

The STORY *of*
CUBAN SUGAR



"Stand" of Mature Cane

The STORY *of*
CUBAN SUGAR

By
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Introductory Note

*T*HIS pamphlet has been compiled in response to numerous requests for general information regarding the Cuban sugar industry. As nearly all Cuban raw sugar is shipped to refineries, principally those on the Atlantic seaboard of the United States, there would be a decided lack in any account that did not include some description of refining operations. The subject, therefore, is treated under three main heads: I "The Plantation in Cuba"; II "The Factory or 'Central' in Cuba"; III "The Refinery in the United States." The description of the industry is based mainly on the operations of the United Fruit Company and those of its subsidiary, the Revere Sugar Refinery.

It is not generally realized that the United Fruit Company, most widely known for its banana activities and steamship transportation, is the best example in the world today of a self-contained sugar enterprise. It owns in Cuba some 89,000 acres of growing cane, as well as undeveloped land suitable for additional planting; 340 miles of railway; and at the seaboard in Oriente Province two large modern sugar mills, Central Boston and Central Preston, each having a rated daily average capacity for grinding 7,000 tons of cane. With the exception of the grinding units, these two factories are electrically operated throughout and represent a combined maximum annual output of 1,400,000 bags (200,000 tons) of raw sugar. Adjacent to Central Preston the Company has recently erected a distillery, complete in every detail, for converting the final molasses of the sugar mill into alcohol-ether motor fuel, to be used in internal-combustion engines instead of gasoline. In some respects, this fuel is superior to gasoline.

The sugar fleet of the United Fruit Company comprises four modern oil-burning steamships. Each of these vessels has a carrying capacity of 24,000 bags, is equipped with a 20-ton lift for handling heavy cargo, has

accommodations for six passengers and can develop a $10\frac{1}{2}$ knot speed. This fleet transports the Company's raw sugar directly to the Revere Refinery, situated on deep water in the Charlestown district of Boston, and on the return trip to Cuba carries the necessary supplies for the two Sugar Divisions of the Company.

The Revere plant, which has a daily refined-sugar output of 4,000 barrels, embodies the most up-to-date construction, the latest mechanical improvements and the highest engineering efficiency in sugar-refining operation. It has direct rail connections whereby its product, of unexcelled quality, is distributed throughout the New England states and elsewhere. It also owns and operates a modern fireproof cooperage plant which has a daily output of 5,000 barrels and 4,500 wooden cases.

In the compilation of this work, the Author has purposely avoided statistics and, wherever possible, technical language. Throughout he has endeavored to treat the subject broadly, yet in sufficient detail to present an accurate picture of the processes which mark the progress of a stalk of sugar cane from the field, through the mill and the refinery, to its final state — refined sugar.

The Author takes this opportunity to express his appreciation of the assistance received in the preparation of this article from the agricultural and the factory staffs in Cuba as well as from the refinery staff at Boston.

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PART I



The Plantation in Cuba

THE STORY *of* CUBAN SUGAR

By

PHILIP KEEP REYNOLDS

Assistant to the President of the United Fruit Company



PART I

The Plantation in Cuba

History SUGAR cane is generally believed to have originated in India, but, according to some authorities, it is also indigenous to the South Pacific Islands. No reference to it is made in either the Old or the New Testament. It is claimed that the first historical mention of sugar cane occurs in certain Chinese writings of the eighth century B.C., where the fact is recorded that the knowledge of sugar cane was derived from India. That it was considered of great value by the Chinese is shown by their manuscripts of about 200 B.C., but it is generally held by the best authorities that the secret of extracting crystals from the sugar-cane juice was not discovered until a much later period. Alexander the Great, more than three centuries before Christ, it is recorded, on the banks of the Indus River gathered the "honey-bearing reed" and took it back to Europe.*

The discovery of the art of making sugar from cane is credited to the Bengalese and, as long ago as the third or fourth century after Christ, travelers from India brought back news of "Indian salt." The name "sugar" is derived from the Sanskrit word "shakará" or "sarkará," which signifies small grains. It is possible to trace from the fifth century the spread of cane sugar into Persia, Arabia and Egypt. Arabian doctors gave sugar in their medicines and Moslem armies included it in their supplies. It was introduced into Spain by the Moors early in the eighth century.

When in the Orient, the Crusaders acquired a liking for sugar which resulted in the development of trade in this commodity between northern Europe and Venice, Genoa and Pisa. During the Middle Ages, Venice was

* "Something about Sugar," by George M. Rolph.

the chief sugar-distributing centre in Europe. One of the earliest references to sugar in Great Britain mentions the shipment of one hundred thousand pounds to London in 1319, by Tomasso Loredano, a Venetian merchant. About 1420 the Portuguese took sugar cane to Madeira, then to the Azores and later to the Cape Verde Islands; at about this time the Spaniards introduced it into the Canaries.

According to Humboldt, sugar cane was unknown in America and the adjacent islands before the advent of the Spaniards. It is of particular interest to note that, following the discovery of America, sugar cane was brought to the New World and its production there, particularly in the West Indian Islands, increased to such an extent that the sugars from the plantations of Madeira, the Cape Verde Islands and the Canaries were eventually driven from the world's markets. In 1751, the Jesuits took sugar cane from Santo Domingo to Louisiana.

In 1747, sugar cane was planted by the French in Mauritius, and some years later in Reunion, nearby; sugar made in these two islands was sent to Europe about the end of the eighteenth century. In Java, sugar cane has been grown since a very remote period; it was probably brought there originally by Chinese traders. There is evidence that the Chinese also introduced it into the Philippine Islands, as the names of the implements and methods used there distinctly point to Chinese origin. The cultivation of sugar cane in Australia was begun some fifty years ago; it was introduced into the Fiji Islands in 1880.*

When Captain Cook, in 1778, discovered the Hawaiian Islands, he found sugar cane there growing luxuriantly; this fact is regarded by some authorities as signifying that it is indigenous to Polynesia.

Sugar cane was introduced into Cuba by the Spaniards as early as the sixteenth century. In the year 1760 the sugar production of the Island was about 4,400 tons, and in 1894 it had increased to 1,054,000 tons. During the long struggle for independence waged by the Cubans against the Spaniards, the sugar industry suffered severely, many of the plantations and mills being ruined. As a result, the sugar output of the Island was, for the time being, materially reduced.† Cuba completed its record crop of approximately

* Rolph deals exhaustively with the early history of sugar.

† The Cuban crop, as noted above, reached its maximum of former days, 1,054,000 tons, in 1894, and then fell off rapidly, owing to the Cuban insurrection and consequent destruction of property, with a minimum crop of 212,000 tons in 1897. Later, under the Reciprocity Treaty with the United States, the sugar production of the Island recovered.



Burning Underbrush on New Land

4,000,000 tons of raw sugar in 1919. It is today the largest single source of the world's supply of cane sugar and for this reason is often termed the "World's Sugar Bowl." In the Island at the present time there are nearly 200 mills, many of which are of the most modern type and do exceedingly efficient work.

It is very interesting to trace the introduction of sugar into the civilized world. At first, it was regarded as a curiosity and was presented to royalty; then it came into use as a medicine; later, it became a luxury; and now it is a necessity. It is only within the past thirty years that the food value, or energy-producing power, of sugar has been appreciated.*

The Plant **S**UGAR cane is a member of the grass family, known botanically as *Saccharum officinarum*. It grows in all tropical and sub-tropical countries and, although attaining its best development in the lower levels, it can be cultivated on elevations of 4,000 feet. A hot, moist climate with copious rains previous to planting and in the growing season, and cool, dry weather during the ripening period, are essential to the production of sugar cane to the best advantage. An annual rainfall of about sixty inches is considered desirable.

* "Food Products from Afar," by C. H. S. and H. S. Bailey.



The sugar-cane plant consists of roots, stalks, leaves and flowers. The roots, slender and numerous, grow laterally rather than downward, and vary in length from eighteen to thirty-six inches. From the original rootstock, several shoots develop, forming finally a hill or stool. Extending the entire length of the cane stalk, joints or "nodes" occur at distances of from four to eight inches



UPPER VIEW: *Making Hill Ready for "Seed"*
 CENTRE VIEW: *Cane Cut as "Seed" for Planting*

apart, five inches being the average interval in a good growing season. Each section between these joints is called an "internode." The top section of the cane, termed "cogollo," contains but little sucrose and is unfit for sugar making.* From each node grows a single leaf, which usually falls from the stalk as the cane



Slipping "Seed" into Ground

* Sucrose is the chemical term for pure cane sugar.

matures. At the top of the cane arises a cluster of long ribbon-like leaves, from the centre of which springs a slender stem bearing the flowers; these form a large tassel of a light reddish-gray color.

