Studies on the Continuous Inversion of Sucrose: III, Physical Installation

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Introduction

In 1969 the Engineering Department of the Spreckels Sugar Division was given the task to design and install at the Manteca Factory an invert production facility of relatively high capacity; a facility which, in an overall economical operation, would consistently turn out product meeting or exceeding the set specifications prevalent in California.

Several production methods were investigated and past experience records evaluated in an extensive and detailed study of invert production installations both within this corporation, and elsewhere, in close cooperation with our Research and Development Department and utilizing computer data runs as described in Parts I and II of this paper.

Based on these studies and on certain specific requirements the conclusion was reached to design a continuous invert production system capable of maintaining close tolerances of the important variables, such as density, temperature, flow rate, and reagent metering, with minimal dependence on an operator and quite unsusceptible to his errors so as to assure true continuity and stability of operation. We were very much aware of the fact that interruptions of continuity - for whatever causes - are inevitably associated with the deterioration of product quality and output capacity and often with the loss of product.

In light of these considerations, a set of rigid design parameters was set up. It was now a matter of strictly adhering to these requirements by assuring proper design and selection of equipment, materials, and instrumentation to accomplish the set goals. The same strict requirements were to be applied to the component fabrication and the actual field installation of the entire project.

The theoretical design capacity was set at 100 gpm of 50% invert syrup with a 20% built-in reserve wherever economically feasible.

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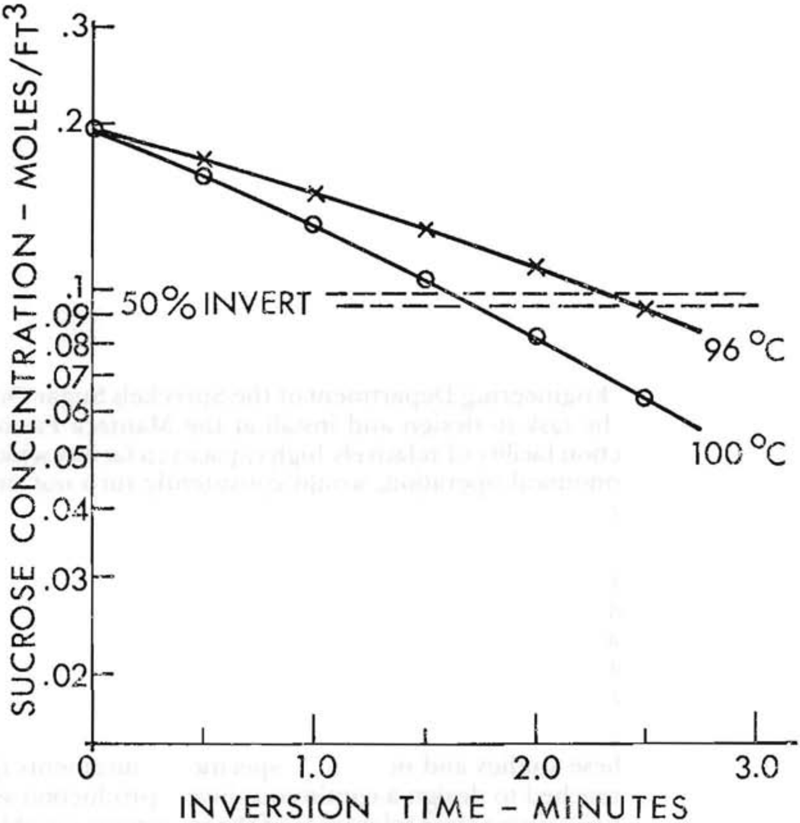

Figure 2.—Inversion of sucrose in continuous inverter, C_H = $2.65 x 10^{-4}$ lb moles/ft^3.

Although designed for the production of 50% invert syrup, the installation lends itself for the manufacturing of other invert grades. The physical installation is described in this paper.

General

The Manteca Factory invert syrup production facility consists of five functionally interlocked subsystems as follows: Dry sugar supply and surge; Stock solution production, or the dissolver system; Invert production; Filtration and Cooling; and Storage and loadout.

