CONTINUOUS PROCESSING OF HIGHER PURITY SUGARS

By Ted D. Milner and Derrald H. Houston

BACKGROUND

Continuous Centrifugals have been used for a long time in the beet and cane sugar industry for A-masseucite, B-masseucite, and affination of C-magma. As early as 1962, Silver Engineering made a 22° basket for continuous centrifugals. This design had only limited success. In 1963, more successful 24° and 26° baskets were designed for use in the high raw beet massecuite. In 1964, Silver Engineering developed the model 104 Continuous Centrifugal with a 28° basket for use in both the beet and cane sugar industries. It was understood at that time, as it is today, that centrifugals with greater basket angles will result in higher color sugar.

The model 104 Centrifugal was designed so the massecuite was fed in the center and flowed to the side of the loading bowl. Often, there was a "roping" problem in which the massecuite failed to spread evenly across the screen. This would change the load on the motor and cause the feeding system to fluctuate. Beside the problems with the side feeding system, it also at times had problems with sugar lumps. In 1965, the model 104 was first equipped with a crystal saving dome made of stainless steel. This was tested in the Pepeekeo Mill. A year later, in 1966, Mr. Clarence Steele of Silver Engineering patented a dome of stainless steel and rubber, designed to combat the sugar lump and crystal damage problems. This device helped point the way for future developments.

The model 3630 Centrifugal was under development in 1972 for use in the beet and cane industry. This machine had a 30° basket and was intended to be used for B-massecuite as well as affination of C-magma.

Silver Engineering's product development program was slowed due to various ownerships of the company until 1989, when it became Silver Weibull.

In 1990 a new design was developed by Silver Weibull, as their model 5000, to meet the demand for higher quality sugar. The new high grade Continuous Centrifugals have a 43 inch diameter basket with a 25° basket angle and a very long working surface for longer purging time of the sugar.
APPLICATION

High grade massecuites and magmas are easy to purge but hard to keep on the screens, so a 25° basket should be used.

One of the best applications for the high grade Continuous Centrifugal is when the sugar is made into magma or is to be melted. Three models are available:
1) The model 5000M high grade Continuous Centrifugals are equipped with magma mixing, which will produce a high brix, lump-free magma with very little damage to the sugar crystals. This model can also be used as a pre-melter which will partially melt the sugar crystals and produce a low brix magma.
2) The model 5000MM high grade Continuous Centrifugals have magma mixing and are also equipped with a melting system which completely melts all the sugar crystals.
3) The model 5000HG high grade Continuous Centrifugals have a dry sugar crystal saving apparatus in the form of a Falling Dome, or a Flutter Dome. With these devices the sugar crystals are decreased in speed to minimize the crystal damage in dry sugar.

Different applications of high grade continuous centrifugals have different capacities:
1) Affination of low raw beet, 89-92 purity magma:
   580 cubic feet per hour or 25 metric tons per hour of magma
2) Affination of A- and B-raw cane, 98.5-99.5 purity magma:
   800 cubic feet per hour or 35 metric tons per hour of magma
3) Intermediate remelt - cane refinery, 88 purity massecuite:
   580 cubic feet per hour or 25 metric tons per hour of massecuite
4) Soft brown sugar - cane refinery, 85-86 purity massecuite:
   500 cubic feet per hour or 21 metric tons per hour of massecuite
5) Intermediate or high raw beet, 88 purity massecuite:
   700 cubic feet per hour or 30 metric tons per hour of massecuite
6) A-raw cane, 85 purity massecuite:
   815 cubic feet per hour or 35 metric tons per hour of massecuite
7) B-raw cane, 83 purity massecuite:
   700 cubic feet per hour or 30 metric tons per hour of massecuite

CAUTION ON APPLICATION

To make the high grade Continuous Centrifugal work properly, it must be used in the right application, and is not intended to replace all Automatic Batch Centrifugals. A 25° basket has some special requirements:
1) A continuous supply of massecuite.
2) Well-mixed massecuite.
3) A minimum of 2.5 meters of massecuite head above the feed valve.
4) Massecuite at a minimum of 65°C.
5) A maximum of 32% coefficient of variation in sugar crystal size.
6) Massecuite brix not higher than 93.
7) Massecuite purity not lower than 83.
8) A working screen with a low coefficient of friction.

