Design for a 600 Ton Beet-Sugar Factory

F. G. Heuchling

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Heuchling, Frederick Gustav
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DESIGN and ARRANGEMENT of MACHINERY
FOR A
600 TON BEET-SUGAR FACTORY

A THESIS

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FREDERICK GUSTAV HEUCHLING
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INTRODUCTION.

It is no longer necessary to begin writings relating to the beet-sugar industry with statistics showing the importance of the enterprise. Beet-sugar is an established article of commerce and figures are no longer needed to impress the magnitude of its manufacture upon the proletariat. Each year witnesses the opening of several new factories in this country, to say nothing of the steady progress of foreign manufacture.

In no other industrial process are the phenomena of chemistry more closely linked with the principles of machinery and of engineering, as they are in the manufacture of sugar from the sugar beet. These facts render the subject valuable and interesting to one who aims to become a chemical engineer, and led to the choice of the sugar-beet as the topic for this thesis.

When it is desired to construct a beet-sugar factory of specified daily capacity, in a certain vicinity, it becomes necessary to prepare preliminary designs of the surroundings, the buildings, and the arrangement of machinery. This necessity arises when contracts for the buildings and machinery are let to the architects and manufacturers. The type, size, and capacity of each building and piece of apparatus must be specified in these contracts. The problem resolves itself, then, into one which is entirely analogous to the design of a power plant; requiring, however; less attention to detail than the latter. As the mechanical engineer must decide as to the type and size
of the engines, condensers, and other accessories of a power plant, so must the chemical engineer decide as to the size of carbonation tanks, the capacity of the multiple effect, and much other data concerning the appliances used in the extraction of sugar from the sugar beet.

With this in view it was deemed unnecessary to go into detail in the design of filters, pumps, condensers, and such appliances as are to be found in nearly all mills and factories, and whose individual characteristics are of secondary importance. This paper is not presented as a description of the process of beet-sugar manufacture and the many principles underlying it. A subject of such broad scope would require the ability and authority of an expert. Only such details of the method of operation are here given as have an influence upon the construction and arrangement of plant.

The writer wishes to acknowledge his gratitude to Prof. L. C. Monin for his aid in the arrangement of this paper. Among the mass of literature consulted, the work of Louis S. Ware, "Beet-sugar Manufacture and Refining", and that of H. Claassen, "Beet-sugar Manufacture" were of signal importance. For information of a practical character the writer is especially indebted to MR. Franklin M. de Beers of the American Foundry and Machinery Company.
When the building of a beet-sugar factory is decided upon, the selection of a suitable site of prime importance. The promoters of the enterprise must be assured of the co-operation of the farmers. For this reason the plant should be located in a farming community, of suitable climate, rather than in a town. In order to avoid the expense of railroad freight upon the greater part of the beets received at the factory, or at least, should be made with the farmers of the neighborhood for the raising of annual beets to run the factory at its full rated capacity for not less than one hundred days of each season.

Railroad communication is also an important point to be considered. Large quantities of beets are sent in the beet-sugar factories, on the railroad, of which the receive from the railroad. Consequently, a reduction in freight rates means great saving to the owner and of power.

The natural resources of the area must not be ignored in choosing a site for the factory. A deep well of clear water is considered essential. Soluble salts have very deleterious effects upon the crystallization process. Water during summer dries out, and it is therefore important that it enter the juices, in a reduced state of purity, through the earth's supply. A deep well, therefore, limestone, should be.

Title: Selection of Plants, Preliminary Arrangements and Precautions
The limestone should be subjected to at least 20% of calcium carbonate, as the presence of more than 5% of impurities renders the burning expensive and yields a poor quality of lime for the operation of the furnace.

Arrangement of Yards and Buildings; Treatment of Beets, Coal, Limestone when Required.

The arrangement of yards and buildings at the plant is represented on Plate 1 of the accompanying drawings. A spur from the railroad, or railroads, is run past the general office building, where all incoming cars are to be inspected and weighed on the crane-scales provided. A wagon road enters the yard at the west of the offices and crane-scales are built at this entrance.

When beets arrive at the factory in railroad cars, the last one after being weighed, is driven to the sidings and placed under the beet store-house. The cars into the store-houses are graded, since the top of the beet store-house is 12 ft. above the ground level. This grading may readily be accomplished with the earth-grading equipment during the construction of the various buildings. The cars are unloaded by hand and fork, or at the further end of the beet store-house, where the second crane-scales to be weighed empty. The scale due to dirt and leaves upon the beets is obtained by taking a sample at the offices.

Beets arriving in trucks are sampled and weighed at the offices. The wheeless drive into a designated entrance to the beet store-house and unloads from the respective platform. The
empty wagons are then 'run out at the farther end of the line.'

Then coal, coke, or lime dust are received, the rick is
re-entered, as usual, at the office, and then turned the other
past the sugar cradle-house and the second curve and the
at the sugar-house or lime-hill. The empty cars are then
at the truck-end and the rear of the main cradle-house for
weight.

Sugar Storage:

The sugar finished in the cradle-house, is conveyed
through a tunnel to the sugar cradle-house. Here it is taken
in the cars, and the cradle-truck, one on the other, to the
roof. If the factory handles 100 tons of beet per day, to 18
sides, if the roof is 30 feet above the floor. The store-
house should be large enough to hold nearly the entire season's
product, or 700,000 bbls. At 240 lbs. to the barrel, that
would be approximately 40,000 bbls. Assuming, on an 7 cu.
ft., to store the beet, the house would have a capacity of
350,000 cu. ft. If the beet was stored in stacks of
20 ft., the floor area required will be 14,000 sq. ft. or
100' X 140'. Allowing for cooking machines, aisles, etc., the
building will need to be 120' X 180'. It may be built of brick,
or of steel, or of brick and steel, as may prove most economical.

Storage of Beet and Factory section to Features.

The beet storage house and factory are shown on
Plate 2 of accompanying drawings. Beets arrive on railroad
cars are unloaded from the three tracks provided. Forms may unload from any of the seven platforms shown. The beet store-house should be capable of accommodating at least a month's supply of beets. The store-house shown here has a capacity of 20,000 tons or 33 days supply of beets. This was figured upon the assumption, taken from the writings of Claassen, that a ton of beets occupy 1.3 cubic meters, or 2.55 cu. yds. The beets are supposed to be piled to a height of 12 ft. from the tops of flumes.

The bottom of the store-house is ridged, as shown, to facilitate subsequent disposal of the beets. Between the ridges are built concrete flumes. A detailed section of flume is shown on Plate 3, with the form used in its construction and the wooden lattice-work which covers it when beets are filled into the shed. The wooden lattice-work is made in sections 4 ft. 1 in. long, with wrought iron rods attached to each section. Then all the lattice-work is wound these rods, ill illustrated, and flume will extend beyond the experiments on beets. Then it is desired to send beets to the store-house at 1st section of lattice is withdrawn by pulling on the extended rod. The beets then fall into the flume and expose the next rod which is used to remove the next lattice, and so on.

The beets falling into the flume strike the water flowing in it. The water used is the river water and under water or water from the water-house, and is usually
Like-like's/rm. Iz enters die beeo score-house at the hzok thro'.

Pipes and Conduits:

The lime-kiln must be connected to the gas-pump in the power-house, and the latter, in its turn, must be connected by a suitable pipe to the condensation tanks in the sugar-house. The lime tank in the kiln-house is connected with an evaporating tank in the sugar-house by means of a pipe suitable for carrying lime-water. Steam pipes or conduits must lead from the boilers in power-house to the various machines in the suan-
house which requires high-pressure steam. Pipes carrying the exhaust steam from the engines to the diffusion tower, multiple-effect, strike-pan, etc. in sugar-house must also be provided.
Section 6

The Preparation of Lime and Ceramic Articles:

The process of burning limestone or ground lime to carbon dioxide has a great influence on the manufacture of beet-sugar, since these materials are the great essentials in the evaporation of the juices. For this reason the factories must be equipped with the very best appliances necessary in the production of a pure milk of lime and gas containing at least 25% of carbon dioxide and a rising air free of suspended particles.

In warm climates the limekiln must be situated in the open air, where the workers will be shielded by the distilled gas. In cold climates however, it becomes necessary to enclose the limekiln in housing, particularly so the work is mostly done during the winter months.