The monitoring, programming, and control of the facility is concentrated in the main operating panel and three small secondary panels: one each for the acid area, the neutralizer area, and for the storage-loadout area. With the exception of the storage and loadout area, the installation is accommodated in a space approximately 40 ft x 60 ft extending from the first floor through the 3rd floor of an existing structure.

An enclosed space of about 40 ft x 40 ft on the 2nd floor comprises the operating area. It contains the main operating panel, motor control center, the reactor, acid mixing and metering, filters, and the central portion of a vertical dissolver which extends through the 2nd and 3rd floors. Since the installation is accommodated in an existing factory, the physical arrangement, both within the structure and in the yard area, was obviously influenced to an appreciable degree by the prevailing conditions.

Description of Individual Sub-Systems

Dry Sugar Supply and Surge

The dry sugar supply system consists of an elevator, a number of screw conveyors, a batch scale, a surge bin, and a variable-speed dissolver feed scroll (Figure 1). The system is capable of handling dry granulated sugar at rates exceeding 800 bags/hr. The dissolver can be supplied with dry granulated sugar either from the bulk sugar storage bins or directly from production.

The 11′-6″ diameter surge bin, equipped with Fuller bin level devices, is built of 14 ga. stainless steel and has a total capacity of 850 cu ft. The batch scale may be bypassed at the operator's choice without interrupting the continuity of operation. Programming, monitoring and operating devices for the above components are located in the main control panel, except for the batch scale panel, which is considered a part of the scale and mounted near the scale.

Stock Solution Production or the Dissolver System

This group of equipment includes: dissolver or a vertical melter; solution water system consisting of a recirculation tank, T&S heaters,