OPERATION

An automatic, air-operated knife gate valve protects the motor, the drive, and the basket. This valve will close in the event of an overload condition or feeding system upset.

The massecuite feed control butterfly valve is automatically adjusted by a process controller to keep a constant load on the motor.

The massecuite flows into a totally enclosed feeding nozzle which has centering cones. These cones drop the massecuite into the feeding bowl in the rotating accelerator bell assembly. At this point, small amounts of water and saturated steam are added to the massecuite through the Silvortex and fed into the accelerating bell to heat the massecuite and lower its viscosity.

From the accelerator bell, the massecuite discharges onto the spreading ring at the bottom of the basket. From here, it flows upward onto the screen saver and then onto the lower part of the working screen. The syrup quickly separates from the sugar crystals in the lower part of the screen. Sprays wash the sugar just above the color line to get a low color sugar. The 25° basket keeps the sugar on the screen longer, which gives the wash water more time to remove the syrup from the surfaces of the sugar crystals and minimizes the amount of wash water required.

Two forces cause the sugar crystals to travel up the basket:
1) The force of the massecuite being fed behind it.
2) The "pushing force," which is the gravity factor times the SINE of the basket angle. The "gravity factor" is the centrifugal force caused by the rotation of the basket.

The largest problem with a basket having a low angle of inclination is that the pushing force is very low. It is very important to keep a good supply of massecuite feeding onto the screen. If the feed is not continuous the sugar can dry in place, causing slabs of sugar to break loose from the basket surface, and an unbalanced condition will occur.
FORMULAS

\[ G = 0.000028416(r)(n^2) \]
\( r = \) The radius at the point where the gravity factor is desired in the basket, in inches.
\( n = \) Number of revolutions per minute.

\[ Q = \text{Capacity in cubic inches per minute} \]
\( Q = \text{Cubic feet per hour} \times 28.8 \)

\[ W_b = \text{Thickness of the wall of massecuite at the bottom of the basket.} \]
\[ W_b = \frac{Q}{D_b(3.1416)n} \]
\( D_b = \text{Diameter at the bottom of the basket, in inches.} \)

\[ S = \text{The speed the sugar will move on the screen in inches per second.} \]
\[ S = \frac{Q}{112.9(D_b^2 - (D_b - 2W_b)^2)} \]

\[ T = \text{Time the sugar is on the screen in seconds.} \]
\[ T = \frac{S(D_b - D_t)}{\sin A} \]
\( A = \text{Basket angle from the vertical, in degrees.} \)

Example:
A high grade centrifugal with a capacity of 500 cubic feet per hour is running at 1500 RPM. The 25° basket has a top diameter of 43 inches and a bottom diameter of 23 inches. We want to find the thickness of the massecuite at the bottom of the basket, the speed the massecuite moves up the basket, and how long the sugar is on the screen.

\[ Q = (500)(28.8) = 14400 \text{ cubic inches per minute.} \]
\[ W_b = \frac{14400}{23(3.1416)(1500)} = 0.133 \text{ inches thick} \]
\[ S = \frac{14400}{112.9(529 - 516.8)} = 10.5 \text{ inches per sec.} \]
\[ T = \frac{4226}{10.5} = 2.25 \text{ sec.} \]
DESIGN

The proper evolution of a design was always toward simplicity, but this usually occurred after the design had passed through a stage of complexity and less than satisfactory operation. The true center-feeding system of the model 5000 has solved the problems which Silver Engineering had in their model 104 side-feeding system.

The type of working screens is an important part of the design. The screen is a round hole design, has a low coefficient of friction, and is made of stainless steel or chromium plated stainless steel. The screen has 15 to 22 percent open area for the syrup to drain through.

The basket is made of special high tensile strength stainless steel having high resistance against stress corrosion. By the process of shear spinning, the basket cone's tensile strength is double the original strength of the material.

