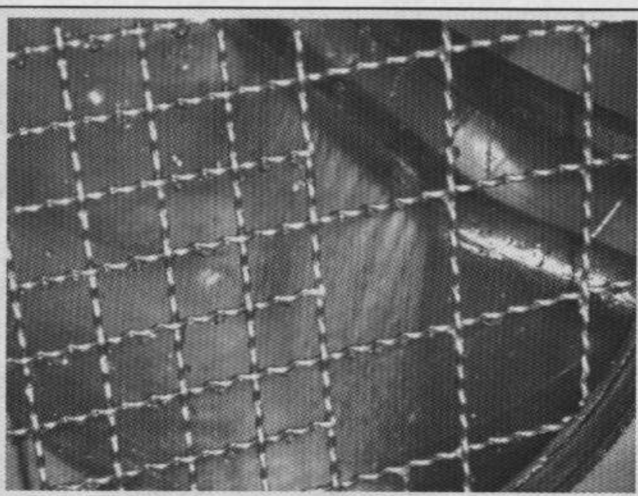


Fig. 6: Rinsing basket inside

In the next stage, the inside of the drum is now cleaned by the operator using a water hose. If this method is used with the necessary care by operating personnel, it is more or less optimal, depending on where the water jet is aimed. Depending on the conditions at the place of use, the operator may also be splashed as the cleaning liquid bounces off the drum. The solids casing is also cleaned in the same process, whereby the operator must stand closer to the machine, which is not particularly pleasant.

Once the drum and solids casing are clean, the outside of the drum and labyrinth are rinsed, for which purpose the respective valves are opened and these areas cleaned at the discretion of the operator - discretion is necessary as these areas are not visible.

In the last stage, the machine is left to dry for 1 - 2 minutes after cleaning before production can be resumed.

New procedure

As the drawing opposite shows, the centrifuge has recently been modified so that a separate jetting lance is available for cleaning the inside of the drum; nozzles are also installed in order to clean the solids casing. These modifications allow the installation to be changed so that cleaning of the centrifuges takes place only via two permanently installed valves, i.e. the drum inside cleaning valve and casing rinsing valve. These valves can be operated manually or (as suggested by Ferrum) from the central control. In the latter case, the necessary rinsing time for both the inside of the drum and casing can be determined during commissioning so that cleaning is optimised in subsequent operation.

This cleaning procedure has shown to be highly reliable in other industries where the centrifuge is closed for process reasons so that manual rinsing is not possible.

The picture opposite shows a jetting lance in use. Clearly visible is how water is uniformly applied over the entire length of the drum.

Influence of the screens on the centrifuge cleaning interval

As mentioned under cleaning, the centrifuge must be cleaned periodically because solid deposits hinder correct operation over extended intervals. In addition to clogging of the solids casing, another effect can occur to a greater extent, which influences the efficiency of the downstream drying section.

If a discharge sample is taken every half an hour to one hour from the time of starting the centrifuge, noticeable is that after a certain time within which the residual humidity remains constant, the humidity gradually increases.

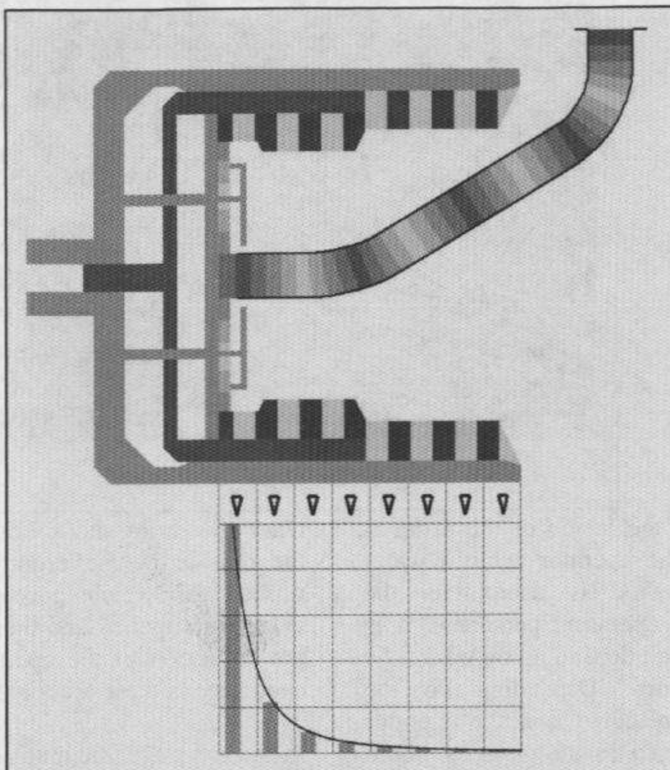


Fig. 7: Filtrate quantity over basket length

In order to better understand this process, one has to imagine how liquid is produced in the filtrate area in a pusher centrifuge. The majority of the filtrate naturally occurs in the inlet area. It can be assumed that up to 90% of the liquid already drains in the first 5 cm. The remainder of the drum then serves only for dewatering the solid matter. This is shown roughly in the graphic opposite.

If we look at the above example of the P80 again and assume that only a residual humidity reduction from 4 to 3% takes place on the second stage, this means that a filtrate quantity of just 537 kg/h discharges through the second stage screen compared to 49463 kg/h on the first stage. The filtrate quantity is therefore just about 1% of the quantity on the first stage. With an assumed free screen area of about 3% respectively, the flow rate on the slot is not fully utilised). The flow rate on the second stage with the same calculation is first stage is about 0.637 m/s (the value is obviously much higher in reality, but for this only 0.007 m/s (please note that this is only a model example to give a better understanding).