The Kiln-House:

The limekiln is situated in a brick structure similar to a tower-house. The kiln-house and its contents are detailed on Plate 3. Nearly the entire space in the kiln-house is occupied by the limekiln. A supporting floor for the fuel stove must be built to a height of 7 ft. from the ground. The kiln-house will have concrete foundations and a concrete floor. The floor beneath the lime-kiln must be 14 ft. high in order to fully bear the load of lime and kiln. If this rule is


soft, it may be necessary to drive piles beneath the kiln.

The Limekiln:

For the purpose of determining the size of limekiln required for a beet-sugar factory, it is necessary to refer to practice. The limekiln here shown is of the Belgian type, wherein fuel and limestone are mixed and burned together. The materials are fed in at the top and the burned lime is withdrawn below. A kiln of this type, when properly managed, will produce 850 lbs. of lime per day, per cu. yd. capacity. For proper epuration of the juices, experience shows that 3 lbs. of limestone are required per 100 lbs. of beets sliced. The factory will then require \((0.03 \times 600) = 18\) tons of lime per day. To provide for unforeseen circumstances the kiln had best be made to produce 20 tons, or 40,000 lbs., of lime per day. The capacity of the kiln must then be \((40,000 \div 850)\) or about 1280 cu. ft. The height may be made from 30 to 60 ft. to afford good working. The kiln here shown, when filled to the gas pipes, which is higher than the materials should be during normal working, has a capacity of about 1350 cu. ft.

The kiln should be constructed of boiler-plate, lined with fire-brick and cinders to a thickness of 12 in. The cinders are packed between the fire-brick and the steel casing and prove to be an excellent non-conductor of heat. After each season, when the kiln is shut down, the lining should be carefully repaired to prevent the necessity of shutting down while the factory is in operation. The weight of the kiln is supported by four
short struts at the bottom, and by four columns which extend upward 12 ft. from the ground. Heavy cast-iron rings afford proper bearings on both struts and columns. In order that part of the lime may not collect on the floor in the center, below the kiln, a conical projection, covered with boiler-plate, is built on the floor at this place. This causes the lime to roll well out around the kiln so that it may easily be shovelled up by the workmen.

The limestone and coke are stored in bins beside the railroad track, just outside the kiln-house wall. Openings in this wall allow the limestone and coke to be shovelled directly from the bins. If it is necessary to break up either of these materials, ample room is provided for such operations on the ground floor. It is not found profitable to use mechanical crushers for this purpose, since the capital invested is not offset by the small gain over hand breaking.

In order that the attendants may readily watch the operations in the kiln and gas-washer, iron frame-work is built around the kiln, and platforms of iron-work are attached to this at intervals of about 10 ft. The method of construction can be better understood by referring to the drawing on Plate 3. Openings are made in the kiln just above each of these platforms, so that the zone of greatest combustion may be located and its position altered if need be. Also, pokers may be inserted through these openings and used in breaking large lumps of lime, which may be formed, during the burning, "Scaffolds" are also liable to be formed, as in blast-furnaces, and these must be broken down. The
There are adheres, to, r-.T. ..sr<'''' pressions to, burning of lilies', but these need not be feared here. The therecically, about lbs. of coke are required to dissociate 100 lbs. of lime. The coke and limestone are thrown into the hopper high, and it forms the boot of a boiler. Thereafter, the material in the kiln is placed by a conveyor. As it melts the material is fed at the rate of two tons in an hour. The material is then further dropped from the main floor.

The Gas-Sher:

The gases are led from the kilns and passed through a series of chimneys and then through a gas-sher. This is a very effective device for cleaning the gases and removing any harmful substances.
as the limekiln itself, so that the gases have about the same velocity in the washer as they have in the kiln. The gases enter the washer from below, through a perforated pipe which is immersed in water. Four shelves are fixed above at regular intervals. Upon the lower three shelves water is fed. This water enters through a pipe above the second shelf from the top, and covers it. When a definite level is reached, an overflow pipe carries this water to the shelf beneath. These overflow pipes are covered with hoods whose rims dip beneath the surface of the water. Thus the gas in passing upward, is forced to bubble through water four times. When the top shelf is reached the gas is moist and carries some water mechanically with it. This is removed, in a measure, by porous coke which rests upon the top shelf. The total resistance of the gas washer to the passage of the gases should be not more than the equivalent of three feet of water.

The wash-water is removed through a siphon-shaped pipe which leads to a closed tank on the ground floor. This is done to provide a proper seal to prevent air being sucked into the washer and thus diluting the gases. The amount of wash-water should be regulated so that the overflow is always hot, since hot water absorbs less carbon dioxide than cold water. The draught through the kiln and washer is maintained by a gas-pump in the power-house, which pump serves also to force the gases into the carbonation tanks in the sugar-house. A relief valve must be inserted in the connecting pipes, anywhere out of doors, so that when no gas is going used in the sugar-house the
pressure will not become excessive.

Preparation of Milk of Lime:

The burned lime, when removed from beneath the kiln, is heaped on the ground floor, beneath the gas-washer platform. At one side of the kiln-house, the milk of lime mixer is situated. This consists of a cylindrical iron drum, set horizontally, which has numerous lug-angles rivetted to its inner surface. The drum is slightly inclined and lime is fed in at one end by means of a wooden hopper. A pipe leads water into the drum at this end. The bearings of the drum are of the common roller-and-saddle type so often used for such vessels, and the drum is rotated by a chain which engages cogs on the circumference of the former, which chain is driven by an electric motor set upon a shelf above. The water and lime are well mixed by the rotation and the action of the lugs. At the other end of the drum the limewater overflows into a reservoir from which it is pumped to the deflecting tank in the sugar house. The resulting milk of lime should have a density of about of about 20° Baume', in order to be readily pumped.
The Sugar House.

The structure, within whose walls the extraction and purification of the sugar takes place, is known as the sugar house. It will contain almost all the machinery and appliances necessary in the manufacture of beet-sugar, and will therefore richly merit detailed attention. Upon Plate 4 will be found elevation views of this building, making clear the method of construction and the arrangement of apparatus.

The prime factors entering into the design of the sugar house building, are cleanliness and roominess. Of course, the usual limitations of cost and durability must be imposed upon the designing architect. But the building must be large enough, in all its proportions, to readily accommodate all the required machinery, and also afford such facilities for the arrangement and subsequent control of that machinery, as will be most conducive to cleanliness and dispatch.

Construction of Sugar House:

The sugar house should be constructed with concrete foundations, brick walls, and reinforced concrete floors, columns and roof. In certain places the floor-spans will be required to be of such lengths that steel beams will have to be used. The investigation of such matters is left entirely to the architect. The building will be 230 ft. X 60 ft. over all and consist of three stories and ground floor. Several pits must
be excavated below the ground floor. One leads from the entrance of beet-flume to the beet-wheel. This must be waterproof, as must also a flume to be built beneath the diffusion battery for disposal of the spent cossettes. A depressed channel for conveyors must be provided beneath the centrifugals. The end of the building containing the strike pans, crystallizers, and centrifugals, may be designated as the sugar end of building, as distinguished from the beet end. At the sugar end a large pit should be built, for molasses storing and mixing tanks.

The three upper floors will have to contain numerous openings for pipes, conveyors and bins. Wherever this is necessary is made plain upon the drawing. Upon the second floor, at the extreme beet end, space is reserved for an office for the superintendent and for the chemical laboratory. Above the fourth floor a balcony or platform is shown at sugar end. This is built for the support of water tanks and sulphitors.

