

Bulk and Liquid Sugar Production at the Brookfield (Chicago) Terminal

L. T. JENSEN AND WHITNEY NEWTON II¹

Received for publication February 11, 1960

The facilities at the Chicago Terminal were constructed to provide truck deliveries of the bulk dry and liquid sugars to customers in that area. The plant is located in the village of Brookfield about 12 miles southwest of downtown Chicago and is served by the C.B. & Q. Railroad.

The Terminal is capable of receiving annually over one million cwt of bulk sugar via railroad cars from the producing factories. It was designed to operate with a minimum of labor and at the same time produce liquid sugar of the very highest quality. The building was made attractive and the equipment was so arranged that the whole station could be kept clean with the minimum of effort.

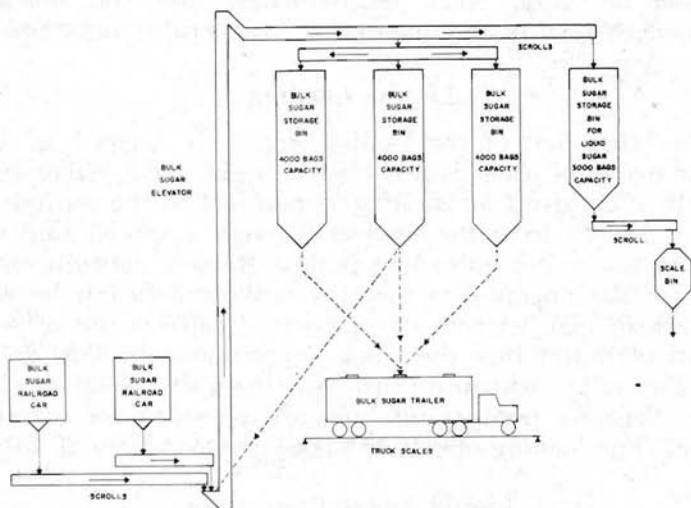


Figure 1.—Bulk sugar handling, Chicago Terminal.

A general arrangement of the bulk unloading and storage facilities is shown in Figure 1. Two parallel tracks under cover are provided with individual scrolls to the elevator. Provisions are made to unload either air-slide or hopper rail cars. Approximately three hours are required to unload an air-slide car.

¹ General Superintendent and Assistant Director of Research respectively, The Great Western Sugar Company, Denver, Colorado.

This sugar is conveyed to a bulk storage bin by means of conventional scrolls and bucket elevator. All sugar unloaded is passed through a magnet. A conveyor system over the bins is controlled remotely so that the sugar can be directed into any of the four 4000-bag bins. Three of the bins are used for sugar that is subsequently loaded as bulk granulated. The fourth bin is used for storage of sugar intended for the liquid station.

Bulk Loading

The loading of bulk trucks takes place inside and is accomplished simply by filling each compartment by gravity from the overhead bin while the truck is on the scale. The truck is moved back and forth to place the proper compartment under the bin for loading. Care must be taken to put the proper amount of sugar in each compartment so that individual axle loads are not exceeded. The sugar, when being loaded, is passed through a small mesh screen. The operation of loading a bulk truck is accomplished by one man with the aid of the truck driver. The complete operation takes approximately one and one-fourth hours. Both gravity and pneumatic type bulk trucks are used.

Liquid Loading

The other half of the loading station is devoted to liquid. A separate set of scales is provided. Liquid sucrose, either sucrose at 67 Brix or invert at 76 Brix, is pumped to the station. The truck is loaded from the bottom through a special line which by-passes the trailer unloading pump. Remote controls are provided for the operator so that the tank trailers can be loaded by one man. He watches the scales and delivers the prescribed amount of liquid into the truck (approximately 3500 gallons), shuts the valve, which in turn automatically shuts down the pump. Separate pumps and lines are provided for invert and sucrose. The loading operation takes approximately 20 minutes.

Liquid Sugar Operations

The process for making liquid sugar is shown in Figure 2. The liquid sucrose process consists of dissolving sugar in demineralized water, treating the solution with carbon, filtering and cooling. When invert is being made the hot filtered solution is inverted with hydrochloric acid, neutralized with sodium carbonate and cooled. The plant is designed to produce either product but, since the same equipment is used, only one product is made at any one time. The process, except for the filtration station, is automated to minimize labor requirements.

