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

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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.

Fig. 1. Sugar cooler at the sugar plant of Lage Germany (Pfeifer & Lange Group).

SUGAR CLASSIFICATION

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

Table 1. Types of crystalline sugar.

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

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).

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.

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

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.

Product flow:	Up to 150 t/h	Bulk density:	850-900 kg/m^3
Product inlet temp.:	60 °C	Particle size:	0.55-0.65 mm
Product outlet temp.:	<34 °C	Moisture content:	0.1-0.18%
Cooling water:	To be determined	Specific heat:	1.3 kJ/kg.°C

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.

Run number	Water temperature °C	Air	Product temperature In °C	Product temperature Out °C	Product feed rate kg/h	Run time min	Caking on plates	Notes
1	30	Yes	35	33	Too high	10	Y	Motor setting too fast. Unit emptied seconds. Air was turned off during the test. Bridging and caking observed
2	28	No	34	-	0	1 night	N*	No caking but slight powder residue observed on the plates, no caking
3	30	Yes	34.5	32.5	200	45	N	No caking. Good mass flow
4	25	Yes	34.5	31	200	45	N	No caking. Good mass flow
5	15	Yes	34	24.5	200	45	N	No caking. Good mass flow

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

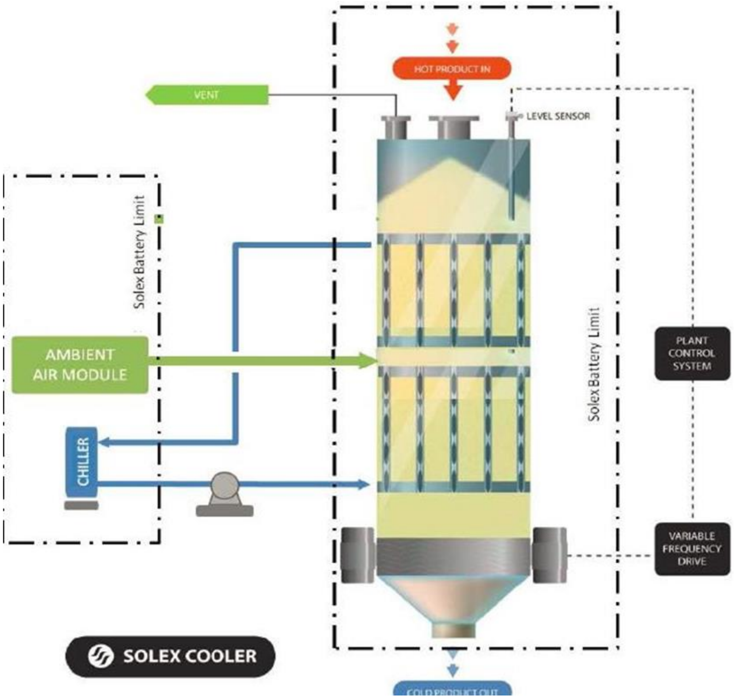
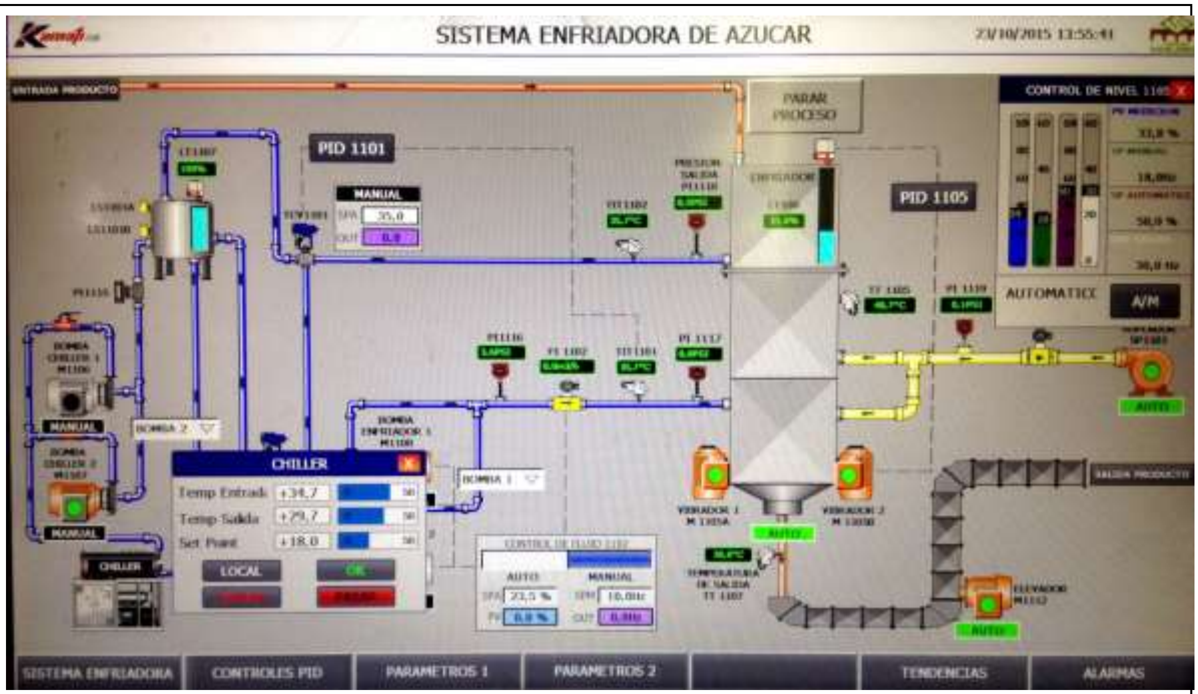