Plan to be Followed in Ensuing Discussion:

Henceforth we shall concern ourselves mostly with the details of appliances in the sugar house, and in order to systematize the discussion, the individual apparatus will be described in the order in which it comes into use in the process. The next (fourth) section will deal with the handling and preparation of the beets previous to sugar extraction, and with the diffusion or extraction of juices from the insoluble parts of the beet-root. The fifth section will treat of the purification of the juices, and the sixth will describe the process and appliances for their
concentration. The seventh section will deal with the crystallization and separation of the sugar from the molasses, while the eighth section will briefly describe the treatment of the molasses for the recovery of more sugar. In the ninth section we shall take up the handling and packing of the finished sugar, while the tenth section will be devoted to the disposal of by-products and a brief consideration of the costs of installation and running expenses. We may thus follow the beets and juices through the sugar house, describing each appliance, in regard to design and use, as it comes into play.
A. Treatment of Beets Preliminary to Diffusion:

Washing of Beets:

The beets, upon arrival at the sugar house, will have been freed from nearly all adhering stones and heavy objects during their passage through the hydraulic flumes. Much soil, leaves, twigs, etc., still clings to them, however, and for the elimination of these the beet-roots are sent through the washer. This must be fed from above, so a suitable device must be provided to lift the beets from the flume to the top of the washing machine. The beet-wheel serves this purpose. It is constructed of iron plate, and mounted upon heavy bearings. The wheel will have an external diameter of about 17 ft. and will lift the beets through a height of about 14 ft., from whence they fall into the washer. The wheel is shown at extreme beet end of sugar house, on main floor, and also in section A - B on Plate 4. The beets are caught in perforated iron buckets, arranged as on a water-wheel, and the flume-water is thus allowed to flow off without entering the washer. The beet-wheel is driven by gearing from a motor, which serves also to drive the washer.

The beet-washer consists of an elevated trough of sheet-iron, within which the beets are thoroughly agitated in water by means of a revolving shaft to which are attached numerous,
projecting, cast-iron arms. The shaft is driven by a gear from a motor which also drives the beet-wheel. For a 600 ton factory the washer should have a length of about 5 meters and a diameter of about 1.5 meters, according to Ware. The one shown on Plate 4 in the sugar house has a length of 1.6 ft. and a diameter of 5 1/2 ft. The power necessary to drive it will be about 7 1/2 horsepower. The dirty beets are fed in at one end and the fresh water at the other. The dirt and stones sink to the bottom, which is perforated, and allows them to fall into a compartment beneath, where they are removed through a door in the base. The clean beets are picked up by revolving blades and fed to a chute which deposits them in the boot of the elevator.

The beet elevator carries the washed beets from the ground floor to the fourth floor. This elevator is inclined, and should be entirely enclosed in a sheet iron casing. The buckets must be large in order that the beets be not injured. A good size would be 2 ft. X 1 ft. X 1 ft. deep. The bottom of buckets are rounded and the buckets are attached to two heavy chains which pass over grooved pulleys at the top and bottom.

Weighing of Beets.

The beet elevator delivers the beets to a large spout which projects over the automatic scales. The weighing of the washed beets is a matter often disregarded in American factories. The unreliability of sampling the beets upon arrival renders this weighing a necessity, if accurate accounts of the amounts of beets sliced are to be kept. The appliances used for the
automatic registration of the weight of beets passing into the slicers, are of very intricate design. They are manufactured by German concerns, and are so well covered by patents that they have but little competition.

This weighing cannot be accomplished with the ease and celerity obtained in grain weighing. The beets cannot be so evenly fed, and the supply cannot be shut off at exactly the required weight. The machine is set, however, to deliver a certain weight of beets at a time, and a special appliance is provided, which registers the variation in each weight taken. The correct weight is thus registered, after allowing for the discrepancy or overweight of each discharge. The automatic scales are not shown in detail on Plate 4, on account of their complexity. Only the position of scale-hopper and supporting frame are shown.

Slicing the Beets:

The automatic scales hopper delivers the beets into a large hopper just beneath the fourth floor. This spacious receptacle is necessary because the slices must be constantly fed to their full capacity in order to perform their duty to the best advantage. Several tons of beets can thus be kept in readiness for the slicers, so that a short shut-down of the washer will not cause any delay. A detailed sketch of the arrangement of elevator, scales, and slicers, is shown on Plate 7.

The beet slicers are situated on the third floor, above the diffusion battery. The beets fall from the hopper above, through
a vertical chute, which opens at each side, feeding the beets to the two slicers. Each of these consists of a cast-iron drum 4 ft. in diameter and 1 ft. 6 in. wide, which revolves upon a horizontal shaft suitably supported. The beets are fed into the center of the drum and are thrown against the circumference by the action of centrifugal force. An interfering projection within the drum causes the beet to be wedged in a compartment whose width gradually diminishes. The beets then strike against projecting knives set in the periphery of the drum, and are thus sliced. The wedge-shaped compartment serves to keep the remnants of the beets pressed against the knife-blades. A small opening is left at the end of this nose obstructor, as it is called, through which stones and other foreign matter may leave the machine. The slices pass the knife-blades and are thrown against the sheet iron casing of the drum, from which they fall into the hopper beneath. The slices are known as cossettes, and are triangular in section, and of lengths varying up to 6 in.

The slicers here shown are of the Maguin fixed blade type, and each is capable of slicing 300 tons of beets per 24 hours. The drums should be driven at the rate of 60 revolutions per minute, and will require a motor of about 4 horse-power for the operation of the two here shown. The beet-slices fall into the cossette hopper, which, together with its delivery spout, has a capacity equal to about that of one diffusor. The spout is supported by a swivel arrangement, beneath the cossette hopper, which allows it to swing in a circle so that its extremity may be moved over the mouth of any diffusor. The diffusors are thus fed directly from the slicers, without requiring any cossette conveyors.
The Diffusion Battery.

The sliced cossettes are made to give up their content of sugar by the process of diffusion, which depends for its success upon the rapid osmosis of saccharine and saline substances through the natural membranes of the beet-cells, and the retention, within the cell, of the colloid, or less osmotic, albuminoids and pectic substances. This is realized in practice by systematically soaking the cossettes in warm water, or in warm juices of less concentration than the juices within the beet-cell. This extraction takes place in sheet-iron vessels, which form a group known as the diffusion battery. A single vessel is known as a diffusion cell, or simply as a diffusor. The diffusion battery is built at the beet end of sugar house, between the main floor and second floor. The details of its construction, as well as the size and shape of diffusors, may be obtained from a study of Plate 5.

The diffusion cell consists of a cylindrical body, with truncated cone top and bottom. The body is made of boiler-plate, while the upper and lower portions are of cast iron. In the working of the factory, 600 tons of cossettes must pass through the battery each 24 hrs. With the usual method of working, a cell is emptied and refilled about once every seven or eight minutes, or about eight times per hour. The battery contains fourteen cells, and of these, two will always be either in the process of emptying or filling. The number of effective cells,
always full of beets, is then twelve. The cossettes are allowed to pack into the cell, and are then tamped down by the attendant. Usually about 50 kilos. of cossettes are packed into a hectaroliter of diffusor capacity. The 60 hectaroliter diffusors in this factory will then each hold (50 x 60 = ) 3000 kilos. of cossettes. The battery may then work (3000 X 3 X 24 = ) 576,000 kilos or about 635 tons of cossettes per day.

The battery here shown is of the circular type. The cells are arranged in the circumference of a circle, and are supported, at the sides, upon I beams which extend radially from a heavy support at the center to columns and cross-beams outside. The cells are supported, at front and back, upon circular I beams which bear upon the aforementioned radial members. These latter serve also to carry the juice heaters and auxiliary piping. The advantages of a circular battery, when land is cheap and the sugar house may be made wide and roomy, are as follows: During the working, a great deal of opening and closing of valves, and reading of pressure gauges and thermometers, is necessary. This is facilitated by the compactness of design and the close proximity of the cells to one another, in the circular battery. The arrangement of the diffusors about a common center allows for their being filled from a central revolving spout as shown on Plate 7, and does away with the necessity of installing cossette conveyors. Also, the superintendent or the battery-man can easily see at a glance, and without changing their positions, the condition of working of the battery, which advantage cannot be obtained by the double line method of arrangement. The circular battery also
requires less piping and less steel for supports. Its main disadvantage is the wide space which it occupies, which requires a wide building; and the loss of space in the middle of the battery and on the floor above where the feeding spout swings to and fro.

The other arrangement, known as the double line battery, has its cells supported in two rows. This requires a long, narrow space, and long cossette conveyors. Also, the two diffusors at one end must be connected by several pipes to the two cells at the other end, requiring a great length of piping. When the last cell in the row is refilled and started, the battery man must go clear to the other end of the battery to start the next cell, thus causing great delay and inconvenience.

Working of the Battery.