Along the stalk, running lengthwise, are fibrous strands serving as channels to conduct the water and the plant food from the roots to the leaves. The preliminary development of the sucrose in the plant takes place in the leaves, where, through the action of sunlight, carbohydrates are formed. This partially elaborated material then passes down into the stalk and is gradually converted into sucrose.

The height attained by sugar cane varies considerably, according to the richness of the soil, the rainfall during the growing season, the amount of cultivation received, and the number of crops gathered from the same rootstock, or stool. A period of drought or of heavy rains leaves its imprint unmistakably upon those sections of the cane that are in process of formation. Drought causes them to remain short and stunted; heavy rains make them grow long and rank. Fully matured cane in Cuba, grown under normal conditions, stands in the fields at an average height of from seven to twelve feet, although it sometimes grows as high as twenty feet. A field of young sugar cane resembles a field of corn; later, when the cane is fully grown and the leaves have attained their normal size, this resemblance is much less marked.

There are a great many varieties of sugar cane, but that almost universally found in Cuba is the *Crystalina*, constituting more than ninety per cent of all the cane grown in the Island.*

Sugar cane will grow in a great variety of soils. The most suitable is a clay loam, which, while retaining moisture, remains sufficiently open to permit of proper aëration and drainage. Potash, phosphoric acid, nitrogen and lime are the principal soil elements required.

* In his book, "Cane Sugar," Noël Deerr gives some thirty pages to a discussion of cane varieties. Classifications have been made according to the color of the stalk, shape of eye, color of pith and other physical characteristics, as well as according to the geographical origin of the varieties. In all these methods the line of demarcation is not always distinct, particularly in the case of canes produced by breeding.

The original cane brought to the West Indies was of the variety since known as Creole. Later, other varieties, known as Otaheite and Batavian, were introduced and named for the islands of their origin. A Batavian cane known as *Crystalina* has been so largely developed that it is now the principal variety in Cuba, and produces most of the world's cane sugar.

It has been found that desirable qualities in cane can be developed by cross-breeding. The experiment stations in this manner have developed hundreds of seedlings, which they have designated by letters and numbers rather than by name. This development has been accompanied by a systematic study of characteristics, the object being the production of a cane which will grow well, which will be resistant to disease and drought and which, when brought to the mill, can be readily worked to produce a high yield of sugar. So far as Cuba is concerned, seedlings have not been developed to a point where they are a commercial factor.

*The Modern
Plantation*

THE number and the magnitude of the operations involved in preparing and equipping a large and efficient sugar plantation in Cuba are not usually comprehended by any one whose basis of comparison may be general farming operations in the United States. Within a few years' time a tropical wilderness is transformed into a cultivated tract, with ample accommodations for the housing and medical care of the army of laborers and other employees. In addition, transportation facilities on a large scale are provided.



Cane One Month Old

The land is first thoroughly examined by experts who decide regarding its suitability for the cultivation of cane. When selected, the land is surveyed and is laid out in sections conducive to the convenient apportionment and efficient handling of the work to be done later, and with a view to keeping proper records of all production and other costs pertaining to each section.

These preliminaries are followed by the work of clearing the land of tropical growth, the digging of main drainage ditches and the actual planting. Then, too, the sugar mill

and the employees' houses are erected; railroads are constructed; and food-stuffs and merchandise are made available at moderate cost. Likewise, hospital treatment is furnished in case of sickness or accident and the general sanitary condition of the plantation is maintained; in short, all means of general and emergency care of the personnel are adequately established.

*Preparation of
the Land for
Planting*

IN the preparation of virgin land for planting, the trees and underbrush are first cut down. All good, hard timber is taken out and saved for building purposes, and a certain portion of the other wood is cut up and delivered to the mill for fuel. The remaining timber and brush, which cannot be utilized in any way, are allowed to dry out and are then burned; whatever part may resist the first burning is gathered up in piles and burned again, until the land is generally cleared. The utmost precaution is taken to prevent burning cinders, carried by the wind, from setting fire to standing cane. The ground, although containing roots and some stumps, is now ready for planting.

Accidental fires, due to sparks from locomotives and to other causes, constitute the most serious menace to growing cane. To minimize this risk, fire lines are established, with an average width of twenty yards. In many instances these fire lines are planted with sweet potatoes and other green vegetables, which not only furnish food for the laborers, but also in themselves provide more or less protection against fire.

The preparation of the land for replanting is effected by means of steam plowing, tractor plowing or bull plowing, the fields usually being first burned over. The expense attached to the steam-plow method restricts its use to large areas, of one hundred rosas (177 acres) or over, but this



Cane One Year Old—Sixteen Stalks from One "Seed"



plow, if properly handled, is very efficient. Tractors are used to advantage in small areas, but if delays are to be avoided, all logs and stumps must first be removed. Bull plows can be used on small areas with two or more yoke of bulls or oxen to a plow. After the various plowing operations, harrows are used further to pulverize the surface of the soil.



Plowing with Oxen

Planting **T**HE methods of planting cane in Cuba vary considerably, as do also the distances between the rows. Planting seven feet apart in the row, with a space of seven feet between rows, is the practice of the United Fruit Company in new lands. The ground should receive not less than three inches of rainfall previous to planting. The usual seasons for planting cane are spring and fall.

Except for cross-breeding and selection work, the flower seeds are not used in planting. It is often difficult to obtain a good "stand" from them and, when they do germinate, the resulting plants are likely to vary in type to a considerable extent. This latter characteristic, however, is turned to good account in some experimental stations in the cross-breeding of desirable varieties and the selection of the most promising plants to propagate in the regular manner. Superior varieties have been obtained in this way.

Ordinary field propagation or planting is effected by means of cuttings from a stalk of mature cane, each cutting having usually three buds or "eyes," corresponding to the eye of the potato, located at the nodes. These cuttings are called "seed." The field of cane to be used for "seed" purposes is selected for its proper age, vigor of growth and general freedom from disease and insect pests.* It is most important that only healthy plants be used. The best seed for planting consists of cuttings from plant cane not over twelve months old. The cane selected is cut down, and in the same field it is prepared for use by being cut into sections of not less than two joints—preferably three. The end of the section cut should be about one inch, on each end, away from the joint or "eye." Any cuttings which have poor or broken eyes, or which show evidences of borer injury or disease, are rejected.

In the cutting of a stalk of cane for seed, the upper portions below the "cogollo" are usually considered superior, while the lowest section, particularly if it shows much rooting, is generally rejected. In the transportation of the selected seed to the field where it is to be planted, great care is necessary to avoid injury to the "eyes" from handling or from exposure to the sun. The seed should be planted not later than three days after cutting.

* Deerr devotes thirty-six pages to the subject of diseases and pests of the cane, which are many, and which are liable to attack the roots, stalk and leaves.

Among the diseases may be mentioned the Mosaic or mottling disease, the rind disease, the red rot of the stalk and the "pineapple" disease. Of the insect pests, the moth stalk-borer is conspicuous because of the holes it bores in the stalk. The damage it causes, while not very serious in itself, induces fungous infection and subsequent deterioration of the sugar content. Frequently, caterpillars cause considerable damage by eating the leaves of young cane.



*Steam Plow (taking on water)
By means of a steel cable the plow or knifer is drawn back and forth*



Tractor Plowing



“Knifing” the Soil

between these two powerful engines stationed at opposite ends of the field

In the planting of new land, the work must be done with a pick mattox or a sharply pointed stick, because of the stumps and roots that remain even after the usual burning. The outer edge of the field is measured off with a tape line for planting, and stakes are set at proper distances as guides. A check wire is used in the lining and in the distributing of the seed. In the planting of the cane, a stick is thrust in a slanting direction into the ground to make a hole, into which one or two pieces of cane are inserted, generally with the upper end not more than two inches under the ground. The earth is then packed tightly around the seed by pressing with the foot.

In the replanting of a cultivated field, a light plow is used to trace the furrows in which the cane is to be planted. These furrows, or rows, are usually six feet apart, instead of seven as in the case of the planting of new land, and the cane cuttings (“seed”) are generally placed in the row six feet apart. The proper interval for planting varies according to the soil, so that throughout Cuba are found such variations as cuttings end to end, every twelve or twenty inches apart, two rows of cuttings in a furrow—and many other different practices. The cuttings are laid in the furrow by hand; then a light plow is run alongside the furrow, and the earth is turned over to cover the cane from four to six inches deep.