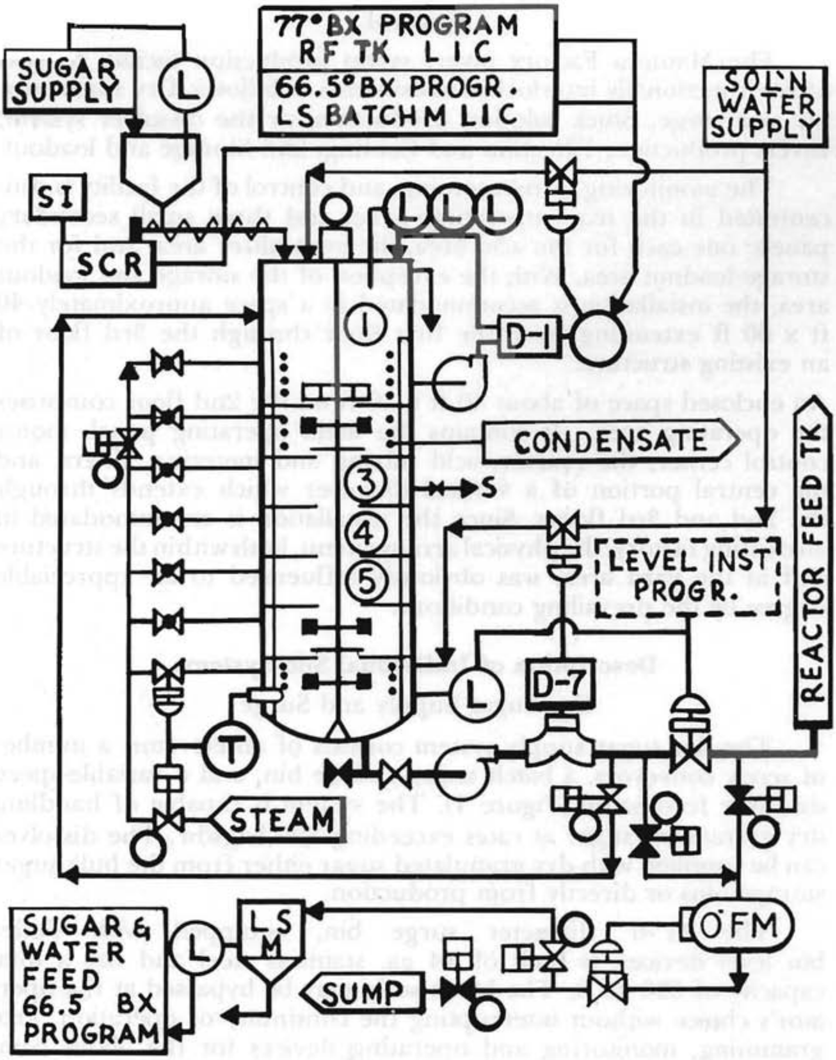

Figure 1.—Stock solution production, or the dissolver system.

Cuno filters, and two centrifugal pumps; steam and condensate system; and dissolver discharge pump.

The continuous dissolver and its control loops are designed to produce either the high-Brix stock solution, which is used for invert production, or to operate as a continuous melter for the production of liquid sucrose. When operating on high-Brix stock solution, the dissolver discharge stream can be split into two streams, one to feed the inverter on a preferential basis and the other to fill an existing batch-melter for liquid sucrose batch production by dilution with water. For future consideration, provisions have been made in the design to incorporate liquid sucrose production from high-Brix stock solution on a continuous basis simultaneously with continuous invert production.

The dissolver operating range is from 40 to 140 gpm of stock solution. By selecting the desired program and production rate at the main operator panel, proportional metering of sugar and water is automatically set up and then automatically adjusted, as dictated by first stage density signals and by the level conditions in the reactor feed tank or in the batch melter, depending on which program has been preselected. The dissolver level condition also has an effect on the sugar and solution water supply. The task of the dissolver controls is to maintain the dissolver in a steady balanced state from the standpoint of output, operating level, temperature and density.

The dissolver loop consists of:

a) First stage density control - Halliburton - settable for high-Brix stock solution and for liquid sucrose Brix. Control within 0.5 to 1.0° Brix. The density sample pump is manually started at the main panel;

b) Final or seventh stage Brix control-Electron Machine Corporation in-line refractometer - settable for Brix of stock solution and for liquid sucrose. Control within 0.1° Brix;

c) Level controls, consisting of a diaphragm type transmitter in stage seven, and of three pairs of B/W probes in the first stage. The B/W probes control the dissolver scroll, the discard valve, the on-off steam valve to stages 1 and 2, and the 1st stage high-density trip reset at low operating level.

The level transmitter in the seventh stage with a number of level switches accomplishes several functions, the main of which is the degree of opening of the dissolver level control valve. This valve will open ONLY if the Brix in the final stage is within the set 0.1° Brix limit. If this requirement is not met, the recirculation bypass valve is automatically opened, permitting the material to be returned to stage one of the dissolver. If the final stage Brix is within the set limit, the control valve opens, and the percentage of opening is regulated by the liquid level in the dissolver and, indirectly, in the surge receivers.

The remaining final stage level switches have the following control functions: 1. High operating band at 77° Brix and at 66.5° Brix; 2. Maximum draindown of high-Brix material and maximum refill of water for layby in dilute condition; 3. Maximum fill with 66.5° Brix material for initial startup; and 4. Minimum level in the vessel at which the agitator may be operated

d) Temperature controls include indicating thermometers for each stage. Manual globe valves are provided on six stages and a temperature indicator controller with a temperature control valve on stage seven. Outgoing product is controlled within 3 to 5°F lower than required for invert production. The temperature controller is of dual purpose, settable for liquid sucrose and for stock solution operation.Positive auto-shutoff valves are provided on the main steam supply to the dissolver, and on the upper two stages of coils for auto-shutoff during draindown operations. 45psig steam serves as the heating medium.

e) Interlocks - The above functions are interlocked with the dissolver agitator drive and with certain programs of the reactor system. All functions cease if the agitator stops.