Years of experience are required for the proper control and operation of a diffusion battery. Several methods are in vogue, but only one will be here briefly described, and the arrangement of piping and valves made plain at the same time. Suppose the cell marked 1 in the plan on Plate 5 to be empty and washed out. The cossette spout is brought over its mouth, and the cossette slices filled into the cell with frequent tamping. When the cell is full the cover is put on and fastened tightly by means of the hand-wheel and screw above. The first operation of extraction is known as mashing. Here juice which has previously passed through eleven other diffusors, and is already quite concentrated, is sent through the fresh cossettes. In order to displace all the air, this filling must take place from the bottom to the top.
For this purpose the juice from the next preceding cell, number 14, is run up through the juice heater next that cell, and from thence through the juice pipe to valve 1 (see elevation view). This valve is opened, and allows the juice to flow through the heater on cell 1 from top to bottom. These heaters are mere cast iron cylinders containing upright steam pipes within them. Exhaust steam from the multiple effect is fed into the pipes, and the condensed water is run out by a 2 in. pipe below, which may be opened and closed by means of a valve controlled from the floor above. The juice, in passing through the heaters, attains a temperature of from 60° to 70°C, and is so heated in order to facilitate rapid osmosis.

From the heater then, the thick juice is run into the cell at the bottom, through the connecting pipe shown plainly on elevation view. The lower part of the diffusor has two shells, the inner one of which is perforated and serves to hold the cossettes in place and still allow circulation of the juices. The juice will be thus run in until it overflows through the faucet at the top, into a bucket hung there to receive it. The valves are then closed and the flow of juice reversed so as to take place from top to bottom. The juice is sent back through the juice heater to its top. There the valve into the juice pipe is opened and allows the juice to flow to the outlet valve on the juice pipe, from whence it proceeds to the measuring tank, which is shown to the left of the diffusion battery in the longitudinal elevation on Plate 4.

As the thick juice leaves cell No. 1 it is displaced by the
juice from cell No. 2, which in turn receives juice from cell No. 3, and so on back to cell No. 12, where fresh water is being run in from a tank on the top floor. In passing from one cell to the next, the juice passes out through the pipe below, enters the juice heater, leaves it at the top, and passes through the valves marked 2 and 3, (see elevation Plate 5) thus gaining entrance to the next cell. This is going on through all the cells, to the cell number 12, where valve 3 is open and valve 2 closed, so that fresh water is allowed to enter from the water-pipe. This fresh water must have a head of 30 ft. at least, according to Claassen, so as to successfully over-come the resistance to its passage offered by the cossettes and valves of the diffusion battery. In this plant the supply tank will have an effective head of at least 40 ft. of water.

The cossettes in cell 12 have been in that cell longer than the cossettes in any other cell, so that they have already had eleven treatments with juices, each juice a little less concentrated than the last and therefore more capable of extracting sugar from the beet-cells. At the twelfth operation then, these cossettes are washed with fresh water, which completes the extraction. This last soaking with fresh water extracts the sugar from the cossettes to such an extent that the spent material retains only from .2% to .3% of its weight of sugar.

The cossettes in a cell having been completely exhausted as described, the cell is ready to be emptied. Valves 1, 2 and 3 are closed, shutting off the diffusor from its neighbors. The inclined hand-wheel above is then turned (see elevation Plate 5)
thus turning a small bevel gear, which causes the vertical rod to revolve and thus opens the catch which holds the bottom shut. The packed cossettes in the cell, as well as the rubber packing under the bottom, holds the cover on tightly. This cover extends beyond the cell, as shown, however, and is attached to a vertical connecting rod, which is driven by a Hydraulic piston. After opening the catch on the bottom, then, the battery-man lets water under pressure into the hydraulic cylinder, and the pressure draws the connecting rod up, lifting the counterweights, and opening the bottom of the diffusor. The cossettes, which are quite wet and soggy, fall out and are deposited in the concrete flume beneath, where they flow to an elevator for further disposal. The cell is then washed out with water, the hydraulic cylinder used to swing the bottom shut, and a tight joint finally made by screwing up the hook-shaped catch again.

The hard rubber ring inside the bottom cover, renders the diffusor air-tight and the cover impervious to the juices which are passing over it under pressure. The water used in the hydraulic cylinder is fed from a small 2 in. pipe encircling the inside of the battery. The water used may be supplied from the same tank as is the water used for diffusion. The steam for juice heating is fed from the circular 6 in. pipe shown on the plan of battery. The steam used will be obtained from the second or third vessel of the multiple effect, and will be at a temperature varying from 100° to 115°C.

The juice from the diffusion battery passes to a measuring tank, from whence it is sent to the purifying apparatus. The
diffusion battery is so constructed that all valves, faucets, hand-wheels and levers are accessible from the second floor. The work of diffusion is then entirely governed by attendants on the second floor. The level of this floor is above that of the supporting beams and columns of the diffusion battery, so that these obstructions are hidden from view.
Section 5

Purification of the Juices.

Measuring:

The juice from the diffusion battery must be accurately measured, in order to be treated with the proper weight of lime in the subsequent purification. Besides this there are additional reasons why the diffusion juice should be accurately measured. From the last section it is evident that as the concentrated juice is drawn from the battery, it comes from the diffusor last filled with fresh cossettes. At the diffusor at the end of the system, however, the place of this concentrated juice is being taken by fresh water. This operation is repeated every time a new diffusor is filled. It is plain then, that the volume of juice drawn from the battery will decide the volume of water entering the end diffusor. Since the quantity of sugar present in the entire battery at any time is about constant, it is evident that the amount of juice drawn each time will govern the concentration of the following "draws". The limiting concentration will be that of the juice within the beet-cells. If the juice drawn is as concentrated in soluble matter as the normal juice in the fresh cossettes in the last diffusor, osmosis will cease and further concentration of the diffusion juice is impossible. The less juice drawn, the more concentrated it will be, of course; but, on the other hand, drawing less juice means less perfect extraction of the sugar. The happy medium must therefore be determined in practice.
Many factories draw off only 100 liters, or 26.4 gals. per 100 kilos., or 220 lbs., of beets. Claassen recommends that not more than 110 liters of juice be drawn per 100 kilos. of beets. With poor beets however, or with abnormal conditions in the diffusion battery, it may be necessary to draw as much as 130 liters of juice per 100 kilos. of beets sliced. In Section 4 it was shown that each diffusor contained about 3000 kilos. of beets. The juice drawn each time will then never exceed (3000 X 1.30 =) 3900 liters. This juice goes to one of the measuring tanks shown to the left of diffusion battery, in longitudinal elevation of sugar house on Plate 4. These tanks are constructed of simple sheet-iron, and have a glass water-gauge attachment on front, to show the height of the liquid contained in them. Each tank must be carefully calibrated and a scale marked on the water-gauge in liters or gallons, as preferred. A better arrangement is to attach an adjustable overflow which will act when the required volume of juice has entered the tank. The battery-man may thus be warned to close the water valve, since the tanks are in plain sight of the diffusion battery. Each tank should have a capacity equal to the maximum volume of juice which may be drawn at one time. Therefore these tanks must each contain 4000 liters, or 4 cu. meters, or about 140 cu. ft. For safety the tanks are made 6 ft. X 4 ft. X 10 ft.

Defecation:

From the measuring tank the juice is pumped to the liming or defecating tank. This is a circular tank with a simple stirring apparatus attached, and contains also, a few coils of steam pipes
for heating the juice during liming. The stirring spindle is driven by a small motor above. The defecating tank has a capacity of two diffusors, or approximately 400 cu. ft. Its dimensions are 7 ft. X 7 ft. X 8 ft. In it milk of lime of a density of 20°Baume is added to the juice until from 1% to 2% of the weight of the juice of lime, has been pumped in. These quantities are according to the recommendation of Ware, and are varied at different localities and different factories according to the quality of beets sliced. While defecation proceeds, the juice is heated to a temperature of from 75° to 85°C.

The milk of lime has both a mechanical and a chemical action upon the juices. Chemically, the lime precipitates the acids which have been formed from the fermentation of the sugars and those resulting from the decomposition of the albuminoids. Also, the lime precipitates the pectic substances, albumins and proteids. The mechanical action then asserts itself, and the coagulated calcium salts and lime form a scum which gradually sinks to the bottom, carrying with it suspended matter, shreds of cossettes, etc., and leaves a clear limpid juice above. This is drawn off and sent to the carbonation tanks with the scum.