Tests have determined that high purity sugar will slip off the screen at a coefficient of friction of 0.58. The sugar crystals will not move at a coefficient of friction of 0.36. To select the basket angle of 25° we took the average of these coefficients of friction, which is 0.47. The ARC TAN of 0.47 gives an angle of 25° from the vertical, and is the safest basket angle to use for high pol, low color sugar.

MAGMA MIXING

The magma mixing system rewets the dry sugar to make a lump-free magma with very little crystal damage. If the magma will be used as footing in a vacuum pan, it should be made with cool clean water to ensure uniform and low color sugar crystals. This will remove small or false crystals and not add more color to the magma. However, if it is going to be affinated in a continuous centrifugal, the magma should be made with a low color syrup. This will hold the magma together so the masscuite feeds better into the continuous centrifugal.

The mixing medium is sprayed onto the upper shroud ring, near the point where the sugar discharges from the top of the basket. Together they are thrown outward onto an inverted cone where the magma is mixed. The heavy layer of magma absorbs the high impact of the sugar and stops most of the crystal damage. The force on the magma causes it to roll on the mixing ring, making a lump-free, smooth magma. By changing the amount of mixing medium, any desirable brix can be obtained. When making a very high quality, low color magma with very little crystal damage, it is very helpful to increase vacuum pan capacity.
VACUUM SYSTEM

The syrup flows out of its collecting chamber via two sealed pipes arranged to allow the use of a vacuum. The vacuum has four main benefits:
1) It keeps the molasses from blowing past the shroud seals and getting into the sugar compartment.
2) It helps hold the sugar on the screen.
3) It helps reduce the sugar color.
4) It pulls some of the syrup from the sugar crystals, which reduces the requirement for wash water.

The vacuum system includes a sealed molasses tank, a molasses trap, a cyclone entrainment separator, and a vacuum fan. The molasses and air from the centrifugal discharge into the top of the molasses tank. By keeping the tank at a negative pressure, a vacuum will also be produced in the molasses compartment of the centrifugal. Vacuum is created in the molasses tank by means of a fan which pulls air from the space above the molasses. Any molasses entrained in the air can be removed by a molasses trap followed by a cyclone entrainment separator. The system is designed to produce a vacuum of 1 to 4 inches of water within the molasses compartment.

MINIMIZING SUGAR LUMPS AND CRYSTAL BREAKAGE IN DRY SUGAR

When a standard continuous centrifugal is used to produce high grade sugar, it can create sugar lumps and cause crystal breakage. Sugar crystals are discharged from the basket at velocities as high as 405 feet per second in low grade centrifugals. After leaving the basket, the crystals travel roughly 2 feet before impacting the wall of the sugar housing. The extent of crystal breakage is a function of the velocity, the angle of impact, and the moisture or film surrounding the sugar crystals. Crystal breakage can be reduced by lowering the velocity at which they leave the basket. In high grade continuous centrifugals, the speed required for separating the crystals from the syrup will vary from one grade to the next. Type B-massecuit will be discharged as high as 304 feet per second, while a type A-massecuit can be as low as 240 feet per second.

In the standard design, the crystals move up the basket, turn a sharp corner, travel across the upper shroud ring, and discharge against the vertical wall of the sugar housing. As they move up the basket, the crystals become segregated, with the smaller crystals concentrating near the working screen and the larger crystals “floating” on top. This effect is more pronounced for a 25° basket angle than for a 30° basket angle.

When they reach the sharp corner, the smaller crystals immediately change direction and slide across the upper shroud, causing them to pick up speed. The higher velocity causes increased breakage when they hit the sugar housing. The larger crystals
cannot change direction as quickly as the smaller ones and follow a higher path. They
do not contact the shroud and do not speed up, so there is less breakage.

The smaller crystals pack tightly together and form lumps when they hit the sugar
housing. The larger crystals impact at a higher point on the housing. They do not
tightly pack together, but build up because the lumps of smaller crystals below them
keep them from falling.

In the past, a number of crystal saver designs were tried, such as domes, air curtains,
rotating vaned rings, and brushes. All of these met with limited success. Only recently,

improved crystal savers have been designed that produce satisfactory results. In a

high grade continuous centrifugal, a crystal saver ring with a rounded corner is attached
to the top of the basket. The crystals flow around the corner and immediately discharge
from the basket at a level above the shroud ring. They do not contact the ring and do
not speed up, so breakage is minimized. As the crystals move around the corner, they
are squeezed together, eliminating much of the size separation that occurred as they
moved up the screen. This mixture of large and small crystals does not pack tightly
together as easily as the small crystals by themselves, and the formation of lumps is
greatly reduced.

