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Sugar centrifugation, drying and cooling

S.I.T. Meeting 2007
Baltimore, MD
Symposium Sugar Drying & Conditioning
Burkhard Bartels, BMA AG

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Example for Modern Batch Centrifugal Concepts

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The essential features of the B-series

- ***Ideal basket height to diameter ratio (0.76 instead of 0.8 and more)***
- ***New design discharger, equal in length to the full height of the basket***
- ***All product contact parts stainless steel***
- ***Efficient syrup separator***
- ***Up to 25 ch/h cycle time***
- ***Sizes from 1,100 to 2,200 kg/ch***
- ***Sturdy, reliable design***

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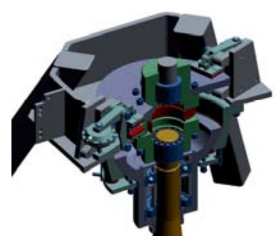
Section view drive head



- ***Ball-and-socket joint unit with bearing metal/plastic friction system***
- ***Flexible claw coupling***
- ***Two bearings only***
- ***Oscillation dampening system to be adjusted from outside***
- ***Emergency disk brake***
- ***All necessary sensors incorporated:***
  - speed
  - oscillation
  - electronic vibration
  - bearing temperature (optional)

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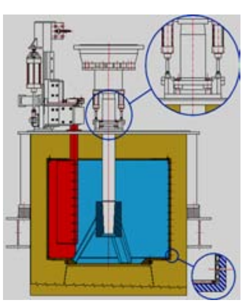
Features of B-series



- ***New design discharger***
  - length to the full height of the basket
  - reduced discharge time (2 ch/h more)
  - actuating and control elements outside the basket (almost maintenance-free)
  - vertical movement takes place in linear guides
- ***Improved Centering device***
  - In position during discharging process
  - only prevents oscillations,
  - ensures safe and gentle removal of the sugar from the basket
  - provides an almost completely clean screen after every cycle

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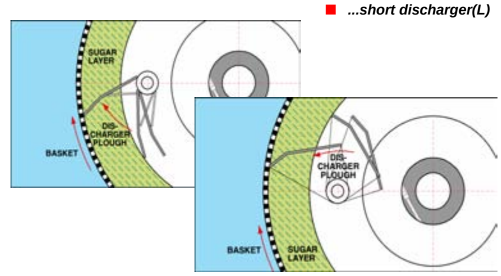
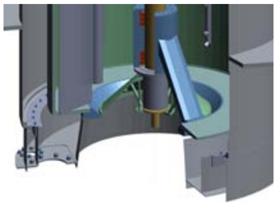
Movement of plough

- ***Long discharger (R)***
- ***...short discharger(L)***



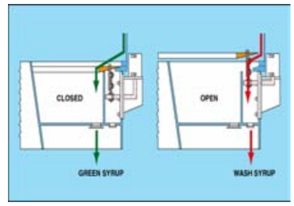
Discharge valve and syrup separator

- ***Discharge valve:***
  - Downward opening/closing valve equipped with novel, almost wear-free actuator
  - Absolutely leakproof
  - Bottom valve cone made from stainless steel



- ***Internal syrup separator:***
  - Seat valve for wash syrup duct
  - Pneumaticly operated valve
  - Ducts for green and wash syrup fully separated

Principle of syrup separator



- ***Syrup separation already at the lower end of the centrifugal housing wall***
- ***Reduces the mixture of green and wash syrup***
- ***High wash syrup purity***
- ***Increased purity drop in the sugar house resulting in***
  - reduced molasses purity
  - reduced B-massecuite flow
  - reduced water evaporation

Summary of cycle times for B 1750

Action	*Time*
Screen washing and charging	*18s*
Accelerating to spinning speed	*37s*
Spinning	*30s*
Braking to discharging speed	*29s*
Discharging and accelerating to charging speed	*29s*
Total cycle time	*143s*
equivalent to 25,2 ch/h	

Advanced centrifugal control

Objectives, Measures, Limitations

- ***Main targets for production process in modern sugar factories:***
  - Low energy consumption
  - Low personnel requirements for
    - operation
    - maintenance
- ***Main measures to achieve these targets:***
  - Highly efficient processes
  - High automation standards
- ***Measures are mainly limited to the specific station:***
  - Internal control nearly automatic
  - No automatic adaptation to changes of incoming product

