Bulk Sugar Storage - Weibull Silo

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Introduction

Storage of large quantities of bulk sugar involves a great many problems both with respect to the handling of sugar in the plant and until it finally reaches the consumer. This paper has been prepared to show the methods and some of the results obtained by Union Sugar utilizing a Swedish design Weibull silo.

Being located near the coast and subject to frequent fogs and winds, the climate at Betteravia is extremely variable. The relative humidity will vary from 40 to 100% within a 24-hour period and frequently will change this much in six hours. Storage and handling of sugar under such varying conditions has dictated a search for means of storing sugar in a more favorable atmosphere. The Weibull silo was chosen as a means of storing sugar under constant temperature and humidity conditions without influence of ambient air changes.

Silo Construction and Design

The silo was designed to hold 20,000 tons (400,000 cwt.) of refined sugar. The main structure is a steel shell 116 feet in diameter by 82 feet high to the eaves, resting on a flat concrete base and containing a central tower 11 feet in diameter. The installation is insulated and waterproofed externally, thus providing a virtually airtight enclosure. The maximum height of the sugar below the reclaiming mechanism is 74 feet.

Filling and emptying the silo is completely automatic in the sense that the operator has only to set and adjust the controls periodically. Sugar enters and leaves the silo through the bottom conveyor which is reversible. Sufficient interlocks are provided so the handling mechanism must be started and operated in the correct order. Panel board lights are provided to assist the operation.

Complete erection including foundations, steelwork, insulation and equipment placement was contracted to the Chicago Bridge & Iron Company. Foundations and steelwork were redesigned by them to conform to American erection methods and all materials, excluding the sugar reclaiming mechanism and air conditioning machinery, were obtained on the west coast.

Description of Silo Internals

The center of the roof is supported by a central tubular steel tower 11 feet in diameter extending from below the floor through the apex of the silo. The tower contains a bucket elevator, a

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manlift, central air ducts and electrical panels. Radial trusses from the tower serve to stabilize the upper part of the shell, like spokes of a wheel.

The main floor of the silo consists of two layers of concrete 5 inches and 7 inches thick separated by special-shaped corrugated, galvanized iron sheeting to allow passage of air underneath the floor. The steel sides are covered with the same type of corrugated, galvanized iron sheeting to form air ducts up the outer wall. Three inches of fiberglass insulation with aluminum sheeting on the outside serve to insulate the sides. Two-inch holes in the top and bottom of the steel plate sides allow the passage of air from underneath the floor, up the outside walls and into the 15-inch space between the aluminum sheathing beneath the radial beams in the roof and underneath the 1/8-inch steel roof base plating. The outer surface of the roof is insulated with three inches of stiff fiberglass board and covered with asphalt roofing paper.

The Silo Bridge

Supported on a rail around the top of the shell and the central tower is a large radial bridge which continuously rotates while the silo is being filled or emptied and provides the means whereby the sugar surface is kept level. The bridge carries two circular spreading mechanisms for sugar distribution and a winch for raising and lowering the reclaiming screw which is suspended below it. Based on two welded plate girders, 52 feet in span and suitably cross braced, the bridge is mounted at the inner end on single-flanged wheels set parallel with its radial axis on either side of the central tower. The outer end runs on four double-flanged wheels. The wheel axles at opposite ends of the bridge, being at right angles to one another, correct for errors in concentricity of the tower and the shell rail track.

The electrical supply to the bridge is through protected bare copper sliding contactors.

Platforms running the full length of the bridge on either side and around the tower give full access to the distribution mechanism and the electrical panel containing the various motor starters.

Silo Temperature and Humidity

Constant temperature and humidity within the silo are attained by constantly circulating warm or cold air in the shell around the sugar in storage and by removing the moisture from the air above the stored sugar. Either warm or cold air, depending on the temperature above the sugar, flows underneath the floor, up the side ducts and through the air space in the roof of the silo at all times. The direction of the flow is reversed every twenty minutes by an automatic timing device. The volume of air, approximately 10,000 C.F.M., is heated or cooled by circulating water radiators located in the ductwork at the base of the silo.