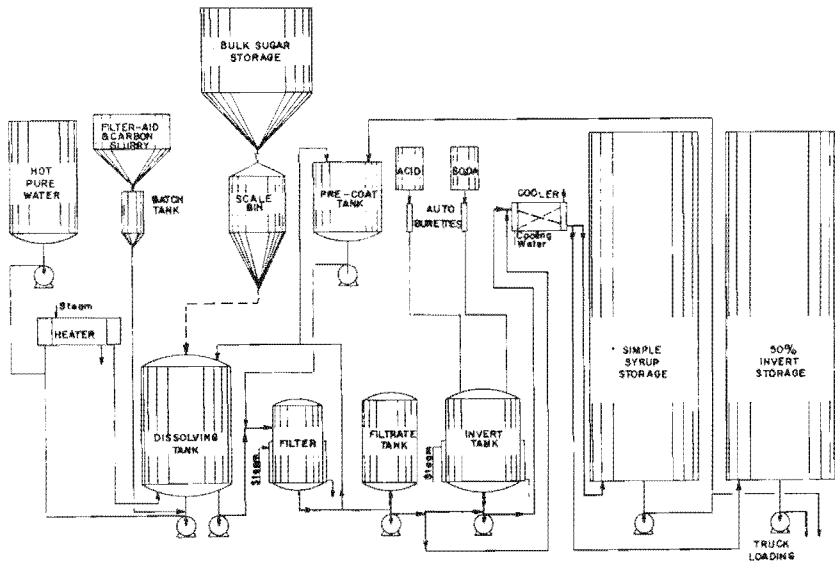


Figure 2.—Liquid sugar process flow.

The Dissolving Cycle

Sugar is weighed in batches of approximately 14,500 pounds and conveyed to the dissolving tank to which 900 gallons of water and carbon slurry have been added. As the sugar is introduced, the mixture is circulated through a stainless steel heater and maintained at 75° to 80° C. Two dissolving tanks are provided so that a continuous flow to the filter station can be maintained. The complete cycle is automated and controlled by a timer. All that is required of the operator is that he set the scale and meter for the prescribed amount of sugar and water and push a button to start each cycle. After completing the first cycle, he manually selects the other tank and starts the cycle again. A series of interlocks are provided in the electrical circuit to shut the operation down if any mechanical failure takes place.

After the dissolving cycle is completed the operator pushes a button that opens the drain valve and starts the filter pump. Three, 150 square feet horizontal plate, cartridge-type filters are provided, of which two are in service during operation. Suitable piping is provided so that the filters can be pre-coated and re-circulated manually. After a filter is filled with cake, it is blown with air to remove the maximum amount of syrup and then put on circulation with water in the pre-coating system to extract as much sugar as possible from the cake. The cartridge is then removed, disassembled and redressed with paper. This

procedure of blowing, recycling and redressing requires approximately three hours. Two men are required during the cleaning of the cartridge. The syrup discharges from the filters into a stainless steel filtrate receiving tank. From this tank it is pumped through the heat exchanger to storage. A filtrate receiving tank is provided to minimize the back pressure on the filters.

A stainless steel, plate-type heat exchanger with 480 square feet of surface is provided to cool the syrup from 80° C. to 38° C. maximum. The syrup side of the cooler is multiple-pass with plates in parallel and series. Two sources of cooling water are used. First, the demineralized water is used to partially cool the syrup. Thus a portion of the heat is recovered. The remainder of the cooling is done with city water, which is subsequently sewered. A recirculating system, with temperature control of the cooling water, is provided on the final cooling so that at no time can the water cool the syrup to the point that pressure-drop across the cooler becomes excessive. This becomes important when cooling 76 Brix invert syrup.

