Refined Sugar Conditioning Presentation to Thai Sugar Millers Co., Ltd.

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By Saovapun Suputtitada
Project Development Manager
Why is it important?

- If sugar is not conditioned, it can lead to caking—sometimes very severe caking.
- Just ask this guy jack-hammering out a 90 tonne sugar lump from a silo in Australia!!
What Happens When Sugar Cakes?

- Crystallisation At Contact Points
- Liquid Bridges converted to Solid Bridges
What Makes Sugar Caking?

1. Defects of Sugar: Twins, Conglomerated-agglomerated, Abrasion, Breakage
   - Formation of Twins at high supersaturation in presence of impurities
What Makes Sugar Caking? (Continued)
What Makes Sugar Caking? (Continued)
2. Dust formation during Drying, Screening

Dust & Broken crystals are more active in water adsorption than separated mono crystals.
What Makes Sugar Caking? (Continued)

3. Fine Sugar: Has more surface area and therefore greater propensity to cake.

4. Large CV: Packs more effectively leading to stronger caking.

5. Sugar dried too fast: Increases thickness of the supersaturated film.

6. Big swings in temperature: Encourages moisture migration which exacerbates the problem.

7. Compression in Tall Silo: Forces crystals together more tightly.

Water Adsorption Lumping and Caking

Schematic steps of lumping

A - Pendular step
B - Funicular step
C - Capillary step
D - Drop step
Water Adsorption Lumping and Caking (Continued)

Pendular step

0% < ERH < 44%
Water Adsorption Lumping and Caking (Continued)

Funicular step

Liquid bridge

44% < ERH < 75%
Water Adsorption Lumping and Caking (Continued)

Capillary step

Solid bridge

75% < ERH < 85%
Water Adsorption Lumping and Caking (Continued)
Sorption Isotherms of White Sugar in Different Temperatures

- For prediction of sugar stability over time in different storage condition
Crystal Size Distribution and Water Vapor Sorption
Types of Refined Sugar Moisture

1. Inherent Moisture (trapped in crystal structure during crystallization in Pan)
2. Free Moisture (Thin Film carried from centrifugal & removed in Dryers)
3. Bound Moisture (trapped underneath the amorphous shell due to rapid drying)
Inherent Moisture is almost constant and surface moisture increases with increased water activity.
What Does Sugar Conditioning Mean?

The definition is: Conditioning is the controlled crystallization of the supersaturated film around each sugar crystal so it is in a stable state of which Bound Moisture will not evaporate and migrate. Then sugar will not cake or harden in storage & transportation.

Important: It is NOT simply water removal, though sugar conditioning is normally associated with a small reduction in moisture content.
How to Condition Sugar?

All of these steps contribute........

- Pan Stage: Low CV, limited inclusions
- Centrifuges: Even quality, no wet lumps
- Drying: Slow drying, avoid hot sugar
- Conditioning: The final step

Notes: First two are just good refinery practice.

The influence of drying method is rarely recognised.
Conditioning is poorly understood.
If the first steps are done poorly, then there is more work required in conditioning the sugar.
Water In and Around Sugar Crystal
A portion of crystal surface undergoing conditioning
Refined Sugar Conditioning

Four processes take place during conditioning:
1. Crystallisation of sucrose molecules out of the supersaturated surface film.
2. Evaporation of moisture at the interface between the film and the amorphous shell.
3. Vapour-phase diffusion of the moisture across the amorphous layer.
4. Diffusion/convection of the moisture into the bulk interstitial air.

The process 3 serves to determine the overall rate of conditioning.
Rate of Moisture Reduction during Conditioning

\[
\frac{dM}{dt} = -\frac{D \rho_a A}{Z} (Y_e - Y_b)
\]

Where:

- \(M\) = Mass of Moisture in Film
- \(t\) = Conditioning Time
- \(D\) = Diffusivity of Water Evaporated (\(m^2/s\))
- \(\rho_a\) = Density of Air
- \(A\) = Crystal Area
- \(Y_e\) = Mass Fraction of Moisture at Equilibrium
- \(Y_b\) = Mass Fraction of Moisture in Bulk Air
- \(Z\) = Thickness of layer
Parameters which affect conditionability.

