Case study: operation of the first Solex sugar cooler with raw sugar and with amorphous sugar

J-M Reichling, C Raineri and C Richard

Solex Thermal Science Inc, Calgary, Alberta, Canada; info@solexthermal.com

Abstract Knowing that vertical-plate heat exchanger technology is successful in cooling crystalline sugar, many plants approached Solex seeking a method to efficiently and reliably cool amorphous and raw sugar. In order to evaluate the unique challenges associated with raw and amorphous sugar, pilot testing was conducted in plants under actual process conditions. The equipment utilized in the pilot-testing works under the same principles as an industrial unit, but on a much smaller scale. Following successful pilot testing, the first industrial-scale equipment has been installed and commissioned. The pilot testing and industrial installations show that, by considering the temperature of the cooling fluid, the volume of dehumidified air to be injected, and the locations at which to inject the air, long-term operation of vertical-plate heat exchangers cooling either raw or amorphous sugar can be achieved without the need for intermediate cleaning. The Solex vertical-plate heat exchanger provides efficient control of the temperature of amorphous and raw sugar prior to storage. Furthermore, when the process parameters are adequately controlled, there is no need for intermediate cleaning of the equipment.

Key words Heat exchanger, sugar crystals, dehumidified air

INTRODUCTION

This paper details the first installation and operation of a Solex Thermal Science Inc. (Solex) Sugar Cooler with raw sugar at the San Carlos plant in Colombia and with amorphous sugar at a plant in Brazil.

Since 2000 Solex has introduced the technology of indirect plate heat exchangers for bulk solids into the sugar industry with great success. This type of cooler has been recognized as a proven and effective method for cooling sugar crystals before storage and packaging. Installations may be found all over the world operating under different climate conditions (France, Germany, Portugal, US, Mexico, Poland, Russia, etc.). The plants using this type of sugar cooler include sugar beet plants, cane sugar plants, refineries, and producers of starch or derivative sugar (maltose, sorbitol). Until 2015 the sugar being cooled in all the different installations was refined sugar. In 2014 Solex began to study the behavior of the other types of sugar and therefore different pilot tests have been conducted with raw sugar and amorphous sugar.

EQUIPMENT DESCRIPTION

The Solex heat exchanger consists of a bank of vertical, closely spaced, hollow, stainless-steel plates (Fig. 1). The sugar flows slowly by gravity between the plates in mass flow. Cooling water flows counter-current through the plates resulting in high thermal efficiency. The cooling occurs by heat transfer through the sugar particles and is based exclusively on thermal conduction. This cools the sugar indirectly and significantly reduces the amount of air injected into the equipment. The treated air is used to avoid condensation and not as a cooling medium. At the bottom of the heat exchanger a vibrating discharge feeder creates mass flow and regulates the sugar throughput.

Solex technology is subject to patents and patent applications in various jurisdictions around the world.
**SUGAR CLASSIFICATION**

The various types of crystalline sugar are defined in Table 1.

**Table 1.** Types of crystalline sugar.

<table>
<thead>
<tr>
<th>Type of sugar</th>
<th>Color ICUMSA</th>
<th>Purity (%)</th>
<th>Moisture (%)</th>
<th>Size (mm)</th>
<th>Angle of repose</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granulated refined</td>
<td>20 to 100</td>
<td>99.8</td>
<td>≤ 0.05</td>
<td>0.45 to 0.85</td>
<td>40°</td>
<td>Most common</td>
</tr>
<tr>
<td>Amorphous sugar</td>
<td>40 to 75</td>
<td>99.5</td>
<td>≤ 0.2</td>
<td>≤ 0.4</td>
<td>40°</td>
<td>No crystal seed</td>
</tr>
<tr>
<td>White sugar</td>
<td>100 (Type1) to 400 (Type 3)</td>
<td>99.5</td>
<td>≤ 0.04</td>
<td>≤ 1.0</td>
<td>40°</td>
<td>Plantation/non refined</td>
</tr>
<tr>
<td>VHP sugar 4</td>
<td>450</td>
<td>99.6</td>
<td>≤ 0.10</td>
<td>≤ 0.9</td>
<td>40°</td>
<td>Lighter raw type</td>
</tr>
<tr>
<td>VHP sugar</td>
<td>1.200</td>
<td>99.0-99.5</td>
<td>≤ 0.15</td>
<td>≤ 1.7</td>
<td>42°</td>
<td>Normal raw type in Brazil</td>
</tr>
<tr>
<td>Raw sugar</td>
<td>2.000</td>
<td>96-97.5</td>
<td>≤ 0.15</td>
<td>≤ 1.2</td>
<td>42°</td>
<td>Darkest raw type</td>
</tr>
</tbody>
</table>

**PILOT TESTS**

The pilot unit utilizes the same principles as the industrial unit but on a much smaller scale (Fig. 2). The tests are performed under the real process and ambient conditions.