The relative humidity is regulated by means of a dehumidifier located in the top of the central tower. A constant stream of air is moved from the space above the sugar through a dust collector and refrigeration coils and recirculated back into the silo. A hygrostat located within the silo chamber regulates the operation of the two-ton coil unit.

The air above the sugar may be changed at any time by opening vents in the silo roof and allowing air from the circulation system to be released directly into the space above the sugar. Simultaneously, vents are opened at the apex of the roof to allow the internal air within the silo to be exhausted into the atmosphere. The fresh air intake for the circulatory air system is located above the highest point of the silo roof.

Sugar Handling to and from Storage

Sugar from production is screened, the minus 60-mesh sugar separated out and sacked each day. The balance of the sugar is conveyed to the silo by means of a screw conveyor underneath the temporary storage bins to a 20-inch, white-rubber belt conveyor. From the belt conveyor the sugar is elevated by a bucket elevator and discharged onto a circular turntable where it is ploughed off into chutes leading to two revolving distributors. The purpose of the distributors is to evenly distribute the sugar within the central tower as the bridge slowly revolves. Most of the dust is carried downward by the thin conical stream as it descends.

Filling the silo by sprinkling in a manner resembling falling snow, as distinct from normal pouring method, produces two important effects: The in-going sugar is cooled in air by spreading it thinly over a wide surface; compacting is reduced by allowing each crystal to rest where it falls without sliding.

Sugar is removed from the silo through twelve 6-inch × 18-inch openings located at the base of the central tower. The rate of discharge through these openings is regulated by sliding gates into chutes extending down to the face of the lower revolving turntable in the base of the central tower.

Sugar discharged from the lower turntable may be either recirculated or withdrawn for shipment by reversing the 20-inch belt conveyor used to transport the sugar into the silo. From the belt conveyor the sugar is discharged to an 18-inch screw conveyor where it may be sent to either the rotex screens or shipped direct. The reclaiming screw within the silo is used only to keep sufficient sugar in supply next to the central tower or to level the sugar in the silo during filling.

Silo Operation and Sugar Quality

With the removal of the minus 60-mesh sugar from the silo feed, the dust problem is considerably diminished. The remaining dust is removed continuously. Other than during the period of filling, the air above the sugar is clear. The small volume of dust removed is transported from the collector base by vacuum lines to the main floor of the packing room where it is sacked periodically for remelt.

As a minimum of equipment is required to handle the incoming and outgoing sugar, breaking of crystals is negligible (as shown in Figure 1). Differences observed are not significant at 19:1 odds (1)[2].

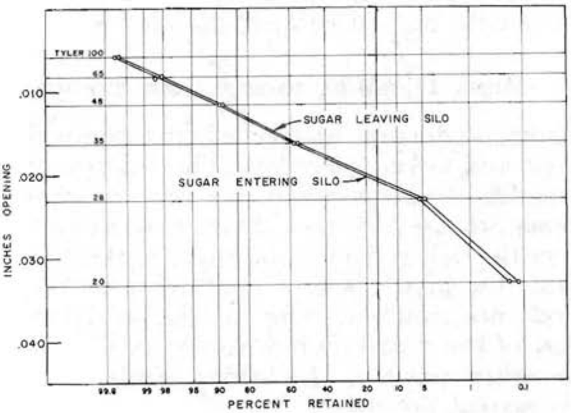

Figure 1.—Composite screen analysis of sugar entering and leaving silo.

The loss by attrition due to the reclaiming has not been significant and to date, all sugar flowing out of the base of the silo has been very free-flowing. Only occasional poking or probing of the outlets has been required. All handling screws are double flight screws to insure an even flow at all capacities and are of ample capacity.

During the first season of operation, sugar was recirculated once every eight hours to keep the sugar next to the center column in a free-flowing condition. This practice has been discontinued and we now depend on normal shipment withdrawals to keep free-flowing sugar in this area. No sugar is circulated over the weekends during interseason.

[2] Numbers in parentheses refer to references.

Color

During any given period, no significant difference can be noted between the color of the incoming sugar and the sugar stored in the silo. Table 1 shows a small difference in the average color analysis of the air slide cars in comparison to the average of the campaign analysis of each strike. This is due largely to the fact that more than ten times as many analyses were run during the year on the campaign samples as on the shipment samples and any variation in the shipment color would be magnified to a greater extent.