The liquid sugar is discharged directly from the cooler into storage tanks. The pressure on the cooler varies with the head in the storage tank. Two steel storage tanks of 15,000 gallons each are provided for liquid sucrose. These tanks are 10½ feet in diameter and 24 feet high with a dished head on top and a flat sloping bottom. All corners are rounded and ground flush. The inside surface is coated with a resin paint. Ultra-violet lights are provided in the roof. A double-filtered air circulating system continuously circulates air. Each tank is provided with a side-entering mixer having mechanical seals with water lubrication. A washing nozzle approximately six feet from the bottom is provided to accept a power rotating washing spray. The outlet nozzle is located twelve inches off the bottom with an auxiliary nozzle on the bottom for complete drainage. Each tank has five nozzles below the liquid level. Every effort was made to minimize places that may create contamination of the product and render washing ineffective. Blank covers are provided to replace the ultra-violet lights during washing. Pressure diaphragms are placed in the bottom discharge line so that tank levels can be recorded on the instrument panel.

The Invert Cycle

The previous description of the dissolving cycle also applies when making invert. The ratio of sugar and water is changed so that approximately 73 Brix simple syrup is produced. The cycle timing is changed slightly to allow for a somewhat longer dissolving period. The volume in the carbon measuring tank is

increased to allow for the greater quantity of sugar in each batch. The operator then proceeds as described previously. Flows through the filter station to the filtrate receiving tank are reduced to allow for the increased viscosity of the higher Brix syrup. The operator must now start the cycle that directs the syrup to the inversion tanks. There are four glass-lined, jacketed, 1000 gallon inversion tanks, each controlled by a sequenced timer. This timer performs each step in the operation—that is, opens the fill valve, starts the pump, stops the pump at the proper volume, closes the valve, brings the tank to the prescribed temperature, shuts off the steam, adds the acid, allows the proper time for inversion, adds the sodium carbonate to stop inversion, opens the drain valve, and starts the discharge pump to pump the invert through the cooler to storage. Burettes are used for measuring the acid and sodium carbonate solutions. The timer circuit also includes filling these burettes and checking to determine that they are full before discharging and empty before refilling—precautions, to assure that the proper amounts of hydrochloric acid and sodium carbonate are delivered to each batch of invert.

One master timer controls the over-all operation; each of the four inversion tanks have timers. Timers start the cycle of each tank in series. After the master timer starts the cycle for a tank, the individual timer takes over and finishes the inversion cycle. The individual timer delays the draining of the tank until the previous tank has been drained and pumped through the cooler. After the tank is drained, the individual timer resets itself and delays the next cycle until the master timer has started the cycle for each inversion tank. During the period of making invert the operator is primarily concerned with operating the dissolving cycle to supply syrup to the inversion station. The inversion conditions used to produce 55 percent invert at 76 Brix are approximately 2.3 pH, 80 to 83° C. and 40 minutes. Slight variations occur which are usually compensated for by adjusting the time of inversion.

The syrup leaving the station is pumped through the cooler to storage. Since the operation of the cooler is in batches of 1000 gallons and inevitably a short delay occurs between each batch, the matter of temperature control of this cooler becomes somewhat more elaborate than might be thought necessary. As described before, two water supplies are used for the sake of heat and water economy. The demineralized water used in the dissolving cycle is the cooling medium in the first half of the cooler. This water leaves the cooler at approximately 60° C.

The amount of pure water used is regulated manually so that a supply of hot, pure water is available for dissolving the sugar. The balance of the cooling is then accomplished with city water. The automatic control of the cooler is accomplished by regulating the amount of recycled city water bled into the system. A three-way valve controls this quantity of hot water bled into the recirculating system, thus maintaining a predetermined temperature of the cooling water going to the cooler. Thus, two temperature controls are used, (1) to control the temperature of the final cooling water, and (2) to control the temperature of the syrup and, by consequence of the increased pressure drop, limiting the flow through the cooler. The problem of overcooling the syrup is, of course, magnified by the intermittent operation associated with automated batch operation.

Two 15,000 gallon storage tanks are provided for invert syrup, the same as for liquid sucrose. Since the same cooler is used for both operations some precaution is necessary to avoid contamination of simple syrup with invert when switching operations. This is simply accomplished by pumping a small quantity of simple syrup through the system to the invert storage tanks before switching the pipe lines to the simple syrup storage.

