EXPERIENCE WITH SLOW CONDITIONING OF WHITE SUGAR IN CONCRETE SILOS
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INTRODUCTION

A recently introduced concept of slow sugar conditioning has been tested at the Nampa factory of Amalgamated Sugar Company LLC. The project had been initiated mainly because of the concerns about safety during silo cleaning. Complete unloading of the silos was difficult due to a high level of sugar build-up on the walls. It also created unsafe conditions for the cleaning crews. The cluster of twelve concrete non-insulated silos at Nampa factory was partially retrofitted to accommodate the new concept, one 40 ft.-diameter silo was completely converted to the new operation. The experimental results obtained during the last several months of testing are discussed.

Review of “slow” conditioning principles

Although traditional sugar conditioning systems usually remove most of the available moisture, remaining water may still create problems with sugar hardening. Conditioning silos are designed for limited sugar retention time (40-50 hours), which means that air circulation is not available during most of the storage period. Therefore, conventional conditioning systems address the problems occurring during the first relatively short period of storage and do not affect water migration within a silo. It is known that the latter is responsible for sugar hardening and crust formation on the walls.

The goal of removing significant amount of water during a limited period of time imposes certain requirements on a conditioning system design. Sugar conditioning is accomplished by supplying the drying air with the partial water pressure less than that of air surrounding the sugar crystals. Typically, to provide sufficient water removal rate either a large air quantity is circulated or desiccants are used for air dehumidification. Pressure drop and dust formation usually impose limitations on the available air flowrate, so some degree of air dehumidification is usually required.

An alternative approach to sugar conditioning was described in our previous publication1. Air is circulated at a relatively low flowrate, only refrigeration is used for dehumidification. A fractal distributor manifold is installed on the bottom of each silo preventing air from channeling inside the sugar bed and minimizing the required pressure drop. Conditioning air has sufficient drying capacity to remove the excess moisture from sugar crystals and keep sugar at optimal storage conditions. Part of the conditioning air is bypassed through the head space of a silo and is used to adjust the relative humidity. The latter feature is important to control the dust formation in the head space. Continuous air circulation during the entire storage period ensures that water migration to the silo walls is limited to the narrow band adjacent to the wall and does not affect the bulk of the sugar.
Discussion of experimental results

A system for silo head space ventilation was installed as a first step towards the implementation of the new conditioning process. The absolute humidity in the head space (grains of water per pound of dry air) was monitored. It is clearly shown in Figure 1 that the air absolute humidity dropped significantly when ventilation started. However, the ventilation did not affect the moisture trapped within the bulk of the sugar.

**FIGURE 1**  
Effect of head space ventilation on absolute humidity

The blower providing the air flow through sugar was installed in one out of twelve silos to test the new concept.

Figure 2 illustrates the rate of moisture removal from the conditioning silo. During this period the head space was still ventilated in all twelve silos. In addition to that the conditioning silo had air flow through the sugar bed. During the first 3-4 days of conditioning the relative humidity in the head space was higher than average, which
indicated that the water released by sugar crystals had been continuously removed. After the initial period when the silo was completely filled, the air circulation maintained the humidity inside the silo at the optimal level. Since the conditioning air was not completely dry, equilibrium was established within the sugar bed, which prevented sugar from being over dried.

The portion of the instrument chart reproduced in Figure 3 reflects the changes in power consumption in the scroll motors. Typically, the curve fluctuations indicate the presence of lumps. The curve clearly shows the difference in sugar flowability, when the sugar stream was switched from a non-conditioned to a conditioned silo.

The pressure drop was monitored as a function of bed height in the silo. The overall pressure drop across the distribution system and the bed of sugar did not exceed 3-4 psi when the silo was completely full. The low pressure drop can be explained by the relatively low air flowrate. The system, however, works efficiently because of the fractal distributor installed in the bottom of the silo. The fractal distributors had been originally designed for large-scale chromatographic columns. The same principle has been applied for design of the silo air distribution system. Because of hydraulic equivalence of all channels the fluid is distributed uniformly across the column. A key feature of the fractal distributors is
independence of the distribution efficiency on fluid flowrate. This distinguishes the fractals from conventional distribution systems based on pressure drop.

Most existing conditioning silos require additional insulation to avoid condensation on the internal surface of the silo walls. This was our main concern, when the experimental silo was retrofitted to test the new concept. In non-insulated silos a temperature gradient across the wall always exists. Since the dew point for the air surrounding well conditioned sugar is around 50-55°F, wall thickness of about 10 cm does not provide sufficient insulation to prevent condensation on the wall. Therefore, the air adjacent to the silo wall should always reach a dew point without the heat compensation. In the absence of air flow through the bulk of sugar the water would migrate towards the walls, eventually causing sugar hardening and crust formation.

During the winter months of 1998 the temperature in Nampa, ID fluctuated around 30-40°F during the day and 18-30°F at night. It is very interesting that no crust formation on the inside walls was observed. Moreover, the old colored crust had been continuously peeling off the walls during loading-unloading cycles. The air circulation must have prevented moisture from moving in the radial direction. The water released by sugar crystals was readily picked up by the ascending air flow and subsequently eliminated from the recirculation loop. Evidently, maintaining a uniform air relative humidity inside the sugar bed is critical for reduction of sugar hardening and lump formation.

Observations before and after installation of the new conditioning system listed in Table 1 confirm that the test goals were successfully accomplished.

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Relative humidity was high when silo was unloaded indicating that moisture was trapped within the bed of sugar.</td>
<td>No significant change in relative humidity.</td>
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<tr>
<td>Used to poke sugar through unloading gates to initiate the flow with gates almost fully open.</td>
<td>Sugar starts flowing when the gates are slightly open.</td>
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<td>Crust on the walls, sometimes colored.</td>
<td>No new crust formation, old crust peeled off the walls.</td>
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<td>Mounds of sugar up to 20 ft. high when silo is unloaded, unsafe cleaning conditions.</td>
<td>Sugar can be drained down to 4 ft. height, which makes manual cleaning safe.</td>
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<tr>
<td>Condensation on silo walls.</td>
<td>No condensation.</td>
</tr>
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<td>Cleaning time - 770 man-hours.</td>
<td>Cleaning time - 24 man-hours.</td>
</tr>
</tbody>
</table>

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REFERENCES