**Pilot test with amorphous sugar in Brazil**

Amorphous sugar is obtained by spontaneous crystallization in the crystallization pan without the addition of seed crystals. Compared to crystals obtain by the addition of seed, amorphous sugar is also in crystal form but much more irregular and smaller. This type of sugar is mainly produced in Brazil.
The objective to cool the sugar for a sugar plant is to preserve the final product quality and bulk characteristic by avoiding the formation of lumps. The sugar cooler can be placed just before storage facilities (silos) or just before the packaging station (bulk bags of 1 t and 500 kg, or small bags of 1, 5, 10 and 50 kg).

![Image](image_url)

**Fig. 2** Pilot unit used for the testing amorphous sugar with Plexiglas window to allow observation of flow.

**Test conditions**

- Product type: Amorphous sugar with a moisture content of 0.2%.
- Cooling water: Water module used (at 2300 L/h) with temperature controller.
- Dry air purge: Testing with and without air injection.
- Product flow rate: 400-800 kg/h.

A variety of scenarios were simulated to give an overview of experimental operating ranges (Table 2).

**Table 2. Summary of results.**

<table>
<thead>
<tr>
<th>Run number</th>
<th>Water temperature °C</th>
<th>Air</th>
<th>Product temperature In °C</th>
<th>Product temperature Out °C</th>
<th>Product feed rate kg/h</th>
<th>Run time min</th>
<th>Caking on plates</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>No</td>
<td>65</td>
<td>57</td>
<td>600-800</td>
<td>40</td>
<td>Y</td>
<td>Caking observed on top half of the plates. Good mass flow</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>Yes</td>
<td>60</td>
<td>50</td>
<td>600</td>
<td>30</td>
<td>N*</td>
<td>No caking but sticky patches observed due to previous was. Good mass flow</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>Yes</td>
<td>55</td>
<td>42</td>
<td>500</td>
<td>45</td>
<td>N</td>
<td>No caking. Good mass flow</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>Yes</td>
<td>55</td>
<td>33</td>
<td>400</td>
<td>75</td>
<td>N</td>
<td>No caking. Good mass flow</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>Yes</td>
<td>65</td>
<td>31</td>
<td>200-300</td>
<td>60</td>
<td>N</td>
<td>No caking. Good mass flow. Reduced flow rate for a better cooling</td>
</tr>
</tbody>
</table>

The average values show steady-state conditions only with a run time per test of a minimum 30 min.

**Plate spacing and flow pattern**

The product exhibited good mass flow characteristics at the selected heat exchanger plate spacing. No signs of bridging or arching were observed.
Caking / scaling on plates

It was demonstrated that air injection is essential to avoid caking on the surfaces of the heat exchanger due to condensation. The first run, performed without the use of air injection, showed a build-up of product on the top half of each plate. Air was injected for all the subsequent runs and good results were observed. The pilot unit was emptied to inspect the plates at the end of each run and no signs of accumulation were observed. The plates remained very clean. A dry air injection system will be integrated as part of the proposed design for this application.

Demonstrate empirical cooling capabilities for pilot conditions

Cooling capabilities were demonstrated within the scaled down limits of the pilot unit. A reduction in temperature of up to 40°C (product entering plate bank at 70°C and leaving the discharge at <30°C) was achieved.

Confirm recommended discharge device type

A fixed-louver vibrating feeder was used for testing and showed reliable product flow as well as good adjustment capabilities for throughput and turn down ratio. This type of discharge device is recommended for this application.

Conclusion

The data and observations collected during the series of tests show that the use of a Solex heat exchanger is a suitable method for cooling amorphous sugar at 0.2% moisture content, offering promising cooling capabilities, convenient operating conditions, and utility savings. In order to avoid caking phenomena, it is crucial to inject some dehumidified air.

Pilot test with raw sugar in Brazil

Typical process conditions for this project are in Table 3.

Table 3. Typical process conditions with raw sugar.

<table>
<thead>
<tr>
<th>Product flow:</th>
<th>Up to 150 t/h</th>
<th>Bulk density:</th>
<th>850-900 kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product inlet temp.:</td>
<td>60 °C</td>
<td>Particle size:</td>
<td>0.55-0.65 mm</td>
</tr>
<tr>
<td>Product outlet temp.:</td>
<td>&lt;34 °C</td>
<td>Moisture content:</td>
<td>0.1-0.18%</td>
</tr>
<tr>
<td>Cooling water:</td>
<td>To be determined</td>
<td>Specific heat:</td>
<td>1.3 kJ/kg.°C</td>
</tr>
</tbody>
</table>

Test conditions

- Product type: Sugar VVHP with a moisture content of 0.1%.
- Cooling water: Water module used (at 2300 L/h) with temperature controller.
- Dry air purge: Testing with and without air injection.
- Product flow rate: 200-400 kg/h.