Auxiliary Equipment

Boiler

A 100 horsepower boiler, generating 3500 pounds of steam per hour, designed for completely automatic operation, has been installed. This gas- or oil-fired boiler provides the process and heating steam necessary.

Demineralizer

A two-bed water demineralizer is provided to produce .5 grain water. This unit has a flow rate of ten gallons per minute and total capacity of 42,000 gallons. The unit is manually operated and regenerated. The only instrumentation required is a conductivity cell that shuts the unit off at a predetermined, maximum allowable conductivity. A float valve is provided in the demineralized water supply tank so that the unit can be operated at night with no attendant. This assures a full supply of demineralized water each morning. A booster pump is provided on the city water supply to increase the pressure, if needed.

Carbon Slurry Equipment

A resin-coated agitated tank is provided for carbon filter aid slurry. Carbon, filter aid and water are added to this tank to make a twenty percent slurry. This station is in a room that is completely isolated from the rest of the plant. A ventilating

system is provided for this tank. Every precaution has been taken to minimize carbon from being carried to other parts of the plant.

The carbon is introduced into the process as a part of the automatic dissolving cycle. A flush bottom valve opens on the slurry tank which fills a small measuring tank by gravity. The float valve on the measuring tank closes this valve and opens the valve on the measuring tank allowing the carbon slurry to be fed into the process. This slurry is introduced into the suction side of the pump circulating syrup through the heater. By adjusting the level in the measuring tank the carbon dosage can be changed as desired.

Precoating Equipment

An agitated, resin-lined tank and stainless steel pump are provided for precoating operations. Simple syrup is used either from the process or storage to slurry the precoat material. A mixture of filter aid and asbestos is added in the amount of 20 pounds per 100 square feet of filter surface. This slurry is then pumped through the filter back to the precoating tank until the material has been deposited on the paper filter medium. This system is also used to remove the sugar from the carbon cake at the end of a filter cycle. Water is recirculated in this system through the filter to reduce the sugar content of the carbon cake. The sweet water is then disposed of by addition to the next dissolving cycle.

Tank Washing Equipment

A two-tank washing system is provided to wash and sterilize tank trailers and any equipment in the plant. This system consists of two resin-lined tanks, a heater, a high pressure pump, a portable, rotating nozzle and return pump. The usual cleaning operation on a tank trailer consists of recirculating the cleaning solution through the spray nozzles for a period long enough for the nozzle to complete three cycles. Subsequently, two washes of hot water are used. The nozzle is allowed one complete cycle for each rinse.

Quality Control of Liquid Sugar

Every step to insure the quality of the liquid sugar has been taken. Superb filtration is accomplished by the use of horizontal plate filters. The turbidity of the liquid sugar produced is beyond reproach. Stainless steel is used throughout to insure the minimum of product contamination. Adequate carbon dosage is used to insure an extremely low solution color and absence of floc. The conductivity is kept low by the use of demineral-

ized water. Every precaution for maintaining sanitary conditions has been provided. The tank trucks and storage tanks are sanitized on a schedule. Bacteriological control is conducted by a commercial laboratory in the area. The following is a typical example of the liquid products produced.

	Liquid Sucrose	Liquid Invert
Solids (RDS)	67.0	75.0
Invert on solids	0.0	55.0
Sucrose on solids	67.0	45.0
pH	5.8	4.6
Reference Basis Color	3.0	11.0
Turbidity	0.3	0.3
Floc	1.0	1.0
Specific Conductivity $\times 10^{-5}$	2.2	7.0
Sediment (white disc)	0	0
Sediment (black disc)	0	0
Odor	0	0
Bacteria		
Flat Sour	0	0
Total thermophiles	0	0
Mesophiles per 10 g sugar	10	10
Yeast and mold/10 g DS	0.2	0.2

At present the process is operated eight hours per day. No difficulties of any kind have developed to mar the quality of the product. Possibly the reason intermittent operation does not produce high bacteria counts is that all filters and pipe lines in process are kept full at all times. With the periodic cleaning of tank trailers and storage equipment no serious bacteria contamination has been encountered.