The high grade continuous centrifugal also includes a crystal saver dome ("falling
dome"). Instead of hitting the vertical wall of the sugar housing, the crystals contact the
dome at a small angle and gently curve downward. The shallow contact angle and the
smooth surface of the dome help reduce crystal breakage and the formation of lumps.
The small amount of lumps that remain in the sugar can easily be removed by passing
the sugar through a screening device (e.g. a Thompson screen).

A crystal saver device called a flutter dome is currently being developed. Not yet
commercially available, it shows great promise in reducing the formation of lumps. The
flutter dome has a series of overlapping, flexible elastomeric rings arranged so the
discharged sugar makes contact with them at a shallow angle and is gently curved
downward to a vertical flutter curtain. Warm, dry air from an external blower is
introduced into the area above the flutter dome. The pressurized air forces its way past
the overlapping ends of the elastomeric rings and causes them to flutter, breaking up
any sugar lumps which may have formed. In addition, the warm, dry air removes
moisture from the sugar crystals, further reducing the tendency of the sugar to form
lumps.

As the design problems are reduced in the centrifugal, we find that the quality of the
massecuite itself becomes of paramount importance. Some sugar crystals are hard to
break and the continuous centrifugal has excellent performance. Other crystals are
easier to break, and the performance of the centrifugal suffers. Problems we have
found with the massecuite are high coefficient of variation (CV) in crystal size, ash,
dextran, soft crystals, pH, and crystal conglomerate.
DOUBLE PURGING OR AFFINATION

Double purging, or affination, of low grade massecuite is a means of improving sugar quality. This method improves the quality of the remelt sugar or magma used for vacuum footings, and results in higher grade B- and A-massecuites. The advantage of double purging is that, when used with the conventional three-boiling process, it is possible to prevent the recirculation of impurities and color back to the high grade station.

Conventional double purging uses two sets of continuous centrifugals. Low grade massecuite is fed into the first stage centrifugals. This type of massecuite is difficult to purge and can best be handled by a standard centrifugal with a 30° basket, such as the model 4630. The first stage centrifugals are equipped with a magma mixing system. Little or no washing is applied in the first stage. The magma mixing system combines the sugar with syrup from the second stage centrifugals to form a magma of about 90 brix with very little degradation of the crystals. If lower color affinated sugar is desired, cool water can be used instead of the syrup.

The high brix magma is fed into a feeder mixer which delivers it to the second stage centrifugals, where it is washed. The mixing process creates a scrubbing action. Holding the magma in the feeder mixer for a few minutes increases the scrubbing time. The longer the sugar is scrubbed, the easier it is to wash the molasses film from the crystal surfaces.

The magma supplied to the second stage centrifugals is very easy to purge. It requires only 1200 to 1600 Gs to purge, and can be handled by model 5000MM high grade machines having a 25° basket. These centrifugals will produce the lowest possible color in the affinated sugar, and are equipped with a magma mixing and melting system that completely melts the sugar. The melted affination sugar is sent to the high grade station, and the syrup is returned to the low raw vacuum pan.

Breakage of crystals during the first purge will drastically reduce the separation rate of the magma during the second purge. To reduce crystal breakage, continuous centrifugals equipped with magma mixing and an open bottom are usually preferred for the first stage. To further reduce crystal breakage, the first stage centrifugals are operated at a lower speed that will produce a maximum of 2000 Gs. The speed can be changed by using different sized sheaves in the drive system.

The low grade massecuite is much harder to purge than the magma. The capacity of the first stage centrifugals will be less than half the capacity of the second stage machines, so the first stage will need more centrifugals than the second. Sometimes three model 4630 centrifugals will feed one model 5000, and other times two 4630s will do the job. Higher capacity plants will require additional machines; for example, five model 4630s feeding two model 5000s.
By having individual centrifugals for the first and second stages, the capacities can be properly balanced, and each machine can be adjusted to produce the best results. In addition, each machine is easily accessible for replacing screens and performing other maintenance work.