As stated above, the dissolver effluent, if it meets the specifications, can be directed to the reactor feed tank, or to the batch melter, or to both with guaranteed supply to the reactor feed-tank first, and to the batch melter on an interrupted basis, as available. If at times both tanks are full, the recycle valve automatically opens to return good product to the top stage, where the level controls take over and put the dissolver temporarily in a dormant stage with no additional ingredients entering the vessel. A discard valve is provided for unforseen emergencies to permit lowering the dissolver level when it is high with high-Brix material.

All programming, monitoring, and operating devices are concentrated in the dissolver section of the main control panel. The main programs of the dissolver are: AUTO-CANCEL-RESET, and MANUAL. The dissolver can also be programmed for invert production, liquid sucrose production, or for "split-stream" operation.

The solution water is obtained from the plant treated water supply. The solution water system for the invert production consists of a closed, stainless steel recirculation loop with a stainless steel tank, 3′-6″ dia. x 8′-6″ high. The tank is equipped with level controls. The driving force is provided by two centrifugal pumps, one running and one on standby.

Two Buxton T&S heater bodies with 90-10 Cu-Ni tubes elevate the water temperature to the desired level. A temperature control valve regulates the admission of steam as required. Two Cuno filters, one in operation, and one as a standby — each 75 gpm capacity, 5 micron cartridge — are used for final filtration of the solution water. Water temperature, tank level, and pump status are monitored at and controlled from the main control panel.

A self-acting, pressure-regulating valve maintains preset pressure in the solution water loop. A Greer accumulator is provided to protect piping against harmful shocks.

The steam and condensate system consist of a Roth compact unit for condensate, and of a pressure-reducing valve to reduce 150 psig steam to 45 psig. The condensate from all sources is collected in the Roth unit and pumped to a boiler feed water tank in the plant.

The dissolver discharge pump is a stainless centrifugal pump, 140 gpm capacity at 55 psig. An in-line strainer is set at the pump suction to remove possible debris which may be carried with sugar to the dissolver. The dissolver discharge pump drives the product through the in-line density element and supplies all points requiring the product, including recirculation to stage one.

Invert Production

The principal components of the invert production system are: reactor feed tank; reactor feed pump; flowmeter; final heater; reactor or inverter; acid mixing and metering system; and neutralizer mixing and metering system.

Reactor feed tank — 4′-6″ dia. x 7′ high made of stainless steel, nonagitated, equipped with level controls consisting of a transmitter and a pair of B/W probes which shut and open the stock solution inlet valve. The diaphragm type level transmitter-controller operates within the operating band of the tank and continuously sends out status signals to the preprogrammed sugar and water feed control loops.

The reactor feed tank also serves as the receiver of recirculated material from the invert system, including the layby cooling recycle loop.

Reactor feed pump — a 25 hp Sier-Bath stainless steel Gearex pump with Polyspede SCR drive which is controlled and adjusted by the flow control loop to assure the programmed output rate within .05% accuracy. The pump, as all positive displacement pumps in this installation, is equipped with a sealed type pressure-relief valve discharging to pump suction.

Flowmeter — Brooks oval, 40 to 140 gpm, of stainless steel construction, with Tach-generator, integrator, and temperature compensation. Accoracy 0.5%. Special wash-out connections are provided to guard against grain formation during layby. (A second flowmeter is used for metering the flow to the liquid sucrose batch melter).

Final heater — AHRCo Spiral heater, of stainless steel, to raise the stock solution to preset final inversion temperature, with high temperature and low flow trip. The temperature control loop is required to maintain ± 0.1°C accuracy.

Reactor or inverter — of our design, continuous, 4″, 10 ga. Ti-coil, with 4 hydrocloric acid inlet points, with a 5′-8″ long, 2.5″ dia. x 15 elements Kenics static mixer for immediate dispersion and intimate mixing of acid with syrup; with one inlet point of calcium hydroxide slurry, and with a "Lightnin" in-line mixer 3.2 gallon capacity, 0.75hp for instant dispersion of the neutralizer in order to control color rise; with delta-T detection loop, monitored at the main control panel. The reactor is insulated. A pH-sensing element is located immediately beyond the in-line blender with pH recording at the main control panel. The pH instrumentation consists of a Foxboro pH-to-current converter and a Beckman electrode holder and electrodes.