The above figures make the following clear:

- The flow rate on the first stage is relatively high as is the filtrate quantity, so that crystallization in the screen slot is inconceivable.
- On the second stage by contrast, the conditions for screen clogging through crystallization are very good.

These flow conditions can generally not be altered because they are primarily dependent on the filtration characteristics of the product, which must be accepted as they are. The question therefore arises as to whether the screens can be optimised.

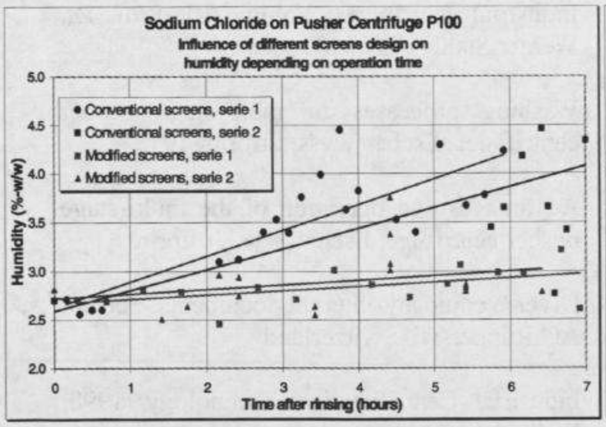
The effects of this screen clogging through crystallization are shown in the following practical example (which is admittedly somewhat extreme). In the case of a new P100 in a European saline, it emerged during commissioning that the residual humidity very quickly increased to values above 3% instead of the guaranteed 2.7%. The screens on the second stage were eventually replaced by special screens with less slots and a modified slot geometry. During initial operation with product after conversion, a drastically changed residual humidity characteristic was noticeable as shown in the diagram opposite. Where a rapid increase in the residual humidity was previously noticeable, a humidity that remained constant for much longer could now be observed.

This positive influence can be seen also on other products and in other plants, as the following data from a plant in Russia shows. In this case, a product is processed at temperatures above 100°C. The increase in the residual humidity with normal screens is generally not very high, but nonetheless a positive influence of these modified screens is clearly noticeable.

Practical information

It can generally be noted that the following parameters are important for screen crystallization:

- Content of dissolved solids in the mother liquor. As higher the content of dissolved solids as more solids may crystallize per quantity of evaporated or vaporised liquid.
- Where temperature has a significant influence on the solubility, crystallization can occur when the liquid cools down only by several degrees centigrade (and this is possible because of the ventilation inside of the filtrate casing).



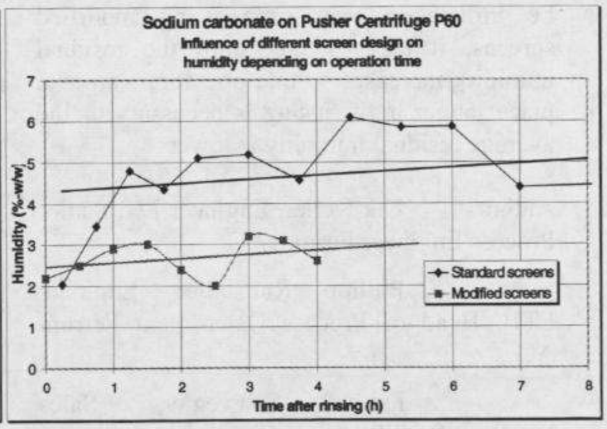


Fig. 8: Influence of screen type to humidity for NaCl Fig. 9: Influence of screen type to humidity for SodiuCarbonate

- The higher the temperature, the more likely cooling or evaporation/vaporisation will take place, which can also result in crystallization in the screens.

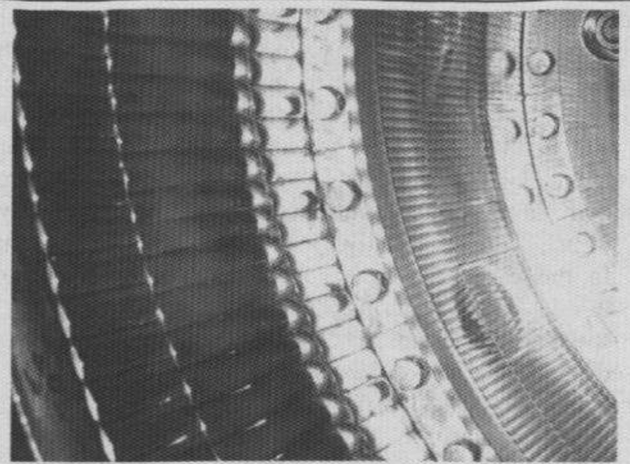


Fig. 10: Modified screens built into the second stage basket.

In order to estimate whether modified screens can have a positive influence, the following procedure is recommended: After complete cleaning of the centrifuge, a discharge sample
The following is important however: The generally achievable residual humidity normally cannot be influenced by the screens, this depends on the product characteristics. The residual humidity behaviour can however be influenced over time using modified screens; it takes longer until the residual humidity increases so that operation can take place longer until rinsing is necessary or the average residual humidity is lower.

Authors Nik Keller, Engineer FH, Senior Process Engineer Ferrum AG

Philipp Ruhstaller, Engineer ETH, Head of Process Department Ferrum AG

Fredy Schwegler, Sales Manager Asia, Ferrum AG

must be taken directly after restarting with product and further samples after every 30 – 60 minutes. This procedure must be continued as long as possible until cleaning is necessary due to clogging or excessive residual humidity. If during this time, a distinct increase in residual humidity is noticeable, it can be assumed that modified screens have a positive influence.

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