Fig. 4. Schematic of the sugar cooler at Ingenio San Carlos

Raw Sugar Cooler San Carlos

Vertical Plate Cooler San Carlos



Control PLC SUGAR COOLER AT 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

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REFERENCE

Jordison N, Urrutia A. 2010. Advanced cooling technology helps Ingenio Tres Valles increase capacity. *Proceedings of the International Society of Sugar Cane Technologists* 27: 7 pp.

Etude de cas: le fonctionnement du premier refroidisseur de sucre Solex avec le sucre brut et le sucre amorphe

Résumé. Sachant que la technologie de refroidisseur verticale pour du sucre raffiné fonctionne avec succès, de nombreuses usines ont approchées solex car elles étaient à le recherche d'une méthode efficace et fiable pour refroidir le sucre brut et le sucre amorphe. Afin d'évaluer les défis associés à ces types de sucres, des essais pilotes ont été menés dans des usines, dans des conditions réelles du processus. L'équipement utilisé dans les tests pilotes fonctionnent selon les mêmes principes que l'unité industrielle, mais à une échelle beaucoup plus petite. Après un essai pilote réussi, le premier équipement à l'échelle industrielle a été installé et mis en service. Les résultats montrent que, en tenant compte de la température du fluide de refroidissement, le volume d'air déshumidifié à injecter, et les endroits où injecter l'air que ce type d'échangeur vertical peut être utilisés avec du sucre amorphe ou du sucre brut tout une campagne sans la nécessité d'un nettoyage intermédiaire. L'échangeur vertical-Solex chaleur à plaques permet un contrôle efficace de la température du sucre amorphe et brut avant le stockage

Mots-clés: Échangeur de chaleur, des cristaux de sucre, de l'air déshumidifié

Estudio de caso: el funcionamiento del primer enfriador de azúcar Solex con el azúcar en bruto y con el azúcar amorfo

Resumen. Sabiendo que la tecnología de intercambio de calor vertical mediante placas ha tenido éxito en el enfriamiento de azúcar cristalino, muchas plantas se pusieron en contacto con Solex en busca de un método eficiente y fiable para enfriar azúcar en crudo/rubio y amorfo. Con el fin de evaluar los retos específicos asociados con azúcar crudo y amorfo se realizaron pruebas piloto en plantas en condiciones reales del proceso. El equipo utilizado en la prueba piloto opera bajo los mismos principios que una unidad industrial, pero en una escala mucho más pequeña. Después del éxito de las pruebas piloto, el primer equipo a escala industrial ha sido instalado y puesto en marcha. Tanto las pruebas piloto como las instalaciones industriales muestran que, teniendo en cuenta la temperatura del fluido de enfriamiento, el volumen de aire deshumidificado a inyectar, y los lugares en los que inyectar el aire de purga, los intercambiadores de calor verticales con placas de enfriamiento pueden operar eficazmente a largo plazo, ya sea con azúcar crudo o azúcar amorfo, y puede lograrse sin la necesidad de limpieza frecuente. El intercambiador de calor vertical Solex mediante placas proporciona un control eficiente de la temperatura del azúcar amorfo y crudo antes de su almacenamiento. Además, cuando los parámetros del proceso se controlan adecuadamente, no hay necesidad de limpieza del equipo hasta pasado un largo periodo de operación.

Palabras clave: Intercambiador de calor, cristales de azúcar, aire deshumidificado