The degree of inversion is indicated and recorded by monitoring the delta-T reaction temperature rise in the reactor. The reagent flow quantities are precalculated and set for a number of production rates with manual loading stations at the main control panel for final adjustment of reagent flows to achieve the prescribed delta-T and pH.

Acid mixing and metering system — undiluted HCl is pumped from a drum to a measuring tank from which it is admitted manually to two rubber-lined mixing tanks, each 3′-6″ dia. x 5′-6″ high, equipped with agitators and vents to atmosphere. Cold domestic water is used for dilution of the acid. Level is monitored by B/W probes.

A single Lapp - HS - 1AP Pulsafeeder of 75 spm with viton Hydratube is the driving force of properly diluted acid to reactor. The Pulsafeeder is equipped with a pneumatic remotely-operated controller for stroke-length adjustment. The stroke length is preset for each production rate. A manual loading station is provided at the main panel for fine adjustment during operation.

An on-off valve located near the reactor automatically responds to invert production programming initiated at the main control panel.

Neutralizer mixing and metering system — calcium hydroxide slurry of set concentration is prepared in two agitated tanks, each 5′-0″ dia. x 7′-3″ high, made of stainless steel, equipped with agitators and B/W probes. The slurry is metered by a single Lapp - HS - 2AP Pulsafeeder with viton Hydratube and a pneumatic stroke controller. The mode of operation is similar to that of the acid pump. An on-off, auto-controlled valve admits neutralizer to the reactor as dictated by the programming at the main panel.

The invert production system has several programs:

a) Reactor feed tank-Charge-Cancel.

b) Recycle program - to stabilize equipment and piping temperatures prior to initiating the inversion reaction. The stock solution is circulated through the final heater and reactor, and back to the reactor feed tank. No reagents are admitted to the reactor during this stage.

c) Continuous invert standby program.

d) Invert production program. When all prerequisites are met, the turn of a keyed switch at the main control panel initiates the termination of the recycle program and activates reagent influx into the reactor.

e) Dissolver layby auto-drain program. This program represents the normal termination of continuous invert production. In this program the dissolver level is worked down below the normal operating band, so as to obtain enough space for water addition and reduction to 66.5° Brix.

The draindown operation also permits the reactor feed tank level to reach the low condition which causes auto-shutdown of the reactor feed pump. As the low level conditions are reached in the balance of the system, all equipment shuts down automatically.

f) Manual layby recycle. The purpose of this operation is to achieve intermixing of materials in the reactor loop and in the reactor feed tank so as to avoid crystallization of material during layby. The lines are always kept full during shutdown.

g) Manual layby cooling-recycle. This is a manually set up interlocked cooling recirculation loop between the reactor feed tank and the plate cooler discharge, designed to reduce color rise of the product remaining in the piping and tanks during the layby or shutdown periods.

Filtration and Cooling

The filtration and cooling portion of the installation consists of: final Brix tank; filter feed pump; filters; filter drain tank; cooler supply pump; cooler; and cooling water pump.

Final Bix tank or filter feed tank is 3′-0″ dia. x 7 ft high, stainless steel, agitated, with level-controlled pump discharge valve.

Filter feed pump — is a centrifugal pump of stainless steel construction, 140 gpm capacity at 200 foot head.

An in-line density device and a control loop, similar to that used in the final stage of the dissolver, are designed to monitor and adjust density if required, by admitting closely-controlled amounts of solution water into the pump suction line. (The Brix control of the preceding equipment is very satisfactory, and this final Brix loop seldom does any work).

Filters — Two stainless steel Sparkler filters with horizontal plates, paper media, each 151 sq ft surface. Filters operate one at a time. Manual valves with limit switches are provided for filter switchover. The filters are equipped with delta-P alarms. Filter status "ON STREAM" and "OFF STREAM" is indicated at the main control panel.