Carbonation:

The juices coming from the defecating tanks contain lime in solution. To precipitate this, the juices are treated with carbonic acid until but .07% to .15% of lime remains in them. It is found that at this degree of alkalinity the juices give the best filtrate. The carbonation tanks are situated on the second floor,
to the right of the diffusion battery (see elevation Plate 4). Each tank must have a volume equal to two diffusors and at least three tanks should be provided for the first carbonation. The juice should never fill a tank to more than half its height, as frothing occurs when the gas is introduced. The tanks may then be (400 X 2 =) 800 cu. ft. in capacity or 7 ft. X 7 ft. X 15 ft.

Each tank is covered, and a large pipe leads the evolved gases to the chimney. A stirring apparatus and steam-heating coils are contained in the tank, and the gas is pumped in through a perforated pipe at the bottom. Near the top of the tank, above the surface of the juice, a horizontal plate is attached, which serves to hold the froth in the tank. The gas passes upward and through a small pipe in the froth arrestor, to the chimney flue. The bottom of the tank is sloped toward the emptying pipe, so that the sediment may be readily drained off. Samples of juice are taken during carbonation, and their alkalinity determined by the attendant. When precipitation is complete the gas is shut off and the juice is fed directly to the filter press pumps on main floor.

Filtration:

The precipitated calcium carbonate, together with the coagulated albuminoids and suspended matter, are separated from the juice by filtration through filter presses. Those presses used in a beet-sugar factory are of the same type as is to be found in any industrial plant where mechanical filtration is resorted to, and no details of the filter presses were therefore prepared.
As to the size of filter presses, practice shows that 1 sq. meter of filtering surface is required for 2500 kilos. of beets sliced per day. This factory, to handle 600 tons (545,000 kilos.) of beets per day, will require a filtering surface of 220 sq. meters. If eight presses are installed, they should have a surface of about 28 sq. meters each.

The pump which feeds the filter presses must be capable of handling 30,000 liters of juice per hour. This is 30 cu. meters or approximately 1000 cu. ft., or at the rate of 17 cu. ft. or 127 gals. per min. Manufacturer's catalogues describe a vertical, electric driven, triple, power pump, with 7 in. cylinders and 8 in. stroke, making 40 revolutions per minute, which could easily perform this duty. A 20 horse-power motor will be required to drive the pump.

When a filter press has filled with press-cake the frames are removed and the press-cake dropped into the large hopper underneath. The shape of these hoppers can best be seen by referring to Section C - D on Plate 4. The press-cake falls from the hoppers to a screw conveyor beneath, which carries it to a tank beside the diffusion battery. The press-cake is here broken up and removed, to be sold for fertilizer.

Second Carbonation:

The filtered juices are sent to the second carbonation tanks, where more lime is precipitated from the juice by the action of carbon dioxide, until the alkalinity has been reduced to .039% to .04% lime. The juices should never be rendered neutral or acid,
as danger of inversion and consequent loss of cane-sugar immediately arises. The second carbonation requires only two tanks, as it requires less time than the first carbonation. The tanks are of the same size and construction as the tanks for first carbonation:

Sulphuring:

The juices from second carbonation are generally treated with sulphurous acid in order to purify and decolorize them. This operation is undertaken before the scum from second carbonation has been filtered off. The sulphiters are situated on the third floor, to the left of the quadruple effect evaporators. The source of sulphurous anhydride is sulphur, which is burned in a horizontal combustion chamber. The fumes enter a tall column, where the sulphur which may have been volatilized, is condensed and returned to the fireplase. The sulphur dioxide passes through a narrow pipe to a collecting chamber, from which it passes to the sulphuring tanks. These are similar in mode of operation, to the carbonation tanks, being smaller, because the juice only remains in them a short time.

From the sulphiters, the juices proceed to mechanical filters, to be freed from the precipitated matter thrown down during second carbonation and sulphuring. Four mechanical filters are shown on the ground floor, beside the diffusion battery. These are pocket, or bag filters, which filter the juice under low pressure, in order that the finer particles from second carbonation and sulphuring may be retained on the cloths. The bags are cut like
pillow-cases, and are suspended in a trough which contains the juice to be filtered. The trough is tightly closed by a heavy cover with counterpoises. The bags are held open by iron frames, over which they are drawn. The unfiltered juice fills the compartment around the bags, and, after passing through them, flows out at the top, leaving the sediment caked on the outside of the bags, where its removal is readily accomplished.

It is frequently customary to sulphur the poorer juices several times, filtering after each time. By this means the alkalinity of the juice is reduced to about 0.01% lime. Ware makes a calculation that the amount of sulphur needed is about 0.2% of the weight of beets sliced. In this factory then \(0.002 \times 600 \times 2000 = 2400\) lbs. of sulphur will be used each day. As a matter of fact, the factory will easily use twice this amount, for much sulphurous acid is used for decolqcising the molasses preliminary to the preparation of second sugar.

Between the various operations of epuration, the juices are liable to collect in large quantities awaiting further treatment, especially as some of the juices require more treatment than others. For this reason ample storage capacity is provided, for juices awaiting their turn to be sulphured, carbonated, or filtered. Tanks are provided for this purpose on the third floor, at sugar end of house, opposite the strike pans, and on the balcony above the fourth floor. Part of these tanks will also be called into use for the storage of concentrated juices.
Concentration of the Juice.

After the juices have been freed from albuminaceous material, pectic matter, and other substances detrimental to ready crystallization of the sugar, they are ready for the concentration process. The greater part of the concentration is done in the multiple effect and the rest is accomplished in the vacuum, or "strike", pans. The partly concentrated juice, or "magma," pumped from the last vessel of the multiple effect, usually has a density of from 27° to 30° Baume. The crystallization of the sugar from this solution is then effected in the vacuum pans.

The Quadruple Effect:

The multiple effect in this factory will consist of four vessels, and is known as a quadruple effect. The size of the apparatus was figured in the following manner. The average crop of beets will contain 18% of soluble solids. This does not mean 18% sugar, as the expressed juice often has a purity of only 80, meaning that only 80% of these soluble solids is cane sugar. During the poorest conditions it will not be necessary to draw more than 130 liters of juice from the diffusion battery for each 100 kilos. of beets sliced. Now 100 kilos. of beets contain (100 X .18=) 18 kilos. of soluble solids. The juice from the diffusion battery will then always contain at least (18 / 130=) 14% of solids in solution. If 600 tons of beets are sliced in 24 hours,
or 50,000 lbs. per hour, there will result 22,680 kilos. of cossettes each hour. If 130 liters of juice are obtained from each 100 kilos. of cossettes, the "green" juices, as they are called, will amount to \((22680 \times \frac{130}{100})\) 29,500, or approximately 29,600 liters per hour. This is then the volume of juice fed to the quadruple effect each hour. Let us first consider one liter of this juice. A 14% solution contains 140 grams of solids in one liter. If this is concentrated to a 50% solution, 280 grams of water will remain with the 140 grams of solids.

The original liter will then lose \((1000 - 280)\) 720 gr. of water. 29,600 liters of juice will then lose \((29,600 \times 720 + 1000)\) approximately 22,000 kilos of water. This is the weight of water which the quadruple effect must be capable of evaporating each hour.

The details of the quadruple effect are shown upon Plate 6, together with the condensing apparatus. The juice to be evaporated is fed into the vessel shown in section, at the left hand side of the drawing. Here it encounters pipes containing steam at a temperature of about 105°C, and a pressure of 5 lbs. above that of the atmosphere, or 20 lbs. absolute. This heating steam is the exhaust from the engine and the gas-pump in the powerhouse. The steam is condensed and the condensed water is forced out by the internal pressure when the draw valve is opened. The cold juice, then, passes over the steam pipes and is heated to boiling. The lower part of the vessel is divided longitudinally into two parts, by a vertical sheet-iron partition. The juice, which enters at the bottom, must pass up and over this partition before it can leave the vessel. It must therefore encounter the pipes on both sides of the vessel. Now the vapor evolved by the
boiling juice in the first vessel passes up to the outlet pipes on top, which lead into a cylindrical horizontal compartment, containing baffle plates. These baffle plates catch any sugar, which may be mechanically carried over by the vapor, and return it through a drip pipe to the first vessel. The vapors then pass into a horizontal pipe, which leads into a down-comer, which in turn opens into the heating pipes of the second vessel. The vapors from vessel No. 1 thus heat the juice in vessel No. 2. The heating vapor is condensed in the pipes in vessel No. 2 and thus creates a partial vacuum which serves to relieve the pressure in vessel No. 1. Meanwhile the juice from vessel No. 1 passes through the pipe on the floor level and enters vessel No. 2. Here the temperature is lower, being about 100°. The juice would not boil in this vessel, were it not that the pressure is less than that in vessel No. 1, being about one atmosphere.