Weeding by Means of Hoes



Cutting Cane

Cultivation **I**F the ground is damp and in good condition, the cane may be expected to show itself above the surface about two weeks after planting. Weeds, however, soon make their appearance, and the work of destroying them should not be delayed. The operation of weeding must be repeated as often as necessary until the cane leaves have grown over so that they completely shade the ground and prevent the sun from penetrating through to the soil. In new lands this cultivating is usually done by means of hoes.

In the case of replanted fields, after they have been cleaned by hand for the first time, the weeds are destroyed by running a cultivator, a light plow or a disc harrow between the rows of cane. Mules, tractors and oxen are used in this work.

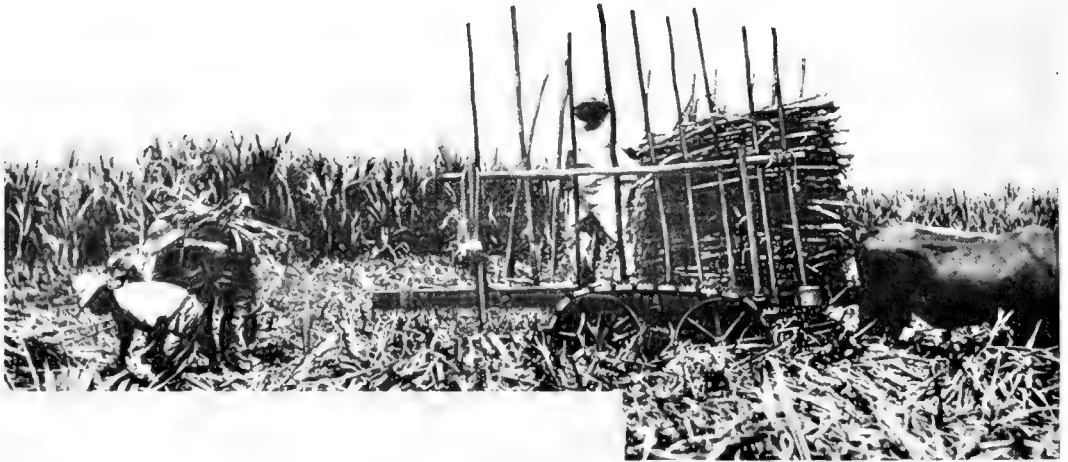
Crops **T**HE first crop, called "plant cane," usually takes from twelve to fifteen months to

mature. Spring cane, however, planted in May, is sometimes cut the following April, or eleven months after planting. After plant cane is harvested, new shoots develop from the original rootstock, and form what is called the second crop, or "first ratoons." These shoots may be cut after about twelve months' growth, and the operation may be repeated a year later, given the right kind of growing weather. However, if enough cane is available for the mill so that the ratoons may be allowed from fourteen to eighteen months of growth, they will give a much better sucrose yield. The question of maturity, as regards each particular field, is something to be considered individually by those in charge of cutting; no set rule can be given to indicate definitely the exact month in which canes should be harvested. Close observation of maturity, chemical analysis of average samples, amount of cane available for the crop, possibility of providing "stand over" cane for beginning the next crop,—all these are factors that enter into the final decision as to harvesting.

Leaving uncut cane too long in the field tends to start a series of new shoots, called "suckers," which are offspring of the parent plant, and which sometimes grow to the size of the parent plant itself, if harvesting is delayed too long. While these well-developed suckers produce tonnage, their sugar



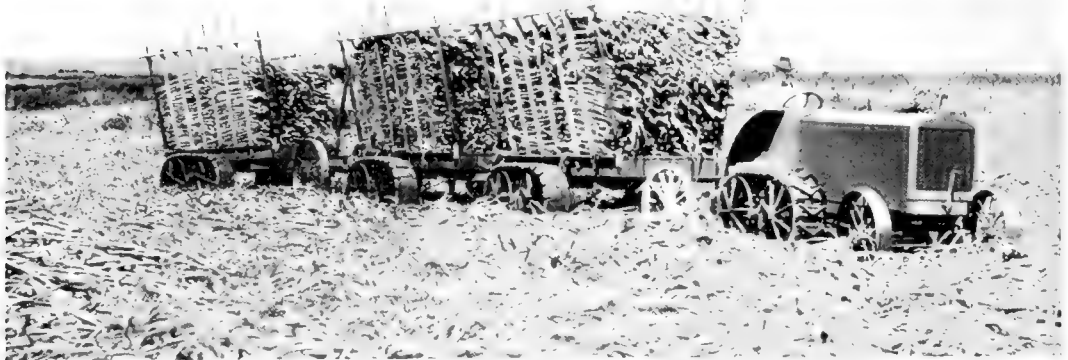
A Future Cane-Cutter



*Hauling Cane in New-Style Cart
(Caterpillar)*



content is very low. Further, there is a heavy accumulation of dead leaves from over-matured cane which increases the difficulty of harvesting. When cane becomes too old, it dries up and the sucrose tends to become inverted.*



*INSERT: Hauling Cane in Old-Style Cart
LOWER VIEW: Hauling Cane with Gasoline Tractor*

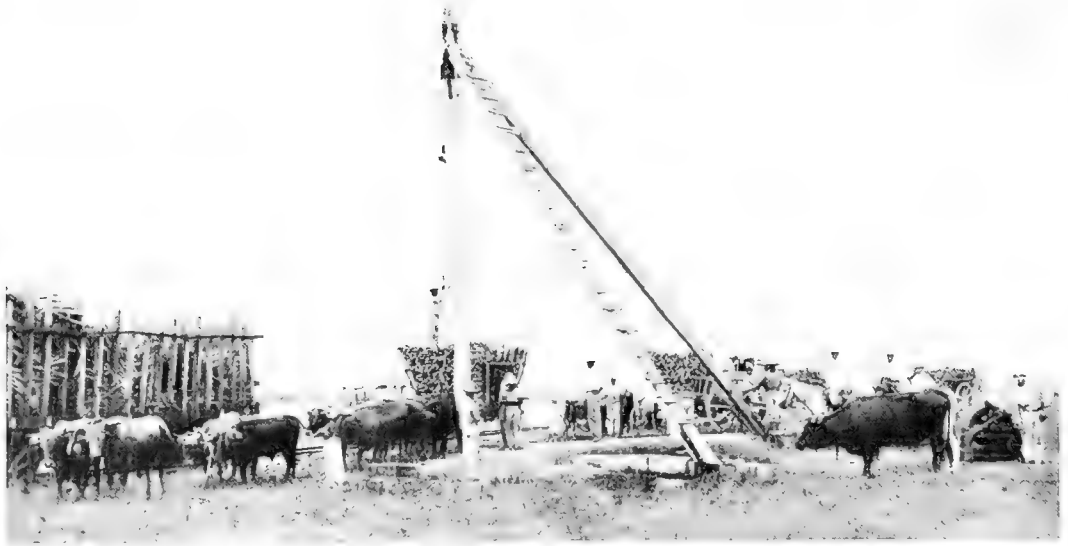
* Inversion of sucrose is the changing of sucrose into glucose through processes of fermentation.

When the cane is very young, its sucrose content is extremely low, being utilized in meeting the needs of the growing plant. When cane of these two extremes is harvested, the yield in sugar at the mill is less than would have been the case had such cane been harvested at the right time, and the operation means smaller financial returns.

The number of successive "ratoon" crops depends upon the quality of the soil, varying from six to eight on lands of medium quality to considerably more on the newer lands. Virgin lands, from which the forests have been cut, produce the heaviest cane, although it is not usually as rich in sucrose as that produced on the old lands. In Cuba, a yield of from 35 to 50 tons of cane per acre can be obtained from virgin lands, and sometimes even more, whereas the average yield for the Island probably does not exceed 18 to 20 tons per acre. When the ratoon crops become so poor that a reasonable profit cannot be obtained from continuing their cultivation, the land is either devoted to other crops, temporarily or permanently, or immediately or subsequently replanted in cane, according to the soil constituents and other factors.

As cane lands become old and the yields decrease, the question of fertilizers and their comparative values forces itself upon the planter's attention. While many commercial fertilizers are on the market, Cuba, particularly the section comprising the Provinces of Oriente and Camaguey, has not as yet developed the practice of fertilization to any considerable extent. It is much behind other countries in this respect. Because of an abundance of available virgin lands, it has heretofore been the practice, especially in these two provinces, to make use of new lands rather than to replant, cultivate and fertilize exhausted areas. Since these woodlands are now scarce, cultivation and fertilization must become important factors if the present Cuban sugar production is to be maintained.