Table 1.—Comparison of sugar colors, sugar produced and sugar shipped.

	1961 Imperial	1961 Coastal
Sugar to Silo	91.9	92.8
Sugar Shipped	91.4	91.3

Sugar color expressed as % T of 50% solution, 50 mm light path at a wave length of 425 mu; instrument standardized against distilled water.
Color of sugar to silo is average value of all sugar introduced to silo.
Color of sugar shipped is the average of sugar colors from air slide shipments.

Sugar Temperature and Moisture

The temperatures of the incoming and outgoing sugar are shown in Figure 2. The incoming sugar temperature is governed by temperature of the sugar leaving the granulators. No special cooling is provided. During the filling of the lower half of the silo, the sugar loses about 15° F by falling through the air and being distributed over the large sugar surface in the silo. This temperature difference is gradually reduced as the silo fills.

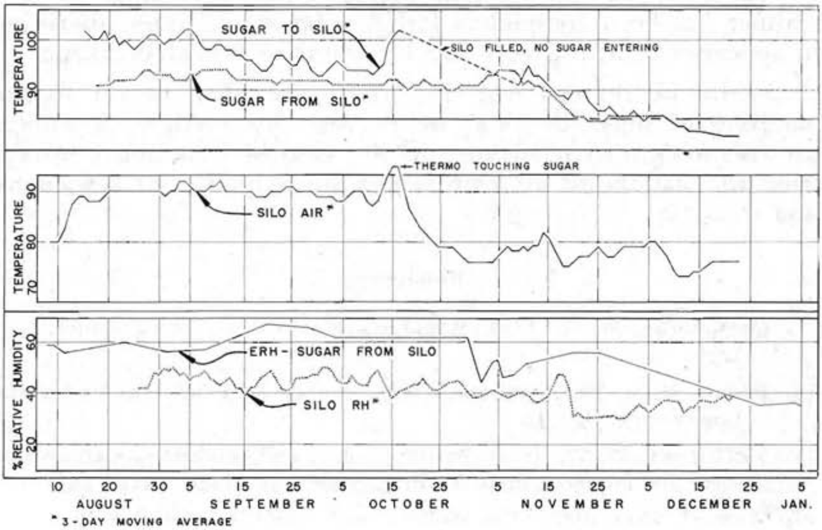

Figure 2.—Temperature of incoming and outgoing sugar.

At the close of the season, the sugar temperature drops slowly as the air temperature in the air space above the sugar is lowered to between 60° and 70° F. The upper limit of the hygrostat controlling the relative humidity of the air above the silo sugar is set at 53%. The average relative humidity of the air in the space ranges between 40 and 50%. This low relative humidity has a slow drying effect on the sugar in storage as evidenced by the difference in moisture between the sugar entering and as shipped. The average moisture content of the entering sugar during 1961 was 0.016% and the average moisture content of the shipped sugar was 0.009%.

During the past season, equipment was purchased and the "Equilibrium Relative Humidity Values" of the stored sugar as described by McGimpsey and Mead (3), were taken periodically.

These values did not change greatly during season when the silo was constantly being filled. A sharp drop was shown during the period when no sugar entered the silo and the sugar was held in storage. Further results are being taken to continue these studies in hopes of finding out more about what actually takes place during sugar storage.

Conclusion

The storage of sugar through the use of a Weibull silo has provided an economical means of handling bulk sugar with the minimum of equipment and labor. The sugar held in this manner has been completely free-flowing at all times, sparkling in appearance, with a very small amount of crystal breakage.

While we do not feel this to be the final answer to the handling of sugar in bulk, we do feel this method of storage presents a significant advance in the field of bulk sugar storage from the standpoint of maintaining sugar quality at low handling costs.

References

(1) QUENOUILLE, M. H. 1959. Rapid statistical calculations. Hafner, New York.

(2) BROWN, B. S. 1961. Six quick ways statistics can help you. Chemical Engineering. 68: 18.

(3) MCGIMPSEY, W. W. 1961. Drying, cooling and conditioning granulated sugar for shipment in bulk. Proc. Sugar Ind. Tech. XIX: 167.

(4) WEIBULL, NILS. 1952. The Weibull raw sugar silo. Socker. 8 (2): 17-23.