The filters are equipped with scavenger leaves and air blow-down, so that the termination of a filter cycle is accomplished with practically zero loss of product.

Filter drain or cooler feed tank — 3′-0″ dia. x 7′-1″, stainless steel, nonagitated, with level controlled spill-back valve for positive displacement pump operation.

Cooler supply pump — Sier-Bath Gearex, made of stainless steel, 25hp, 145 gpm capacity.

Cooler — Plate-type APV R55, 316 stainless steel. 1,333 sq ft with oversize frame, 300 psig operating pressure. 212°F to 90°F at 115 gpm with 700 gpm cooling water at 80°F in and 98°F out. The plates are 20 SWG. Water flow is indicated by a flow switch. The quantity of cooling water is controlled by the temperature control valve of the effluent product.

A manual hot water circulation system to preheat the residual material in the cooler after shutdowns consists of a small tank, injection steam heating, and a small centrifugal pump.

Cooling water pump — Byron-Jackson centrifugal, 750 gpm capacity at 140 ft head. Main factory water from the cold sump is passed through the cooler and returned to the basin. The pump is monitored at and operated from the main control panel and is interlocked with the invert production program control loops.

Storage and Loadout

The storage programming and tank level status indication and alarms are at the main control panel. Tanks must be switched by the operator at the control panel upon receipt of alarm. Failure to switch the tanks on alarm results in cessation of invert production after a time delay. A "Full" condition in all tanks also stops production. Invert production cannot be initiated with all tanks full or when the operator fails to select an available tank.

The following equipment comprises the storage and load-out system: storage tanks; startup product return pump; loadout pump; loadout operator house; loadout station; and final pH adjustment.

Storage tanks — There are two invert storage tanks of a total capacity of 100,000 gals., and one of 25,000 gal. for either liquid sucrose or invert storage. When on invert service, the dual purpose tank is used to temporarily store the somewhat higher colored product resulting during the first few minutes of invert system startup.

As soon as the production is stabilized, the higher colored product is introduced into the main stream to storage at carefully metered rates by means of the startup product return pump.

All tanks are of mild steel construction, "Plasite" lined, and equipped with fully filtered vents, Sterilamps, level devices, and Varec gages.

Startup product return pump — This pump is a small Sier-Bath, stainless steel Gearex pump with a 5 hp variable speed drive, manually adjustable. It is used to reintroduce the "startup product" into the main product stream to storage.

Loadout pump — The loadout pump is a 400 gpm, stainless Sier-Bath Gearex, equipped with 50 hp variable speed drive, with local, manual speed adjustment.

Start-stop push buttons are provided at the pump and at the loadout station platforms for railcar and truck filling.

Loadout operator house — The operator's shelter is constructed of steel and houses the final pH adjustment equipment, sample jars, log book, field utility panel, storage cabinets, and a sink.

Loadout station — There are four closed loading points, equipped with Chicksan counterbalanced spouts, spring-loaded valves and manual butterfly shutoff valves. Two truck islands are provided for simultaneous loading of invert and liquid sucrose tank trucks. Access to tank truck tops from an elevated steel platform is facilitated by air-cylinder operated retractable platforms.

Independent spouts are provided for loading rail tank-cars with invert or liquid sucrose, one at a time. Access to the rail tank-car is gained similarly as for tank trucks. A retractable Roto-jet assembly for rail tank-cars is accomodated at this station, while the tank trucks are washed at a Roto-jet station near the liquid sucrose storage.

Final pH adjustment — The final pH adjustment equipment includes an agitated neutralizer mixing pot, a locally adjustable neutralizer metering pump, a blender, and an elevated batch mixing and loading tank. Local interlocks extend from the loadout pump to the batch mixing tank. Determination of final pH is accomplished by manual sampling prior to tank-car or truck filling.