At the beginning and the close of the crop season, the sugar content of the cane is usually the lowest. It is always the endeavor to grind the cane during its period of maximum sugar content, although, where large cane areas are involved, it is sometimes necessary to begin grinding earlier, and continue later, than the sucrose content would seem to warrant. In the western and middle parts of the Island, the crop season generally starts the latter part of November or early in December and plantations in these sections finish their grinding—at the very latest—by the first of June, as the rainy season usually starts about the middle of May. In the eastern section of the Island, however, grinding usually begins the latter part of December or early in January



Transferring Cane from Carts to Cars - Stiff-Leg Hoist

and is continued until July—in the case of a few mills, until September or October. Weather conditions in Cuba, which vary considerably from year to year, as well as in different parts of the Island in a single year, affect the length of the grinding season.

Harvesting **W**HEN the cane is ready for harvesting, it is cut by hand at the base of the stalk, flush with the ground, a long knife or cleaver being used.* The leaves and the green top are then severed and the stalk is cut into lengths of from three to four feet and thrown into piles.†

* Cane is cut at the ground level for the reason that the lower portion of the stalk is rich in sucrose, and further, if the end of the stalk were left above ground, and there should be any "eyes" in it, they would be likely to sprout and impair the fertility of the stool.

† The top is removed at a point between the end of the solid cane and the beginning of the soft, growing portion. Inspection of any cane stalk will readily reveal, even to the uninitiated, where the solid cane ends.



Transferring Cane from Carts to Cars - Vila Hoist

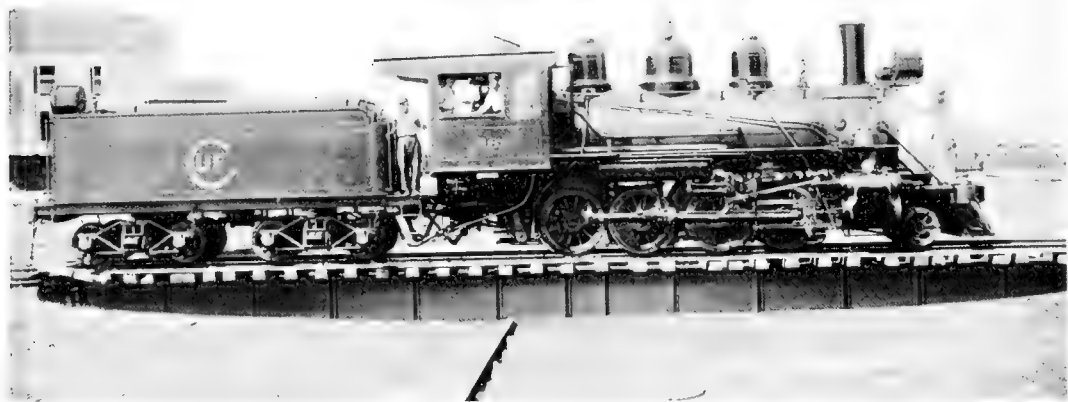


Herd of Steers Bred on Plantation

The leaves and the green tops are left in the field. They conserve the moisture in the ground, and form an excellent mulch that aids in preventing the growth of weeds and grass until such time as the new cane affords shade for the ground. This mulch, when it decays, has some value as fertilizer. The green tops also afford an excellent fodder for the cattle and constitute their principal food during the crop season.

It is essential to economical operation that there be proper supervision of the cane cutters to ensure proper cutting and loading of the cane and to prevent the loading of the top portion, trash and leaves. Otherwise, the factory pays for this trash—which has no sugar value—and carries the additional and superfluous burden of eliminating these impurities in the manufacturing process.

The operation of harvesting the cane, as well as its cultivation, is usually handled on a contract basis, the contractors having direct charge of the laborers, and their lodgings, food and wages. The mill settles directly with these contractors, but at all times exercises close supervision over their work and the treatment accorded their men. The mill actively assists the contractors in obtaining their supply of laborers, and erects the lodgings, called “barracones,” for the men. It is the general practice for the mills to supply some of the bulls and carts used in hauling the cane. In the case of the United Fruit Company, practically all of the carts and more than half of the live stock used for this purpose are furnished by the company.



Type of Plantation Locomotive—Baldwin

The standard of weight on which payment is made for cutting and loading the cane is the *arroba*, or 25 Spanish pounds. (A Spanish pound is equivalent to 1.0143 English pounds.) Laborers are paid by the contractor usually from 75 cents to \$1.00 per 100 arrobas for cutting and loading into carts. The cost of the haul to the railroad siding is figured on the basis of the distance, and ranges from 25 to 50 cents per 100 arrobas, for labor only; when the cartmen supply their own carts and the cattle that haul them, they are usually paid double rates.

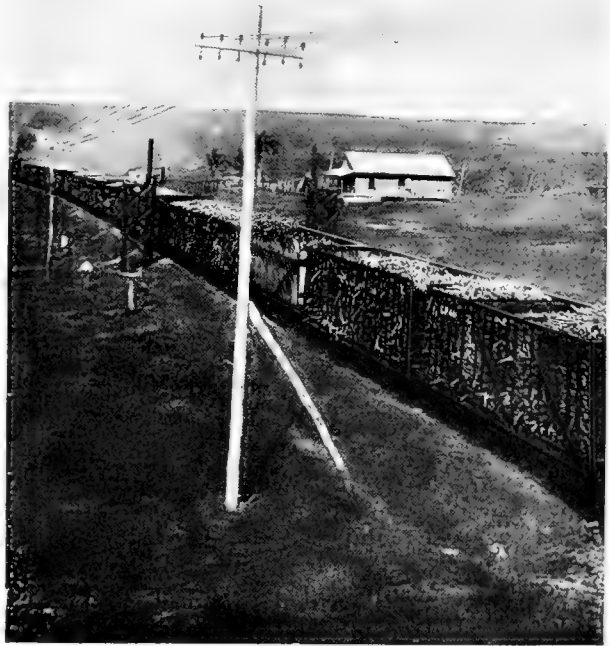
Cane-cutting involves the most serious labor problem that confronts the sugar planter in Cuba. In the first place, to operate the mill economically it is necessary to furnish it with sufficient cane to keep it running night and day throughout the crop season. In the second place, cane-cutting is a laborious hand process, and the supply of labor is inadequate for the Island's needs. It is to be noted that thus far no mechanical cane-cutting device has proved successful in Cuba.

*Transporting
the Cane* **T**HE methods used for delivering cane from the field to the factory are twofold: animal and mechanical. The piles of cut cane are loaded into two-wheeled bull carts and hauled to the nearest railroad siding. Here the cane is weighed and then transferred, generally by means of field cranes, sometimes by hand, to railroad cars of special design. The weighing of the cane in the

field is effected by means of either a platform or an overhead scale. When the former is used, the cart is weighed with its load of cane, the tare, or weight of the empty cart, being deducted. When an overhead scale is used, the cane alone is weighed. The contractor pays his men on the basis of weights thus obtained, while he in turn is paid on the basis of the weights determined at the mill.

On the United Fruit Company's plantations the clumsy high wheels of the cane carts have been replaced with caterpillar treads, which make it possible for fewer animals not only to haul greater loads of cane, but to haul them under all kinds of road and weather conditions. These caterpillar treads, moreover, improve the condition of the roads. On the Company's plantations, hauling experiments have recently been made with tractors, and it is not unlikely that within the next few years tractors will gradually replace bulls and oxen to a considerable extent in this phase of the work.

When each car is loaded, a tag is affixed giving the data required, such as the name of the farm, the contractor, the siding, the date when loaded and the car number. The farm overseer makes a daily estimate of the number of empty cars required for his district, together with the distribution by sidings, for the ensuing twenty-four hours. A proper distribution of "empties" is essential for purposes of maximum economy; it is particularly important when the mill is running to capacity that every available empty car be utilized in keeping the factory properly supplied with cane day and night. As the



Train of Loaded Cane Cars



Administration Building

railroad is efficient only when each car carries its capacity load of cane, it is one of the duties of the farm overseer to see that every car is loaded full. The cane is delivered to the mill in long trains, each car containing from ten to thirty tons of cane, according to the gauge of the railroad.

“Colono” Cane **I**T is the policy of most of the centrals in Cuba to purchase by contract a considerable portion of their cane from adjacent planters, called “colonos,” who grow the cane on their own or leased land, or on land belonging to the central.* This practice on the part of the centrals encourages the planting of cane by individuals within a convenient radius of the factory. As a rule, the centrals advance the necessary working capital to the colonos, and the settlements for cane delivered by them are applied against such loans. The usual form of contract stipulates that the colono must supply cane of proper age and condition, without tops or suckers and not fermented, and that he shall receive therefor a certain percentage or unit of sugar, based on the weight of his cane as determined by the factory scales, or its cash equivalent.