1. Initial moisture (%) of sugar crystal.
2. Thickness of the amorphous layer, the nature of the amorphous layer and crystalline sub-layer.
3. Size of crystal (MA) and Coef. of Variation (CV)
4. Conditioning Air Flow Rate
5. Relative Humidity
6. Conditioning Temperature
7. Conditioning Time
Conditioning curves - fitted vs actual.
A Conditioning system typically requires:

- An Air Dehumidification system
- Air Blowers
- Storage Silos
- Dust Extraction/ Collection (or Scrubbing) system
- Upstream and Downstream Conveying systems
- PLC Control system for automation of process
Air Conditioning Plant

Conditioned Air to Silo
35 - 40°C, RH 20 - 25%

Conditioning Air Plant

AIR 90-95°C
1 Bar(g)

SILENCER
ROTARY BLOWER
SILENCER

AIR 12°C, RH 100%

Chilled Water In 6°C
Chilled Water Out 12°C

Air Handling Unit
Air in 30 - 35°C

Ambient Air
RH 60 - 65%
Good Design of Conditioning Silo

- Ensure the feed-in sugar evenly distribution inside the Silo;
- Ensure the First-in First-out System for sugar tracability, and no dead zone;
- Maintain sugar in the silo for conditioning at least 48 – 60 hrs;
- Keep sugar moving and continuous flow of sugar discharged from the silo with control-valve;
- Evenly distribution of Conditioning Air;
- To protect the silo with Explosion Vent and Vacuum Breaker.
Bosch Projects’ Conditioning Silo
Conditioning Silo System
Performance Guarantee of Conditioning Silo

The sugar discharged from the conditioning silos have the following quality:

<table>
<thead>
<tr>
<th>Grade of Sugar</th>
<th>Max. moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super Refined Sugar or Refined Sugar</td>
<td>0.04%</td>
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</table>

- The moisture content is determined by the Karl Fischer Method

This above is subjected to the following conditions of sugar entering the silo, and discharging from the silo bottom continuously.

- Colour of sugar not to exceed 20 ICUMSA
- Moisture of sugar not greater than 0.03% when determined by oven drying, or 0.08% when determined by Karl Fischer Method
- Coefficient of variation < 25
- Mean Aperture 0.4 mm. – 0.6 mm.
**BOSCH Projects’ Conditioning Silo Reference**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>PROJECT TITLE</th>
<th>DURATION (months)</th>
<th>CLIENT</th>
<th>PROJECT SERVICES PROVIDED</th>
<th>YEAR COMPLETE</th>
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<tbody>
<tr>
<td>Thailand</td>
<td>Kaset Thai 600Ton/day</td>
<td>10</td>
<td>Kaset Thai International Sugar Corporation Public Co., Ltd.</td>
<td>EPC/Wellman</td>
<td>Aug 2015</td>
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<tr>
<td>Thailand</td>
<td>Mitr Phu Viang Conditioning Silos 600Ton/day x 3 nos.</td>
<td>12</td>
<td>United Farmer Industry Co., Ltd. (Mitr Phu Viang)</td>
<td>EPC/Wellman</td>
<td>2013</td>
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<tr>
<td>South Africa</td>
<td>Conditioning Plant - 32 RSO</td>
<td>12</td>
<td>Illovo Sugar Ltd-Pongola</td>
<td>EPCM</td>
<td>2005</td>
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<td>Swaziland</td>
<td>25,000t Conditioning Silo</td>
<td>11</td>
<td>Swaziland Sugar Association, Ubombo</td>
<td>EPCM</td>
<td>1993</td>
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<tr>
<td>South Africa</td>
<td>Sugar Conditioning (and Extensions)</td>
<td>4</td>
<td>Huletts Refinery, Durban</td>
<td>EPCM</td>
<td>1988/91</td>
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<td>South Africa</td>
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<td>6</td>
<td>CG Smith, Gledhow</td>
<td>EPCM</td>
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<td>South Africa</td>
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<td>6</td>
<td>CG Smith, Noodsberg</td>
<td>EPCM</td>
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Bosch Projects’ Conditioning Silo in South Africa
Bosch Projects’ Conditioning Silo at MPV in Thailand
Bosch Projects’ Conditioning Silo at MPV in Thailand (Continued)
Bosch Projects’ Air Conditioning Plant
Bosch Projects’ Air Conditioning Plant (Continued)