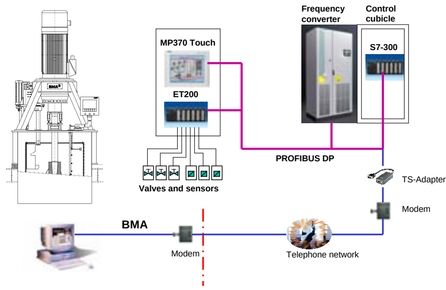
New control cycles

- ***Controlling layer thickness***
- ***Controlling wash water rate***
- ***Controlling nozzle assembly position***
- ***Controlling sugar quality***

Prospects for the future

- ***Procedure:***
  - Measuring the actual situation
  - Evaluation and definition of new set-points
  - Measuring the result
  - Comparison with expectation and definition of new set-points
- ***Forward-looking batch centrifugal control concept***

Control system with teleservice



Sugar drying

Required sugar properties

- ***Residual moisture of less than 0.03 - 0.04 %***
- ***Temperature of no more than +/- 5 K above/below the mean ambient temperature at which sugar will be transported***
- ***Minimum layer of amorphous sugar on the crystal surface for which a relatively high aw -value is indicative***

Drying the sugar

- ***Conditions after centrifugation:***
  - Sugar moisture content is normally 0.3 - 1.0 %
  - Sugar temperature between 50 and 70 °C (122 ... 158 °F)
  - Moisture in saturated sugar solution (up to 4.5% on total mass)
- ***Drying process:***
  - Evaporation of water increases the syrup concentration
  - Start of a further crystallization process
  - Start of crystallization from seed crystals
- ***If either the required time or the seed crystals are missing, the syrup will dry into an amorphous layer favouring the entrapment of moisture ("case hardening" or "skin effect")***

Rotary drum (cascade) dryer

- ***Arguments for sugar drum dryer:***
  - Air flow independent from transport of sugar
  - Mechanical treatment of the crystal surface combined with low drying velocities
  - Homogenization is achieved with the large drum volume
  - Fluctuations in throughput and temporary high sugar moisture contents are tolerated

Rotary Dryers
with counter current operation

- Favouring relative crystal motion
- Provide for an optimum temperature profile
- Central pipe allows temperature control as required within the drum dryer
- Counter current principle ensures efficient use of the internal heat of the sugar for sugar drying

Fluidized-bed conditioning

Sugar cooling: Final product specification

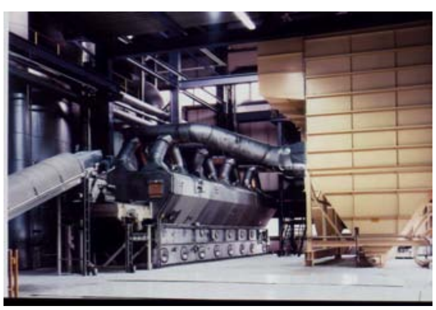
- *Residual humidity*
  0.03 % - 0.04% depending on the sugar quality
- *Temperature*
  as requested by the customer

  Problems at critical ambient air conditions with high relative humidities and high temperatures

Processes and apparatus already known

- *Fluidized-bed cooler*
- *Moving-column cooler*
- *Fluidized-bed apparatus with integrated heat-transferring surfaces*

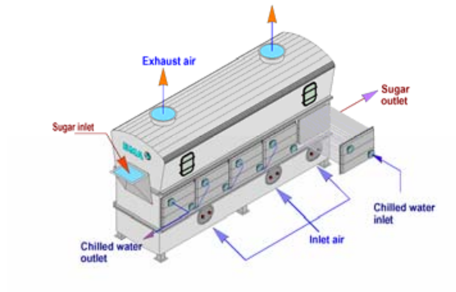
Fluidized-bed cooler



Moving-column cooler

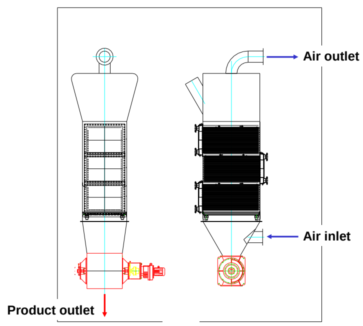
- *Contact cooling at the surfaces of a heat exchanger*
- *No use of cooling air*
- *Limited heat transfer*
- *Vertical transport of sugar by gravitation*
- *Constant sugar outlet temperature by controlling the temperature of the heat-transfer medium*
- *No exchange of matter*
- *No dust removal*
- *Cooling is limited by the relative air humidity in the void volume*