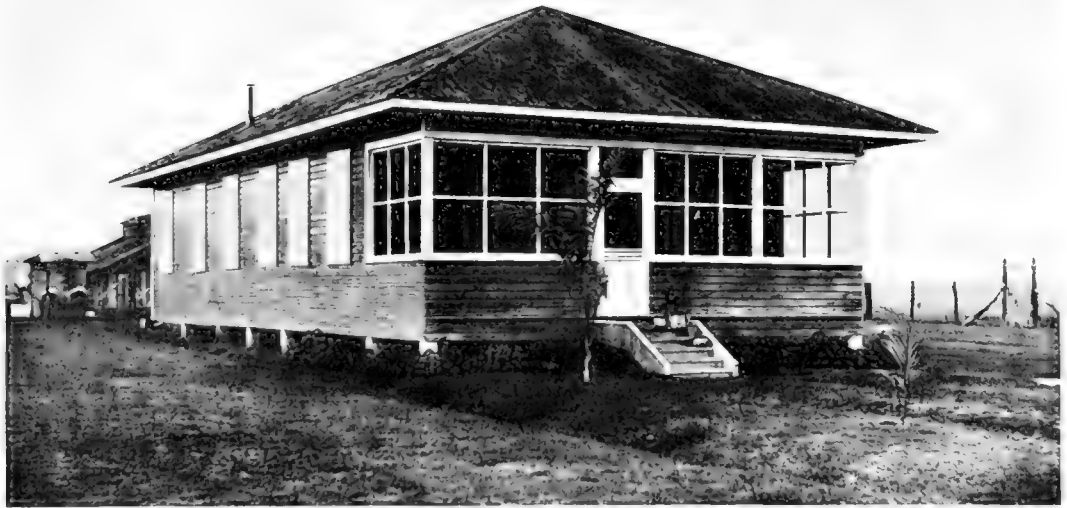
* The cane farms operated by these planters are called “colonias.”



Hospital

This sugar unit varies from 5 to 8 per cent, according to conditions and customs prevailing in different parts of the Island. For example, if a colono has a contract stipulating 5 per cent, he receives, for every 100 arrobas (2,500 pounds) of cane which he delivers, 5 arrobas (125 pounds) of 96° test raw sugar, or its equivalent in cash. The latter usually represents the average of the market prices of raw sugar, as reported officially from Havana, during the week or fortnight within which the cane is delivered by the colono to the mill. It is the general practice to liquidate the colono accounts in cash, but some of the Cuban-owned mills pay the colonos in actual sugar. It is interesting to note that while about 80 per cent of the cane produced in the Island is raised by colonos, the greater portion of the cane ground at the two mills of the United Fruit Company (Centrals Boston and Preston) is company-grown or "administration" cane.

Factors of Yield **T**HE tonnage yield of cane per acre is the figure closely followed by the agricultural management, while the raw-sugar yield per ton of cane ground is the controlling factor in the case of the sugar mill. Thus the basic figure, when available, for the sugar company's executives is the number of pounds



Farm Overseer's House

of raw sugar produced per acre of cane. This latter factor, however, is not employed extensively in Cuba, because of the "colono" system, and because the cane is usually delivered to the mill simultaneously from so many different points, that it is difficult, if not impracticable, to keep an accurate record of the commercial sugar yield per acre. This record, however, is available in Hawaii and is in general use there.



Latino's Barracks Erected by Company



Native Huts

PART II



*The Sugar Factory or “Central”
in Cuba*



Central Preston

PART II

The Sugar Factory or "Central" in Cuba

The final product of a central is raw sugar of a light brown color and of approximately 96 degrees polarization, or sugar 96 per cent pure. The term polarization, as employed in the sugar industry, indicates the method of determining the percentage of sucrose by means of an instrument known as the polariscope.

Usual Method of Manufacture **T**HE usual method of manufacturing raw sugar from cane may be considered under four general heads:

Extraction of the Juice

Clarification

Evaporation, and Formation of the Crystals

Separation of the Crystals from the Molasses

Chemical Control **I**N the manufacture of raw sugar there are some unavoidable losses of the original sucrose in the cane, principally in the "bagasse," or crushed cane; in the filter-press cake; and in the final molasses. To reduce these losses to a minimum, strict chemical control of the factory is essential. This involves keeping an exact account of the sucrose entering the factory in the form of crude material—cane; and of the sucrose leaving the central in the form of finished product—raw sugar, as well as of the losses of sucrose in the bagasse, the filter press cake and the final molasses. This work requires that all weights and measurements be accurately taken and that the material in process at the various stations throughout the factory be properly sampled and carefully analyzed. A compilation of the various data constitutes what is known as the daily and the weekly report.

Factors of Efficiency **C**ERTAIN basic factors are of vital interest to the management in the proper checking of plant operation. These are: first, the milling or grinding efficiency, indicated either by the percentage of juice extracted, based on



Central Boston

total juice in cane, or by the percentage of sucrose in the extracted juice, based on total sucrose in cane; second, boiling-house efficiency, indicated by the percentage of sucrose, in the form of raw sugar, recovered from sucrose in extracted juice; and third, general factory efficiency, determined by the percentage of sucrose in raw sugar produced, based on total sucrose in the cane entering the central.

The average results obtained by the modern centrals in Cuba show a grinding efficiency of from 91 to 95 per cent; a boiling-house efficiency of from 92 to 97 per cent; and a general factory efficiency of from 85 to 90 per cent.



Its Clubhouse, Church and Cottages for Mechanics

Delivery of the Cane **O**N arrival at the mill yard, or "batey," the cars of cut cane are weighed individually. The net weight of the cane in each car is ascertained by deducting the tare, i.e., the weight of the empty car. It is on this basis that the contractor and the "colono" are paid for company and private cane, respectively.

After being weighed, the cars are placed alongside a conveyor which feeds the factory with cane. Next, each car in turn is shunted to a dumping platform, or tipping table, where it is securely held by clamps. One side of the car is then opened, and the platform, together with the car, is tilted towards a dump pit into which the cane falls by gravity. The floor of this pit is the initial unit of the conveyor which gradually carries the cane upward to the grinding or milling plant, located on the ground floor of the factory, where the juice is extracted. The conveyor, or cane elevator, is driven independently of the milling plant, a method which tends to insure uniformity in the delivery of the cane. After the car is emptied, the tilting platform resumes its horizontal position and the empty car is removed. The handling of cars from the scales to the tipping table and from there to the mill yard is usually effected by means of an electric or steam winch.

Extraction of the Juice **T**HE milling plant in the smaller factories usually consists of one "tandem," comprising a "crusher" and three or more "mills." The larger plants are usually equipped with two or more tandems (paralleling each other), each comprising double crushers and three or more mills. In two or three of the most modern installations in Cuba, the tandem consists of triple crushers and five or six mills. Independent records are carefully kept of the work of each tandem.*

A "crusher" consists of two rolls, placed one above the other, with interlocking or corrugated teeth, or with deep grooves in their surface. A "mill" is composed of three rolls, as contrasted with the two cylinders of a crusher, one roll being on top and the other two on the lower level. Their surface is annularly grooved to facilitate the grinding action and to enable the rolls better to grip the cane mat. Both the crusher and mill rolls are high-grade cast-iron shells shrunk on heavy steel shafts and, in the larger plants, are usually seven feet in length and about three feet in diameter.

* The first cane mill was a tree stump, hollowed out to form a mortar. In this mortar, a log, acting as a pestle, was revolved by oxen. Then came stone mortars, then wooden rolls and then the hydraulically-operated metal rolls of the present day.



Switching Cane Cars at the Mill Yard

Each crusher and mill unit is heavily mounted on substantial bedplates and housings. The top roll of the crusher and of the mill units is controlled by a hydraulic ram which permits the roll to rise and fall or "float" with the variations in the feed of the cane. Practice varies as to the hydraulic pressure applied to these top rolls. In the more modern plants, this pressure approximates about 250 tons on the crushers and ranges from about 350 tons on the first mill to about 500 tons on the last mill unit. The tandem is driven by steam or electricity, through a train of double reduction gears, the shafts being directly connected to the top roll of each mill unit. The gears are so arranged that the speed of the rolls is gradually increased from the first to the last mill unit.*

Upon entering the factory, the cane falls evenly from the head of the conveyor by gravity chute to the first crusher, and then passes by gravity to the second crusher below. This preliminary grinding breaks down the hard structure of the cane, which is prepared for milling by being crushed, torn and

* Central Boston milling plant comprises the following: two tandems, each consisting of two sets of crushers and five sets of mills; also two tandems, each consisting of four sets of mills, the first set being grooved and functioning as crushers.