In recent years, centrifugals have been built which combine the two stages into one machine. These centrifugals are very hard to operate and adjust for correct results. The baskets are stacked one above the other, which makes access and maintenance extremely difficult. The capacities of the two stages cannot be balanced by adding more machines. Magma passes quickly from the first stage to the second stage, and there is no mixing or scrubbing of the crystals to improve the washing process. If both baskets are driven by one shaft, the speeds will be the same and the G-forces cannot be changed on one basket without affecting the other.

THREE BOILING WITH AFFINATION AND FIRST WHITE REBOILING

At a cane sugar factory in the Cauca Valley of Colombia, S.A., a very good quality of direct to white sugar has been produced by using a double affination process. The normal Plantation white sugar uses a Sulfonation process, and the color returns after a few days. The double affination process does not require Sulfonation. The first affination step is a normal double purging of low grade massecuite as described earlier. The second affination step is a double purging of the final raw sugar. Without this second affination step, a normal raw cane sugar has a color of 2000 to 3000 by the ICUMSA scale. With the double affination process and reboiling, we were able to obtain a color of 40 to 90 on this direct to white sugar. In a less sophisticated market, this product is very desirable as a direct consumption sugar.

CONCLUSION

The technology of using specially designed baskets in continuous centrifugals has been developed for 35 years at Silver Engineering. We have made a lot of progress in the purging of high purity sugars. Using special high grade continuous centrifugals such as the model 5000 in the beet and cane sugar industries has made it very easy to create magma and to completely melt the sugar. The longer retention time on the 25° basket has helped reduce the recirculation of color and nonsugars. Although making dry sugar with "NO" crystal damage is not as easy to solve, we are still working on this problem. In making dry sugar, the final breakthrough will probably be made in the way the massecuite is boiled. In some circumstances, the high grade continuous centrifugal cannot and should not be used as a substitute for the automatic batch centrifugal. With the sugar factory and the centrifugal manufacturer working together, realistic capacities and performance can be mutually determined and goals can be set.
The technology referred to in this paper as well as in the development of the Silver Weibull centrifugals is patent protected under the following patent numbers: 5286299, 5286298, 5269849, 5114489, 5205489, 5281275, and 5196068. The crystal saving flutter dome and curtain are filed and patent pending, Docket No. 1998-SI-NO.

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MODEL NO. 5000M
CONTINUOUS CENTRIFUGAL

- LOWEST POSSIBLE COLOR SUGAR
- HIGH POL SUGAR
- HIGH BRIX MAGMA
- VACUUM CRYSTAL CLEANING SYSTEM
- 25 DEGREE BASKET
- INTERNAL MAGMA MIXING
- CAN BE USED AS A PRE-MELTER
NOTE:
THE SUGAR FLOW ON THE SCREEN IS DYNAMICALLY REGENERATING AND NOT A PLUG FLOW, WHICH WILL ALLOW MASSECUITE WITH A HIGHER CV TO BE PURGED.

THE SUGAR CRYSTALS TRAVEL SLOWER NEAR THE SCREEN DUE TO THE GRAVITY FORCE AGAINST THE SUGAR AND FRICTION AGAINST THE SURFACE OF THE SCREEN.

THE SUGAR CRYSTALS TRAVEL FURTHER AND FASTER AT THE OUTER SURFACE

\[ n = \text{ROTATING SPEED OF THE BASKET} \]
\[ V = 0.194168 \times n \]
\[ V = \text{CRYSTAL VELOCITY, FEI ft/sec.} \]
\[ V = 0.05918 \times n \]
\[ V = \text{CRYSTAL VELOCITY, METER/SEC.} \]

\[ G = 0.0006109 \times n^2 \]
\[ G = \text{GRAVITY FACTOR} \]
\[ N = \text{NORMAL FORCE} \]
\[ P = 0.4226183 \times G \]
CONVENTIONAL THREE-BOILING PROCESS WITH AFFINATION
THREE BOILING WITH AFFINATION AND WHITE REBOILING