Fluidized bed cooler with internal cooling coils

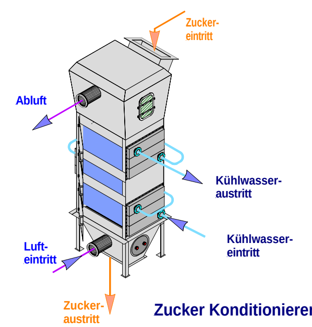


Fluidized-bed apparatus with integrated heat-transferring surfaces

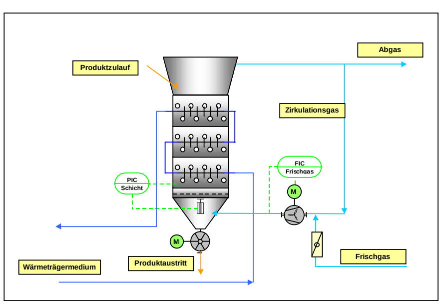
Vertical fluidized-bed conditioner



Design



Schematic diagram



advanced
technologies
- worldwide

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SIT 2007 SYMPOSIA #923 (B)
Drying and Conditioning of Granulated Sugar

CONDITIONING

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Sugar Australia & New Zealand Sugar

CONDITIONING:
What is it, and how to cope when it doesn't quite work?

Experiences in Auckland with a small silo and limited conditioning residence time.

What is Conditioning?

- Conditioning is slow drying of recently dried sugar to further remove surface and bound water to produce a dry, stable, free flowing product that does not cake during transport or storage.
- Several excellent technical papers over the years explain the processes involved and operational requirements.
- See references for further reading

Conditioning Principles

- Rapid drying increases the supersaturation of the surface syrup film faster than sucrose crystalises.
- This results in a high viscosity syrup film, potentially with micro-crystals or amorphous sugar at the syrup/air interface, trapping water under the surface.
- Conditioning is the slow process of:
  - Crystalisation of sucrose onto the base crystal
  - Water migration to the surface,
  - Evaporation of water from the surface

Traditional Caking Model, Humidity/Temperature Gradient Model

- This model assumes a simple three phase system:

  solid crystal / liquid syrup / air

- Caking is a result of crystalisation of the syrup driven by increased supersaturation.
- Supersaturation may increase by loss of water to air, or by reduced temperature.
- Water loss (or gain) driven by air relative humidity

Alternative Caking Model, Amorphous Sugar

- An alternative model assumes amorphous sugar is created during rapid drying.
- This amorphous sugar subsequently dissolves and recrystalises on the base crystal.

Conditioning Silo – Chelsea Refinery

- Without a conditioning, caking was a periodic problem in the packing bins and from time to time for customers.
- 48 hours generally is recognised as the minimum for reasonably full conditioning.
- Benchtop trials in Auckland demonstrated that 24 hours conditioning was sufficient to significantly reduce caking risk.
- An 800 tonne silo was built in the 1983
- Conditioning with about 24 hours residence time was a success. Caking in refinery packing bins greatly reduced and customer complaints eliminated
– for several years.

Lessons Learned the Hard Way

- The Chelsea conditioning silo air system:
  - Filter, Dehumidifer, Blower supplying air to the silo bottom
  - Fan/dust collector extracting air from the silo top
  - The blower was interlocked with the dehumidifer, the dust collector fan was not interlocked.
- The dehumidifer failed, the blower stopped, the extraction fan continued to operate.
- Operations continued satisfactorily for an extended dehumidifier outage, >8 hours.
- On restarting the dehumidifier & blower, sugar flow from the silo stopped within 10 minutes.
- The silo had caked very hard, attempts to clear it were unsuccessful.

Caking is Reversible

- The fan had sucked moist ambient air up the sugar outlets, increasing sugar water levels, which caked on drying when the dehumidifier started.
- The solution – stop the dehumidifier, keep the fan on. The caking became softer within minutes, allowing flow to resume.
- The silo was totally emptied before restarting the dehumidifier.
- Lesson 1 - never allow ambient air into the silo.
- Lesson 2 - if lesson 1 ignored, never start the dehumidifier till the silo is empty.
- Lesson 3 - caking is reversible.

Caking Problems Started, and Solved Again

- Over several years, sales increased, reducing silo residence times from 20-24 hrs to 14-18 hrs. Caking become a problem again.
- Single drum driers converted to double drum units, increasing drying capacity at lower temperature. Caking problems overcome.
- Sales and refinery rate continued to increase.
- Caking risk managed by reducing drier air temperatures and better management of silo levels to maximise residence times.
- Customers and packing teams happy again, for several more years.

Then One Customer Started Complaining

- One customer began reporting caking of bulk deliveries and delays unloading shipping containers. It was a real and serious problem.
- All other customers free of caking issues.
- A geographic issue:
  - Refinery in Auckland, in the north of the North Island
  - Most bulk sugar customers close to the refinery
  - This customer in the south of the South Island
  - Long supply chain resulted in 2+ weeks delivery times.
- Regardless of geography, the refinery had to solve the problem.