Vessel No. 2 is constructed just like vessel No. 1. The vapors given off pass through a sugar catcher, as before, and then into the steam pipes of vessel No. 3. Here they condense, and thus keep the pressure in vessel No. 2 down. The juice from No. 2 passes into No. 3, where the temperature is but 90°C and the pressure only 10 lbs. absolute. This reduced pressure causes the juice to boil and thus produce vapor for the heating of vessel No. 4. In vessel No. 4 the temperature is only 50°C, and the pressure is less than 2 lbs., absolute. At this pressure, the juice, heated by the vapors from vessel No. 3, which are at a temperature of nearly 90°C., boils rapidly, and gives off vapors which are condensed in a surface condenser to the right, above.
The circulation is thus established, the juice being aspirated from one vessel to the next, by virtue of the higher vacuum existing in the succeeding vessels. As the juice becomes more concentrated it passes into vessels with a higher vacuum and thus boils at low temperatures, which do not endanger the sugar. A 50% sugar solution under atmospheric pressure would boil at so high a temperature that much sugar would be lost by inversion. Since a vacuum exists in the heating pipes of all the vessels but the first, condensing pumps are shown attached to these vessels to remove the condensed water. The steam heating pipes are all 1 inch boiler tubes, set in clusters of eight about central bolts at each end, which bolts serve to attach them to the front and back of the vessel.

It was shown that the quadruple effect must be capable of evaporating 22,000 kilos. of water per hour. Theoretically, since a higher vacuum exists in the fourth vessel than in the third, the former is capable of evaporating more water per sq. ft of heating surface than the latter, and the third, in turn, can evaporate more than the second, and so on. However, steam is frequently taken from the second or third vessels to be used in heating the juices during diffusion and carbonation, so the vessels are each made with the same amount of heating surface. We may then assume that one-fourth of the total evaporation in the entire effect takes place in each vessel. Each vessel must then evaporate \( \frac{22,000}{4} \) 5500 kilos. of water per hour.

From experiments and practical data, it has been found that in a quadruple effect about 30 kilos. of water may be evaporated
per hour, per sq. meter of heating surface. To allow for extra steam which may be withdrawn from the several vessels, assume that but 25 kilos. of water are evaporated per sq. meter of heating surface, per hour. Each vessel must then have \((5500 \div 25=)\) 220 sq. meters or 2360 sq. ft. of heating surface. This is afforded by 5850 lineal feet of 1 in. boiler tubes. If the tubes be 15 ft. long, as shown on Plate 6, there will have to be \((5850 \div 15=)\) 460 tubes. With eight tubes in a cluster there will be required 56 clusters, which is the number shown.

From the required tubing, the necessary dimensions of each vessel were easily found. The height was made twice that of the depth of juice, to allow for violent ebullition or frothing. As to the weight of steam required in the multiple effect, no very exact figures can be given. In the first vessel the entire amount of juice must be raised to the boiling point, and then 5500 kilos. of water evaporated. The amount of steam necessary will depend upon the concentration and temperature of the entering juice, and may amount to as much as 10,000 kilos., or 22,000 lbs., of steam per hour. The condensing pumps must each be capable of removing 6600 kilos. of water from their respective vessels each hour. This is 6 cu. meters or about 200 cu. ft. per hour. A pump with 5 X 5 in. water cylinder and 4 X 5 in. steam cylinder, making 100 strokes per minute, will perform this duty.

A vacuum of from 26 to 28 in. of mercury is constantly maintained in the last, or fourth vessel of the effect. The vapors, before entering the condenser, pass through a large sugar catcher equipped with several baffle plates. The sugar is returned to the
vessel through a drip pipe, while the vapors pass on to the condenser. This latter is of the jet type, worked on the dry-air system. The vapors enter the condenser at the bottom and, passing upward, meet sheets of falling water which is fed in at the top. The water is spread in thin layers by placing three shelves in the condenser, which have a rim attached so that the water collects on each shelf to a height of about 1 \( \frac{1}{2} \) inches.

There is always found large quantities of entrained air and ammonia gas in the juices as well as in the cooling water. These gases cannot be condensed, and would soon destroy the vacuum if means were not provided for their removal. It is therefore found necessary to attach a pump to the top of the condenser to pump out the gases. The water is removed below, and flows by gravity to a hot-well beneath. The hot-well must be at least 30 feet below the condenser or the reduced pressure in the latter will cause the water in the hot-well to be sucked up into the condensing chamber.

The size of condenser required was obtained from tables given in Hausbrand's "Evaporating, Condensing and Cooling Apparatus." To condense 6000 kilos. of steam per hour, will require 85,500 kilos of cooling water at 15°C. The condenser will have to be at least 4'-0" in diameter inside, and should have a height of 10 ft., measured from the top shelf down. The steam pipe will be 2 ft. 3 in. in diameter, and the fall pipe 9 inches in diameter.

If the cooling water is at 15°C., and the final temperature is 55°C., there will have to be 1338 liters of air removed for every 100 kilos of steam condensed. The vacuum pump must then
remove (60 X 1338 =) 80,000 liters per hour, or 48 cu. ft. per minute. The Deane Steam Pump Co. describe a duplex pump with steam cylinders 7 in. in diameter and air cylinders 9 in. in diameter, with an 8 in. stroke, which is capable of displacing 58 cu. ft. per minute. This should be well able to keep up the vacuum, even when leakage occurs.

The concentrated juice leaving the multiple effect has a specific gravity of from 27° to 30° Baume, and contains about 50% of sugar. It is known as magma, and is removed from the fourth vessel by a magma pump. This pump must handle from eight to ten thousand liters, or 10 cu. meters, per hour. That is about 350 cu. ft. per hour or 6 cu. ft. per min. A 5 in. X 7 in. pump making 30 strokes per minute will perform this duty. The magma is pumped from the quadruple effect to the top floor where it is sulphured and filtered through bag filters. It is then sent to the storage tanks shown on the third floor, from which it is fed to the vacuum pans.

The Vacuum Pans:

In the vacuum pans the magma is concentrated until the sugar crystallizes from the solution. The vacuum in the pans is always kept at from 25 to 28 in. of mercury. The process of concentrating consists in filling the pan with magma and boiling until very fine, almost invisible crystals appear. Then more magma is slowly fed into the pan, the boiling being continued, and these minute crystals used as the bases of the large sugar crystals in the finished massecuite. This method is called "boiling in grain,"
and is the one most used.

After about eight hours of boiling and constant feeding of magma into the pan, the vessel is full, and the finished massecuite, as the resulting mixture of molasses and sugar crystals is called, is dropped out through a pipe at the bottom of the pan.

The strike pans at this factory are situated on the third floor, at the sugar end of the house. They appear in Section E-F on Plate 4, and are detailed on Plate 7. They are cylindrical in shape, with a dome-shaped top and a cone-shaped bottom. This latter arrangement allows ready removal of the thick massecuite after boiling is complete. The heating is done by means of exhaust steam from the engines in the power-house. The steam enters a manifold feeding arrangement, which leads it to spiral coils laid around the sides of the vessel. These coils are made in sections so that they may be removed through the man-hole for repairs. The pan must be equipped with pressure and vacuum gauges and thermometers, as well as several "proof-sticks," These are ingenious devices which allow for the removal of a small sample juice from the vessel, without destroying the vacuum within.