Central Preston milling plant has two tandems, each consisting of two sets of crushers and five sets of mills; also one tandem with two sets of crushers and three sets of mills.



Unloading "Side-Dump" Cane Car

matted. The larger percentage of the juice is extracted in this initial operation.

The mat of crushed cane is then carried by an apron or slat conveyor, called an "intermediate conveyor," to the first and succeeding mill units. A heavy curved metal plate, supported by a proportionately heavy bar, and placed between the two bottom rolls of each unit, guides the cane, which first passes between the top roll and the front bottom roll, called the "cane roll," and then travels between the top roll and the back bottom roll, called the "bagasse" or "discharge" roll.

The blanket of cane in like manner passes through all the mills, the rolls of each succeeding unit being set closer together than those of the preceding. The function of the mills is to grind the cane more thoroughly than the crushers and to extract as much additional juice as possible.

After passing through the last set of mills, the blanket or mass of crushed cane (bagasse) is mechanically conveyed to the furnaces, into which it falls by gravity, and is burned as fuel to generate steam. Any temporary excess of bagasse is mechanically diverted to storage, and is reclaimed by the same conveyor system and returned to the furnaces as required. Since the fuel value of bagasse is inversely proportionate to its moisture content, it is important to obtain as dry bagasse as possible. In a modern plant the bagasse from the



Cane Being Conveyed to the Crushers and the First "Mill"

last mill will usually contain from 2 to 5 per cent of sucrose, and from 47 to 55 per cent of moisture. As a rule, after the crop is well under way, little fuel other than bagasse is necessary, except where maceration (described below) is practiced extensively. Crude oil or wood is used for auxiliary fuel.

The raw juice, which is turbid and yellowish or greyish-green as expressed from the mills, falls into juice pans directly below the tandem; thence over strainer plates or screens, which remove the foreign matter and the fragments or particles of cane fibre, to the gutters or troughs; whence it flows by gravity to the juice wells. The strained juice is then weighed or measured and pumped to the clarification department, ordinarily situated at the top of the house.

To obtain the maximum extraction of sucrose, water (some factories using hot and others cold) is applied to the cane mass while it is passing through the tandem, usually in front of all the mills except the first set. This practice, called "maceration" (also "imbibition" or "saturation"), assists in washing out part of the remaining sucrose from the cells of the cane. The water used for this purpose varies from 10 to 25 per cent or more, figured on the basis of weight of cane. The extraction of sucrose is affected by the quantity of maceration water used, which, in turn, may be limited either by the insufficient capacity of the evaporating plant to handle it or by the lack

of water itself. To avoid the introduction of too much water into the juice, and the consequent necessity of evaporating it, in modern practice much of this washing is done with diluted juice. The water is then usually applied in front of the last two sets of mills, and the diluted juices from these mills are sprayed on the cane in front of the forward mills.

The grinding capacity depends more or less upon the setting and the grooving of the rolls, and the speed at which they are run, which averages about three revolutions a minute. This slow grinding is necessary to secure a proper extraction of the juice. By increasing the clearance between the rolls, a mill can be forced to grind considerably more cane than its rated maximum capacity, but such practice will cause a serious reduction in the amount of sucrose extracted.

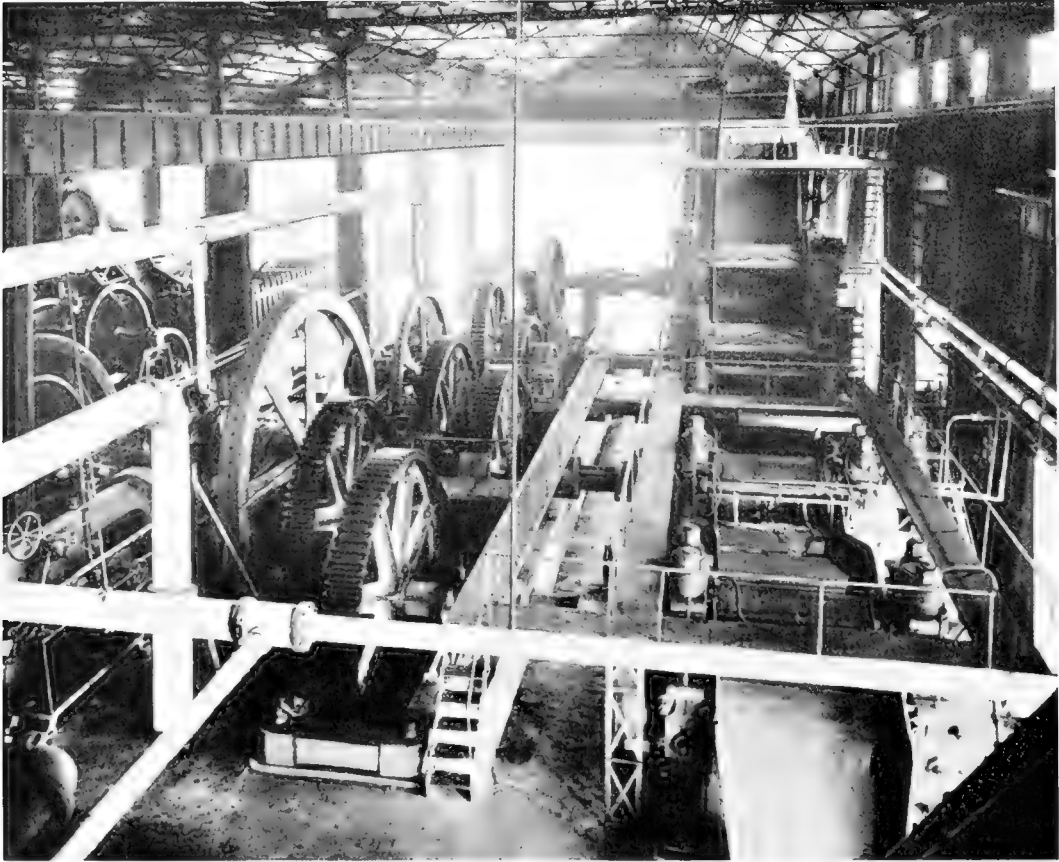
A single tandem in an average factory grinds about 2,000 tons of cane per day of 24 hours, while in a few of the most modern plants in Cuba the rate is from 3,000 to 3,500 tons. In one or two instances, a single tandem on a spurt lasting eight or ten hours has sustained a grinding rate of from 4,000 to 4,200 tons per day, the rate



Cane Mat in Foreground Leaving Second Crusher

dropping back because of the inability of the railway switches in the mill yard to handle the necessarily large number of cane cars for a longer period of time. These enormous cane capacities are only possible with the so-called "super-tandems," equipped with eighteen rolls and double or triple crushers.

It is essential to economical operation that there be a proper balance, not



Tandem with Double Crushers and Three "Mills"

only between the cane supply of a factory and its grinding capacity, but between all departments throughout the plant itself. When the grinding efficiency is developed to the maximum, not only is additional sucrose extracted from the cane, but also additional impurities are obtained, and it is highly important that the clarification equipment be made adequate to handle properly the burden of these increased impurities.

Clarification **S**UGAR cane contains from 8 to 16 per cent of fibre; the remainder of its weight is juice. This juice, although composed chiefly of water, contains from 12 to 18 per cent of sucrose and from 1 to 2 per cent of impurities. The latter are principally gums, pectins, glucose, nitrogenous bodies, inorganic salts and fine particles of bagasse, commonly termed "bagacillo," which go through the juice screens. These impurities are partially removed from the raw extracted