The final pH adjustment facility is provided for those infrequent instances when prolonged storage of product at lower than the shipping pH is desired. It also contains the basic equipment which, with certain future additions, lends itself for producing batches of product of other than the 50% specification.

Summary

The continuous invert manufacturing installation, as described herein, has met the design requirements in a very satisfactory manner, by consistently turning out the specified product with minimal color rise and with practically zero losses.

By interlocking all the critical process functions and by grouping them into a number of programs, we succeeded in our atempts to give the operators a facility which is not readily susceptible to oversight or error, and which, therefore, can operate in a truly continuous manner.

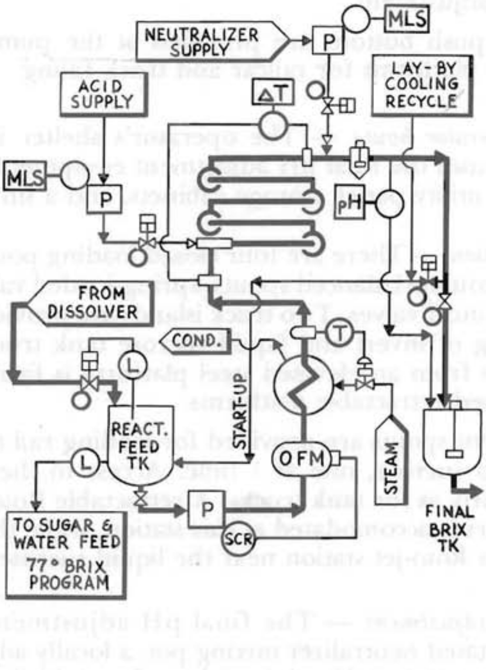

Figure 2.—Invert production (reactor).

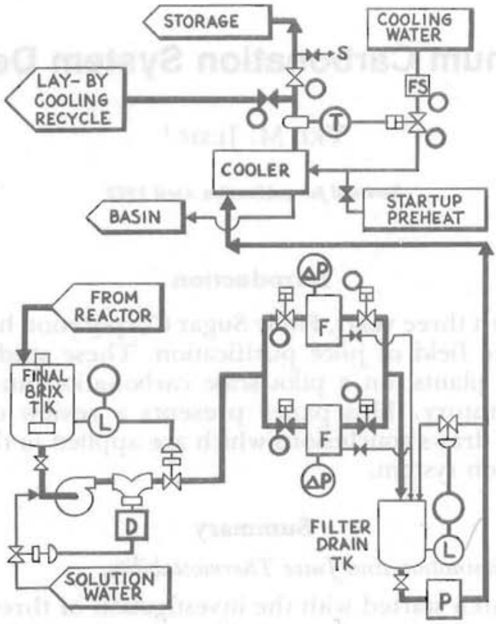

Figure 3.—Filtration and cooling.

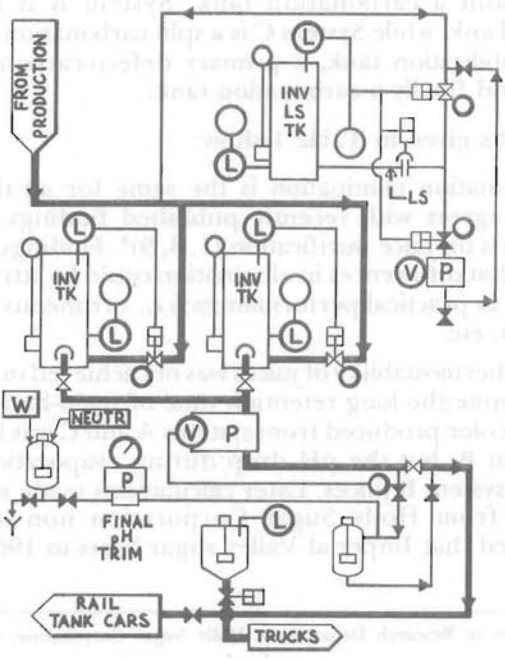

Figure 4.—Storage and loadout.