The evolved vapors pass out through a large pipe above, which leads them through a sugar-catcher, previously described, to a jet condenser of similar design to the one attached to the quadruple effect. The massecuite dropped from the vacuum pan will contain over 90% of sugar, and will have a specific gravity of about 1.5. If 600 tons of beets are sliced, containing 15% sugar, the pans will have to handle at least 90 tons of sugar, or about 100 tons of massecuite each day. The first and second molasses
are treated for more sugar, and pass through the vacuum pans also. The pans must therefore be made to handle at least 150 tons of massecuite each day. That is, about 136,300 kilos. or 63,200 kilos. for each pan. Since the sp. gravity is about 1.5 the volume of this massecuite will be \( \frac{63,200}{1.5} = 45,000 \) liters or 45 cu. meters, which is equal to 1615 cu. ft. If a strike requires eight hours for its boiling, three strikes can be made each day. Allowing for stoppage, the daily capacity will then have to be about 1800 cu. ft. or 600 cu. ft. per strike. Each pan must therefore hold 600 cu. ft. of massecuite. With a diameter of 12 ft. this massecuite will fill the pan to a depth of 5 1/2 ft. above the bottom of cylinder. This allows the volume of the cone-shaped bottom to accommodate the steam coils. The pans were then shown with an effective height of 12'-0" to allow for violent ebullition and frothing.

The dimensions of the condenser shown in detail on Plate 7 were obtained from the tables in Hausbrand. Each pan drops 22,000 kilos. of massecuite at a strike. It receives this massecuite with an equivalent weight of water, as in a 50% solution. During eight hours then, 22,000 kilos. of water must be evaporated, or, for safety, about 3000 kilos. per hour. The condenser, to handle this amount, must be 9 ft. in effective height and 3 ft. in inside diameter.

The vacuum pumps for the condensers will each have to handle, \( (1680 \times 30\%) = 50,400 \) liters per hour, or about 30 cu. ft. per minute. The Deane Steam Pump Co. offer a single horizontal, rotative vacuum pump, with 6 X 7 in. steam cylinder and 8 X 7 in.
air cylinder, which displaces 40 cu. ft. at a speed of 100 revolutions per minute. One of these should be attached to each vacuum pan condenser.

As to the amount of heating surface required in each pan, definite figures cannot be given, as in the case of the quadruple effect, because of the viscous sirups handled and the poor circulation obtained. Claassen recommends, for a pan handling 20 long tons, as ours does, a heating surface of about 80 sq. meters or 860 sq. ft.
Section 7

The Crystallizers:

The "strike" of massecuite is dropped from the vacuum pans and falls into a screw conveyor which carries it to any designated crystallizer in one of the two rows of six provided. The function of the crystallizer is to afford a slow cooling of the massecuite and to keep it well stirred during the cooling. This prevents the formation of new crystals of sugar, which would be so small that they would pass through the baskets of the centrifugal machines. The slow cooling is accomplished by keeping the crystallizers warm by means of steam pipes.

The crystallizers are large cylindrical tanks of sheet-iron, equipped, as stated, with a steam jacket. A horizontal shaft extends through the cylinder at its axis, and has a projecting framework of iron rods, arranged in a helical form, attached to it. This helix serves to agitate the cooling massecuite when the shaft is driven by the worm gear fixed to its outer end. The massecuite is kept in the crystallizers until it has cooled to from 45° to 50°C. This may require from 20 to 30 hours. The strike pans, when running at full capacity, will each drop 1800 cu. ft. of massecuite per 24 hours. If the massecuite be kept in the crystallizers for 30 hours, the latter must be designed to hold 30 hours supply from both pans or \((30/24 \times 1800 \times 2) = 4500\) cu. ft. If the crystallizers are 8 ft. in diameter and 15 ft. long and are half filled with massecuite at a charge, there will
be \((84 \times 3.1416 \times 15 \div 8)\) 375 cu. ft. of massecuite in each crystallizer at a time. There will then be \((4500 \div 375)\) 12 crystallizers necessary.

The Centrifugals:

After the massecuite has been properly cooled to 50°C. and crystallization has been promoted in the most favorable manner, the warm massecuite is dropped from the crystallizers into the mixing tanks above the centrifugals and under the second floor. The mixing tanks, two in number, are constructed of sheet iron and are supported on I beams, so that one tank is under each row of crystallizers. A long shaft extends along the bottom of each tank, and is equipped with prongs which stir up the massecuite when the shaft is revolved. By this means the different classes of massecuites coming from the strike pans are thoroughly mixed so that the product sent to the centrifugals is of nearly constant composition. When especially poor massecuite is being worked up from second molasses it may be necessary to reserve one mixer for it in order that the entire stock be not contaminated. From the mixing tanks the massecuite is fed to the individual centrifugal machines through spouts, which are opened and closed by the man in charge of the centrifugal.

A centrifugal is a cylindrical copper vessel whose sides are perforated by minute slits. This vessel, known as the basket, is suspended by a vertical shaft from a heavy ball bearing. The shaft also carries the armature core and winding of an electric motor.
Supported below the bearing are the stationary field coils, which surround the armature and thus form a motor direct connected to the shaft. The centrifugal basket hangs in a sheet-iron drum, which serves to catch the molasses purged from the massecuite. Spouts from the mixing tank above feed the massecuite to the centrifugal baskets. The attendant opens and closes the mouth of the spout to regulate the amount dropped into the basket. The bottom of the basket is closed by a copper plate. In the center of this plate is an opening through which the sugar crystals are dropped after being centrifugated. This opening is closed by a tight-fitting cover during the working of a charge.

When the basket is filled with the proper amount of massecuite, the motor is started and the basket made to revolve at a speed of about 1100 rev. per minute. The massecuite is thrown up on the side of the basket, and at this terrific speed, assumes a uniform thickness from top to bottom. The quantity of massecuite used in one charge must be regulated so that the layer of sugar thrown against the sides of the basket will not be so thick that the molasses is not well thrown out of it. The centrifugals in this factory are situated at the sugar end of the sugar house, on the ground floor. Their arrangement and support is shown more in detail in Section E—F on Plate 4.

When the charge has been well centrifugated it is washed, first with water, and finally with a dilute syrup. This removes spots of brown clinging molasses. Some factories use a bluing solution to wash the sugar, giving it a pure white color. The molasses, thrown from the centrifugal basket, is collected in
the surrounding drum and runs out beneath, to a conveyor which carries it to tanks set in a pit at extreme sugar end of the building. After the machine has been stopped the bottom opening of the basket is uncovered and the sugar shovelled out into a conveyor which carries it to the boot of the sugar elevator. The latter delivers the sugar to a spiral conveyor which delivers the sugar to the sugar store-house.

Twelve centrifugals are shown installed in this factory, each of which has a diameter of 40 in. If these were all worked continuously they could easily handle 200 tons of massecuite per 24 hours. This is 50 tons more than the strike pans can turn out. There will be times, however, when especially thick or cold massecuites must be centrifugated in a hurry, or when several machines are out of action for cleaning or repairs. Twelve machines will therefore be none to many.
Treatment of the Molasses:

There are several methods in use for the recovery of more sugar from the molasses which is obtained from the centrifugal machines. It is frequently the practice, when the first molasses is of pure quality, to send it back to the vacuum pans for a second concentration. It is then sent through the crystallizers and centrifugated, and yields more sugar. If this second sugar is well washed and blued it may be mixed with the first sugar in the sugar dryer and not affect the quality of the product.

The second molasses, obtained from centrifugation of the first molasses, is too impure to be treated for more sugar. Many patents have been taken out for special treatment of molasses for the recovery of sugar. None have proven of great profit, however, and it was not thought wise to show an equipment of that kind in this factory. The second molasses is often diluted and, after defecation, carbonation, sulphuring and filtration, is concentrated and yields a brown sugar. This brown sugar is melted up and dissolved, the resulting solution being treated in the usual way for white sugar. Thus the entire product of the factory is white granulated sugar.

A process is used in Europe, whereby the third molasses is treated with powdered quick-lime, which precipitates the sugar as sucrate of calcium. This precipitate is filtered off and used in place of pure lime to defecate the diffusion juices. When the latter are carbonated the sucrate is decomposed, and the
sugar returned to the process. The profit accruing from this last method is questionable, and many factories sell their third molasses for the manufacture of alcohol. This will be taken up in the consideration of the by-products.
Section 9.