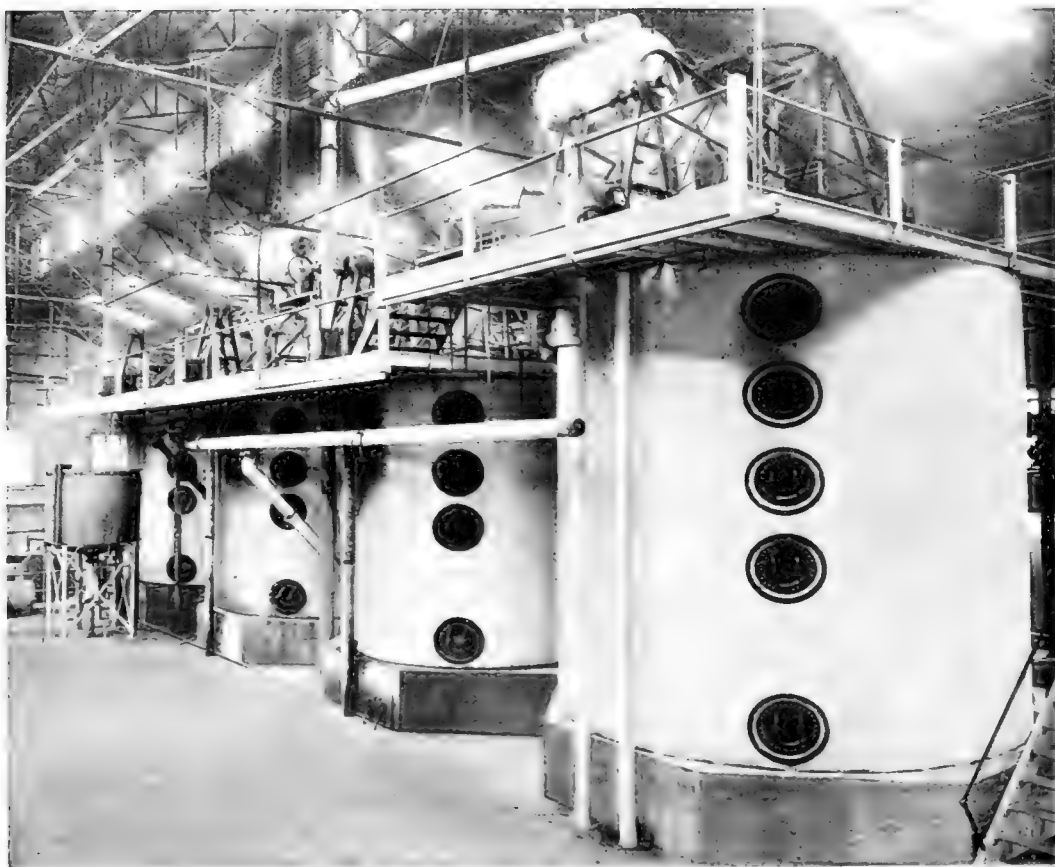
juice by clarification, and in part are accumulated in the final molasses. A good clarification of the juice is very important to remove the impurities which prevent the crystallization of the sugar, and which make difficult its separation from the molasses. Several methods are in vogue, the defecation process being generally used. In all of these processes, however, the crude juice is treated with lime, which neutralizes the acids and causes a partial precipitation of the impurities.*

In the defecation process the limed juice is pumped into heaters where exhaust steam is used to raise the temperature of the juice to about 200° F., or a little below the boiling point. From these heaters the juice is discharged into large open tanks, called "defecators," where live steam is applied to raise the juice temperature to the boiling point. The combined action of lime and heat results in a coagulation of the impurities, the mineral or heavy compounds settling to the bottom of the tank, carrying down also some organic or lighter impurities which envelop the mineral particles. The greater part of the organic impurities, however, is rendered insoluble and rises to the surface, carrying along the bagacillo, and forms a blanket of scum resting on top of the body of the juice.

The clear, amber-colored juice is now confined between the two layers of impurities and is drawn off until the two layers meet. The entire mass of impurities then is washed with water into the scum tanks below, where it is heated and allowed to re-settle. The available clear juice is then drawn off and is sent to the evaporators. The mud remaining is diluted and, while hot, is put through a filter press, consisting of a series of flat cast-iron plates with strong cotton filter cloths placed between the plates and hollow frames. After the plates have been screwed tightly together, the mud is subjected by pumping to a pressure of from 40 to 50 pounds per square inch, and the filtered juice is combined with the rest of the clear juices in process. A certain amount of hot water is forced through the presses and carries off a portion of the sucrose remaining in the scum. This mud, called filter-press cake or "cachaza," remaining in the presses and containing from 50 to 60 per cent of moisture, is dumped into cars and sent to the cane fields for use as fertilizer.

Some of the larger and more modern factories in Cuba, including

* Every effort is made to deliver the cut cane promptly to the mill to avoid the extraction of any fermented juice. According to the best practice, cane is usually delivered to the central not later than two days after it is cut, or before the juice undergoes any perceptible chemical change. When extracted, the juice quickly ferments unless the chemical action is promptly arrested; the crude juice is therefore limed with the least possible delay.



Four-Unit Dorr Clarifiers

Central Boston and Central Preston, have recently installed Dorr Clarifiers to replace the defecators and settling tanks. These clarifiers, large cylindrical tanks, each divided into four compartments, continuously remove the impurities from the strained raw juice, which has been previously limed and heated.

The scums from the juice rise to the surface and are automatically skimmed off and discharged. The mud settles in each compartment and, by means of mechanically operated arms, is moved to a central opening through which it drops to the bottom compartment. The mud is now of the consistency of porridge and is removed by an especially designed type of pump, which delivers it in a uniform, continuous flow to the filter presses.

From each of the four compartments the clear juice flows by gravity to a common overflow box, the discharge from each compartment being regulated by sleeves which permit the overflow level to be raised or lowered. This clear juice is sent to the evaporating department.

At Central Preston, in conjunction with the Dorr Clarifiers, the Petree Process has also been installed.* The principal object of this process is the elimination of the filter-press station with its attendant sucrose losses and high cost of operation and upkeep. Under this process the rich juice from the crushers and the first mill is independently and separately clarified from the thinner juice resulting from the subsequent milling of the macerated cane. This practice constitutes what is termed "primary clarification" and "secondary clarification."

The juices are limed at the mills by means of a new type of liming apparatus. This is operated from one of the mill rolls and thoroughly mixes the milk of lime with the juices at an early point, whereby considerable inversion and fermentation are thus avoided.

In the operation of the Petree Process, the rich juice from the crushers and the first mill is mixed with the juice from the secondary clarifier. This mixture is heated and delivered to the primary clarifier, the clear overflow of which goes to the evaporators.

The mud from the primary clarifier is mixed with the juice coming from the second and the third mills. This mixture is heated and delivered to the secondary clarifier, which separates it into "secondary" clear juice and "secondary" mud. The former, as shown in the preceding paragraph, is mixed with the rich "primary" juice and thus undergoes a further clarification.

The "secondary" mud is mixed with the juice from the fourth and the fifth mills. This mixture is evenly distributed in a thin stream over the whole width of the bagasse coming from the first and the second mills. It is of interest to note that the bagasse acts as a filtering medium, the solid particles of the mud being enmeshed with the crushed fibres of the cane. This entrapped mud is carried to the furnaces as a part of the bagasse, and constitutes a certain addition to the fuel. The ashes, which are remarkably free from clinkers, are collected and used in the fields as fertilizer.

The mud returned to the mills cannot get into the clear juice going to the evaporators, because any sediment passing through the bagasse goes only to the secondary clarifier, whence it is returned to the mills. With continuous settling and withdrawal of mud from the clarifiers, there is a steady flow to the mills; on an average, to each 100 tons of cane passing through the mills, there are returned 5 tons of mud.

* The Petree Process is still in the experimental stage and has been installed at Central Preston on trial.



Two Sugar Ships at Preston Wharf

*Evaporation, and
Formation of the
Crystals*

THE clear thin juice obtained by clarification must now be reduced to the consistency of a syrup and it is sent, by either gravity or pumping, to the supply tanks of the evaporators.

The evaporator is a series of large closed vessels called "effects," in which the clarified juice, under a partial vacuum, is concentrated and its water content reduced from about 85 to about 40 per cent. Four vessels are usually employed, the apparatus then being called a "quadruple effect." The sugar manufacturer, making use of the principle that liquids boil in a vacuum at a lower temperature than in an open vessel subject to normal atmospheric pressure, reduces the atmospheric pressure in each effect to a point below that of the preceding one, in order to secure the maximum of economy in operation. The first vessel is therefore heated by means of steam, the second by the vapors evaporated from the juice in the first vessel, the third by the vapors from the second effect, and so on to the last effect.

From the evaporators the thickened juice, called syrup or "meladura," now dark brown in color, is pumped to storage tanks on the pan floor to be boiled in the vacuum pans as required. These "pans" are closed vessels heated by steam and are somewhat similar in construction to the evaporator

effect. A portion of the syrup is admitted to the pan where the final boiling down takes place. This is accomplished under a vacuum of from 25 to 27 inches, maintained by means of a steam or motor-driven vacuum pump and a large barometric condenser. When the syrup boils down to a certain density, generally 88 degrees Brix, the grains or crystals of sugar begin to form.*

The principle of sugar crystallization is embodied in the fact that water can hold only a given amount of sucrose in solution. As the water is driven out of the cane juice, the latter finally reaches a stage where there is not enough water left to hold all the sugar dissolved. As evaporation proceeds, therefore, the sugar, deprived of its water, is compelled to pass out of solution into crystal form.