Various scenarios (Table 4) were simulated in the pilot unit (Fig. 3) to give an overview of experimental operating ranges.
Fig. 3. Pilot unit fitted with a Plexiglas front used to test raw sugar.

Table 4. Summary of results.

<table>
<thead>
<tr>
<th>Run number</th>
<th>Water temp °C</th>
<th>Air</th>
<th>Product temp In °C</th>
<th>Product temp Out °C</th>
<th>Product feed rate kg/h</th>
<th>Run time min</th>
<th>Caking on plates</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>Yes</td>
<td>35</td>
<td>33</td>
<td>Too high</td>
<td>10</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>No</td>
<td>34</td>
<td>-</td>
<td>0</td>
<td>1 night</td>
<td>N*</td>
<td>Motor setting too fast. Unit emptied seconds. Air was turned off during the test. Bridging and caking observed</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>Yes</td>
<td>34.5</td>
<td>32.5</td>
<td>200</td>
<td>45</td>
<td>N</td>
<td>No caking but slight powder residue observed on the plates, no caking</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>Yes</td>
<td>34.5</td>
<td>31</td>
<td>200</td>
<td>45</td>
<td>N</td>
<td>No caking. Good mass flow</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>Yes</td>
<td>34</td>
<td>24.5</td>
<td>200</td>
<td>45</td>
<td>N</td>
<td>No caking. Good mass flow</td>
</tr>
</tbody>
</table>

The average values show steady-state conditions only with a run time per test of a minimum 45 min.

Conclusion

The objectives for this pilot experiment were attained. The data and observations collected during the series of tests show that the use of a Solex heat exchanger is a suitable method for cooling raw sugar (type VVHP tested), offering promising cooling capabilities and convenient operating conditions. The optimal plate spacing was determined during the test for this application. A vibrating discharge feeder will provide target production feed rates and turn down. A dry air injection system will be integrated as part of the proposed design for optimal use of the cooler without the need for frequent cleaning.

INSTALLATION AT INGENIO SAN CARLOS, COLOMBIA OPERATING WITH REFINED CRYSTAL AND RAW SUGAR

Ingenio Mayagüez is one of the leading producers of sugar in the Valle del Cauca region of Colombia and is one of the main references in the sugar industry in the country due to its continuous improvements and commitment to more advanced technologies in every phase of the production process. Ingenio Mayagüez is also the major shareholder of Ingenio San Carlos. Due to the modernization of the San Carlos plant, the engineers were in search of the most cost-effective and
efficient way to solve the problems associated with high sugar temperature and decided to evaluate the indirect heat exchanger solution offered by Solex. The goal for the investment was to lower the final sugar temperature to the storage level (<35°C) to avoid caking during storage.

The decision to implement Solex technology was taken based on the results of pilot tests conducted with VHP sugar in Brazil and after a visit to Ingenio Tres Valles in Mexico (Jordison and Urrutia 2010), where this technology has been operating for several years. Following the visit, the client’s management, engineering, and maintenance departments fully supported the selection of this equipment.

Due to the high relative humidity in this part of South America, a small amount of air generated from a blower is injected into the equipment to help remove the moisture that migrates during the cooling process and ensures proper flow of sugar between the plates. This blower only demands a fraction of the energy that would be necessary for a rotating drum or fluidized bed cooling system.

The Solex sugar cooler was successfully commissioned in October 2015 (Fig. 4), and is now a reference site for other customers in South America.

Process data for the sugar cooler at San Carlos:

- Product flow: 15 t/h
- Sugar crystal size: 0.9-1.1 mm
- Moisture content: < 0.15%
- Product inlet temperature: 55°C
- Product outlet temperature: <35°C
- Cooling water temperature: 25°C
- Cooling water flow: 20 m³/h
- Dew point of injected air: 20°C

Fig. 4. Schematic of the sugar cooler at Ingenio San Carlos
CONCLUSIONS

Cooling amorphous sugar or raw sugar is possible using plate heat exchanger technology when a thorough understanding of the process condition and ambient conditions has been attained. Raw sugar and amorphous sugar have higher moisture contents and do not flow as well as fined granulated sugar. Injection of dry air will assure that the dew point of the air surrounding the sugar will always be above the temperature of the water in the plate and this will subsequently avoid any build up in the cooler. The Solex cooler allows efficient temperature control of the sugar that goes to the storage and this is one of the conditions that will guarantee preservation of the high quality of the sugar.

ACKNOWLEDGEMENT

We thank Ingenio San Carlos for their cooperation during the installation and commissioning phase of the equipment.

REFERENCE