Project to indentify the dominant caking mechanism

- Before jumping to solutions we wanted to understand what was driving the caking.
- Our expectation was that amorphous sugar would be the dominant mechanism, leading to the need to further reduce drier air temperatures.
- A research project was done by Massey University to measure amount of amorphous sugar.
This work was reported in SIT paper #835 in 2003
- The percentage of amorphous sugar at various stages of the process were as follows:

Amorphous Sugar Content

Process Stage	Amorphous Sugar %
Drier Top Drum Outlet	0.16%
Drier Bottom Drum Outlet	0.10%
Silo Outlet	0.09%
Packed Product	0.09%

- Conclusion: amorphous sugar existed, but the quantity was too low to be significant.
- Is this a valid conclusion?

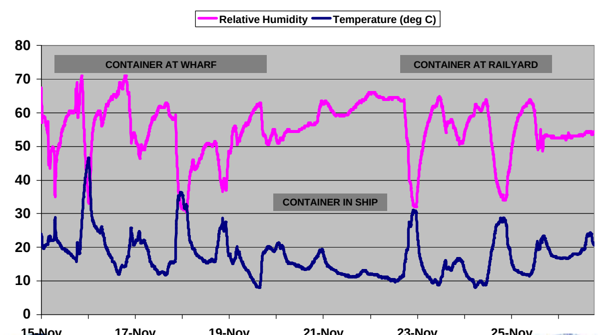
What was the problem?

- To develop a solution we had to understand the problem. Was it due to inadequate conditioning time, or other causes such as temperature or delivery time?
- Data collection involving several customers and various trials did not give a clear picture.
- Silo levels had some correlation to caking, but was not the only cause.
- Data-loggers used to measure temperature and relative humidity inside the delivery container gave surprising results.

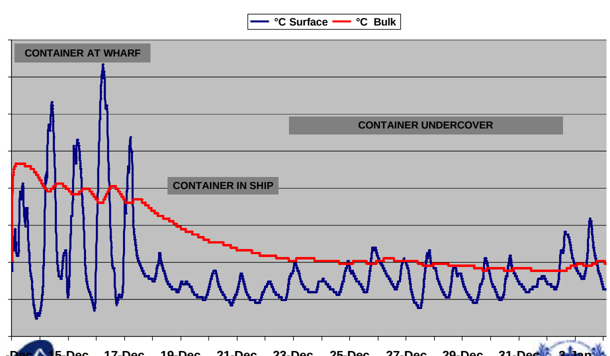
Data Logger
Temperature and Relative Humidity

Data Logger
For use inside bulk sugar container

Bulk Container Data Logger
Probe in head space inside container



Containers Stored Undercover
Data Loggers in Head Space and 1m Depth in Bulk Sugar



Contributing Causes Of Container Caking

- Excessive fine crystals
  - Not a cause; Massey University reseach project confirmed high levels of fines magnified caking but there was no effect at the levels of fines in delivered product
- Extended transit time, >2 weeks
  - Not much ability to control this
- Customer climate cooler than the refinery
  - No control of this
- Temperature and RH 24 hour cycles
  - Undercover storage reduced caking, not a total solution
- Conditioning time <16 hours due to limited silo residence time
  - This was a key contributing cause
  - We had to find a way to control this
  - How? Silo volume fixed, Throughput driven by sales.

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How to extend Conditioning Time?

- Refinery operates 5-days, shutdown on weekends.
- Loading of bulk containers for this customer on Sunday resulted in 48 hours conditioning.
- Problem solved.
- New Problem – excessive labour costs on Sunday.
- New Solution - sugar from the silo stored in an unconditioned packing bin for 2 days, before loading into containers.
- The extra 2 days “maturing” after conditioning had the same effect on eliminating caking as 48 hours conditioning.
- Problem solved.

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References for futher reading

- Design and Implementation of Conditioning Silos and Bulk Loading Facilities at Lantic Sugar – Saint John Refinery. J. N. Lemon and D. A. Ryan, SIT Paper #608, 1990
- Somewhat dry – a new look at the conditioning of refined sugar. D. M. Meadows, Proc of SASTA June 1993
- Towards a clearer understanding of Refined Sugar Conditioning – A Process Model. D.M. Meadows, SIT Paper #669, 1994
- Conditioning of White Sugar in Silos. R. T. Burke, SIT Paper #700, 1996
- Drying and Conditioning, SIT Symposium 1996

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