Treatment of the Sugar:

The finished sugar is carried by a spiral conveyor to the sugar store-house. Here it is fed to a long horizontal drum heated by steam coils, and kept slowly revolving. The sugar is thus freed from traces of moisture and the crystals are separated from each other and prevented from forming lumps. This sugar dryer is continuous in its operation, receiving the damp sugar at one end and delivering the dried granulated sugar at the other. The sugar is then sent to revolving screens, where any hard lumps are removed. After the sifting process the sugar is fed to automatic weighing and packing machines, which pack it in sacks of 100 lbs. and barrels of about 350 lbs. each. These are stored until a favorable market presents itself for their sale. Although granulated sugar made from beets is identical with that made from sugar-cane, the wholesale price of beet-sugar is always 10 cents per hundred lbs. less than that of cane sugar.
The By-Products:

Chief among the by-products obtained in beet-sugar manufacture are the spent-cossettes. These are deposited in the flume beneath the diffusion battery. The spent material contains some 95% of water. The cossettes flow to one end of the flume by virtue of the slope in it. Here they enter the boot of a cossette elevator which carries them to the top floor and deposits them in a tank. From this tank an Archimedean screw lifts the cossettes and delivers them to a conveyor which feeds the cossette presses. The collecting tank has a drain-pipe connected to it, so that the cossettes are well drained of water.

The cossette presses consist of a small hopper, set with its bottom on the level of the fourth floor. This feeds the cossettes to a heavy boiler-plated cylinder, which contains an inverted cone within it. The upper part of the cone, being narrow, leaves a large space, which is filled up by the wet cossettes. At the lower end of the cylinder, however, the cone is nearly as large in diameter as the cylinder, so that the open space between the two is only an inch or two. The cone is firmly fixed upon a vertical shaft which is driven by bevel gearing above. The outer surface of the cone has numerous projections set askew upon its surface. These form a sort of open screw and force the cossettes lower and lower in the machine. The cossettes are thus forced into an ever contracting space.
and subjected to an enormous pressure. Both the cone and the cylinder are perforated and the exuded water flows out into a surrounding jacket, from which it is drained off.

The pressed material is dropped out of the bottom of the machine and falls into a conveyor which takes it to a spout that feeds it onto a heap outside the building. The pressed cossettes are buried in silos in the open air, and keep for several months without serious decomposition. They have about 14% solid matter and 86% water, and are said to be as valuable for cattle food as the original beets were. The presses require about 2 1/2 horse-power each, to drive them, and can handle from 75 to 100 tons of cossettes per 24 hours. There will seldom be more than 500 tons of cossettes produced per day, so that five presses will be sufficient.

Besides the spent cossettes there will be filter press-cake and molasses as by-products. The press-cake may be used as fertilizer, but in many localities no market can be found for it. The molasses are frequently mixed with the pressed cossettes to improve their value as a cattle food. In most cases, however, it is sold to distilleries to be used in the manufacture of rum or alcohol.
Bibliography.

Beet Sugar Gazette. Current numbers.
Church, Edward The Sugar Beet. Agriculture and Extraction.
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Hausbrand, E. Evaporating, Condensing and Cooling Apparatus.
Lock & Newlands Bros. Handbook of Sugar.
McIntosh, John G. The Technology of Sugar.
Mechanical Engineer. February 1905. Multiple effect Evaporator.
Morse Calculations made in Cane Sugar Factories.
Myrick, Herbert. The American Sugar Industry.
Peffner, E. S. Beet Sugar Analysis.

Progress of Beet Sugar Industry in U. S. in 1900:

\[
\begin{align*}
\text{""""""""""""1901}\} \\
\text{""""""""""""1902}\} \quad \text{Government Reports.} \\
\text{""""""""""""1903}\} \\
\text{""""""""""""1904}\} \\
\end{align*}
\]

Taylor, Jas. W. Sugar Machinery
The Sugar Beet Current numbers.
Ware, Lewis S. Beet Sugar Manufacture and Refining.
Weichmann F. G. Sugar Analysis.
## ESTIMATED COSTS.

### Sugar House.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>$150,000</td>
</tr>
<tr>
<td>Beet wheel</td>
<td>900</td>
</tr>
<tr>
<td>Beet washer</td>
<td>1,500</td>
</tr>
<tr>
<td>Diffusion battery</td>
<td>15,000</td>
</tr>
<tr>
<td>Carbonating tanks</td>
<td>10,000</td>
</tr>
<tr>
<td>Sulphuring tanks</td>
<td>1,500</td>
</tr>
<tr>
<td>8 Filter presses at 1000</td>
<td>3,000</td>
</tr>
<tr>
<td>14 Bag filters at 300</td>
<td>4,200</td>
</tr>
<tr>
<td>12 Centrifugals at 1500</td>
<td>18,000</td>
</tr>
<tr>
<td>Pumps, juice, vacuum and water</td>
<td>16,000</td>
</tr>
<tr>
<td>Gas pump</td>
<td>4,000</td>
</tr>
<tr>
<td>Quadruple effect</td>
<td>25,000</td>
</tr>
<tr>
<td>12 Crystallizers at 1250</td>
<td>15,000</td>
</tr>
<tr>
<td>Granulator</td>
<td>3,500</td>
</tr>
<tr>
<td>Weighing machine</td>
<td>1,800</td>
</tr>
<tr>
<td>Beet slicers and accessories</td>
<td>3,000</td>
</tr>
<tr>
<td>2 Vacuum pans at 8000</td>
<td>16,000</td>
</tr>
<tr>
<td>Motors aggregating 540 H.P.</td>
<td>-</td>
</tr>
<tr>
<td>at $20.00 per K W for large sizes</td>
<td>11,000</td>
</tr>
<tr>
<td>at $30.00 per K W for small sizes</td>
<td>30,000</td>
</tr>
<tr>
<td>Piping (including labor)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Totals.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar house</td>
<td>$334,400</td>
</tr>
<tr>
<td>Storage shed</td>
<td>100,000</td>
</tr>
<tr>
<td>Lime kiln complete</td>
<td>5,000</td>
</tr>
<tr>
<td>Machine shop Bldg. and Mchy.</td>
<td>20,000</td>
</tr>
<tr>
<td>Warehouse</td>
<td>13,000</td>
</tr>
<tr>
<td>Offices</td>
<td>3,000</td>
</tr>
<tr>
<td>Power plant complete 1000 H. P.</td>
<td>65,000</td>
</tr>
<tr>
<td>Track and wagon scales</td>
<td>3,500</td>
</tr>
<tr>
<td>Site 5 acres at $200.00</td>
<td>1,000</td>
</tr>
</tbody>
</table>

**Total investment in Bldgs. and Mchy.**  

Beets in storage, 20 days supply:

- 12,000 tons at $5.00 per ton = $60,000 for 110 days or for year:
- $18,300

Sugar in warehouse 700 tons at $50.00 per ton = $35,000 for 110 days or for one year:
- $19,000

**Interest bearing investment**  

**Total:** $585,200
**Running Expenses**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of beets at $4.50 per ton for 12 1/2% beets and $5.40 per ton for 15% beets average $5.00 per ton</td>
<td>$330,000</td>
</tr>
<tr>
<td>Labor for treating beets at $.151 per ton</td>
<td>99,660</td>
</tr>
<tr>
<td>Repairs at 32 cts. per ton</td>
<td>21,120</td>
</tr>
<tr>
<td>Supplies per ton of beets at 70 cts. per ton</td>
<td>48,200</td>
</tr>
<tr>
<td>Interest at 5% and depreciation at 7% 12%</td>
<td>70,224</td>
</tr>
<tr>
<td>Sinking fund 7%</td>
<td>43,800</td>
</tr>
<tr>
<td>Total expenses for year</td>
<td>$514,004</td>
</tr>
</tbody>
</table>

**INCOME.**

Assume 12 1/2% of weight of beets is recovered as sugar or 75 tons per day (75 x 110 =) 8250 tons per year (110 days campaign)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income $8250 X $.20 per ton</td>
<td>$742,500</td>
</tr>
<tr>
<td>Pressed cossettes at $.10 per ton</td>
<td>29,700</td>
</tr>
<tr>
<td>(assume 45% of weight of beets)</td>
<td>29,700</td>
</tr>
<tr>
<td>Molasses at $.20 per ton</td>
<td>1320 tons</td>
</tr>
<tr>
<td>(assume 2% of weight of beets)</td>
<td>2,540</td>
</tr>
<tr>
<td>Net Profits $157,836</td>
<td>3,000</td>
</tr>
<tr>
<td>Employer's Liability and Fire Insurance</td>
<td>$157,836</td>
</tr>
<tr>
<td>26.9% on investment.</td>
<td></td>
</tr>
</tbody>
</table>

Average of costs at 13 Michigan factories according to Bulletin No. 72, U. S. Dept. of Agriculture.