The number and size of the crystals, and their proper growth as the syrup further evaporates, constitute a problem of skillful manipulation of the vacuum and involve the rate at which additional syrup or "first molasses" or "second molasses" is drawn into the pan. This important work is under the control of well-trained men called "sugar boilers." The resultant product of the vacuum pan is a heavy mass of crystals, dark brown in color, termed "massecuite."† It is not possible to boil all of the syrup and molasses down to a crystal and at the same time separate the pure sucrose from the impurities; therefore, enough moisture must be left in the massecuite to permit separation of the crystals in the drying process. The impurities remain in the mother liquor and are carried off as molasses.

In the process of manufacture the chief aim is to extract the greatest possible amount of sugar from the syrup. For this purpose various methods of boiling have been evolved, but the "three-massecuite" system, described on the following page, is the one most widely used.‡ This involves the manufacture

* The sugar industry uses floating spindles, called hydrometers, to indicate the amount of solids contained in a sugar solution. The scales enclosed in the stems of these instruments are graduated according to either the Brix or the Baumé system.

Brix hydrometer, floated in a pure sugar solution, will indicate directly the percentage of sugar by weight. Any other substance present will increase the reading, so in an impure solution the Brix gives an approximation of the total solids. By dividing the percentage of pure sugar, as found by the polariscope, by the Brix reading, the purity of the material may be found. For this work, the Brix scale is used in the laboratory.

The Baumé scale, originally made to read percentages in a salt solution, has been revised so that now its reading is purely arbitrary. Its graduations are farther apart than a Brix scale of the same range, and therefore easier to read. This explains its continued use in the factory.

† A complete operation, or cycle, of the vacuum pan is called a "strike" in both a central and a refinery, but in the latter it is also sometimes known as a "skip."

‡ First, second and third massecuite are called A, B and C massecuite, respectively.

of "first," "second" and "third" sugar. The first and second sugars are mixed and sold as raw sugar of "96° test," while the third sugar is returned into the factory process.

To make first sugar, the syrup or "meladura" is drawn into the vacuum pan continuously from the time the grain is formed until the pan is full of massecuite, some first molasses being usually drawn into the pan towards the end of the operation. When the pan has become filled with massecuite (called "first massecuite"), the contents are discharged first into a mixer and then into the centrifugal machines, where the crystals are separated from the molasses, as described on the following page. The sugar thus obtained is called "first sugar" and the molasses, which is thrown off, is "first molasses." The molasses is pumped to storage tanks above the pan floor where it is heated, and diluted with water to a density of about 30 degrees Baumé, equivalent to 54.3 degrees Brix, to be used in making second sugar.

In the making of second sugar, the pan is filled to about two-thirds capacity with grain formed as previously described; then half of its contents is drawn over into an adjacent empty pan. First molasses is then drawn into both of these pans and boiled down. As the concentration proceeds, the sucrose crystallizes out of the molasses on to the previously formed grain. The crystals in this "second massecuite" are then separated from the molasses in the centrifugal machines in the same manner as for first sugar. This second sugar, having an average polarization of a trifle less than 96°, is mixed with first sugar as previously described. The second molasses is diluted and heated in the same way as the first molasses.

Third sugar is made in the same manner except that second molasses is drawn into the pan instead of first molasses. After the required boiling in the pan, the massecuite is discharged into crystallizers. These are large cylindrical tanks provided with stirring mechanism, each crystallizer usually having a capacity equal to that of a vacuum pan. The massecuite is slowly but constantly stirred in these crystallizers for a period of from three to five days and during this time the grain continues to grow until the massecuite is cooled to atmospheric temperature. When this process, which may be considered as a continuation of the vacuum pan work, is completed, the massecuite is discharged into the centrifugals and treated in the same manner as the first massecuite. The resulting crystals are then mixed with meladura or first molasses and are used as "seed" grain in the pans in making first sugar.

*Separation of the
Crystals from the
Molasses*

WHEN the first or second massecuite has been boiled to a proper density the entire contents of the vacuum pan are dropped into a V-shaped mixer equipped with paddles which revolve and keep the massecuite from hardening. From here it is drawn into the centrifugal machines as required. Each of these machines has a strong perforated bronze basket, about 40 inches in diameter and 24 inches in depth, lined with a very fine screen. After having been filled with massecuite, the basket is made to rotate at a very high speed (about 1,000 revolutions per minute). This centrifugal motion separates the crystals from the molasses and forces the latter through the screen. The process is termed "drying of the crystals" or "purging." After a few minutes' operation, the machine is stopped and the almost dry sugar, now of a light brown color and packed against the walls of the basket, is discharged through a plate valve on the bottom of the centrifugal.

*Bagging and
Storing*

THE sugar is then carried by a screw conveyor to a mechanical elevator where it is deposited in a large storage hopper overhead. From here it is fed by gravity to automatic weighing and bag-filling scales, which also record the number of bags filled. As a rule, raw sugar is bagged without any drying other than that received in the centrifugals. It is packed usually 325 pounds to the bag in jute bags imported from India. An empty bag ordinarily measures 29 by 48 inches and weighs about 2.5 pounds.*

During crop time, work in the sugar house goes on day and night, generally in six-hour shifts. A great portion of this work, as well as the stevedoring of the sugar, is done on a contract basis.

The storage of raw sugar without loss in polarization has been, and still is, a subject of much study. To possess good keeping qualities, raw sugar should be well made in a clean factory, should polarize not less than 96 degrees and should have a moisture content not in excess of 1 per cent. The crystals should be of good size and should have received little or no washing in the centrifugals. The modern central is provided with a suitable warehouse of adequate capacity where the bagged sugars are automatically handled and properly stored until shipped. According to the best practice in Cuba, the bagged sugar is not piled more than eighteen tiers.

* Until about forty years ago, it was the general practice in Cuba to export raw sugar in hogsheads.

Marketing **R**.III sugars are generally sold through the medium of a broker. His usual commission is $\frac{1}{4}$ of 1 per cent when he only passes a contract and does not attend to rendering account sales or making collections from the refiner. When the latter work is undertaken, the customary brokerage charge is not less than $\frac{1}{2}$ of 1 per cent.

In the old days the planter in Cuba, having little cash and meagre storage facilities, was compelled to ship his product as fast as it was made, sometimes unsold; consequently, being at the mercy of the buyer, he was forced to accept what price he could secure; he was not able to hold his sugar for a possibly higher market. Today, most of the planters in Cuba are in a stronger financial position and, as a rule, have ample storage facilities. As a result, Cuban sugars are rarely shipped unsold, and when marketed, the price is more in line with the world's quotations.

“Blackstrap” or Final Molasses **T**HE molasses obtained from the centrifugal machines in the drying of the third sugar is called “blackstrap” or final molasses and is stored in large tanks within pumping distance of the factory. It is usually sold to distilleries for the manufacture of alcohol or to manufacturers of cattle feed. In exceptional cases it is spread on the fields as fertilizers, or mixed with bagasse and burned in the boiler furnaces.

As stated in the Introductory Note, the United Fruit Company has erected, adjacent to Central Preston, a distilling plant for converting the blackstrap output of that sugar factory into alcohol-ether to be used for motor fuel instead of gasoline.

PART III



The Refinery in the United States



Recvere Sugar Refinery

PART III

The Refinery in the United States

The refining of raw cane sugar is carried on in a refinery—a plant distinct and separate from a central where the raw sugar is extracted from the cane. The refinery first purifies the raw sugar, which is unsuitable for direct consumption, and then transforms it into the different grades demanded by the individual tastes and requirements of the consumers.

Basis of Purchase **R***AW* sugar is purchased on the basis of 96° test, which is the commercial standard. A certain allowance per pound for each degree above, and a certain deduction per pound for each degree below, 96° is made.* It is bought on terms of cost and freight; cost, insurance and freight; and f.o.b. the shipping port. In the latter case the seller delivers the raw sugar on the wharf within reach of the steamship's tackle without further expense to him beyond this point.

Of the remaining 4 per cent in raw sugars of 96° test, about 1 per cent is water and represents an immediate loss to the refiner, and the other 3 per cent is composed of various impurities. Some of these impurities are insoluble and comparatively easy to remove by simple filtration, while the elimination of others is most difficult and involves processes requiring the consumption of about 20 pounds of coal and 500 gallons of water for every 100 pounds of "raws" refined. In refined sugar each crystal is of identical composition and analyzes practically 100 per cent pure.

The refiner secures approximately 93 pounds of refined sugar from 100 pounds of 96° raws, the yield of refined sugar being less when the raws are below this test. Thus the higher the purchase price of raws, the greater the refiner's financial loss by reason of this shrinkage.

Import Duty **T***HE* present United States Tariff Act, enacted September, 1922, prescribes an import rate of 2.206 cents per pound on full-duty raw sugars of 96° test, with an addition or deduction of .046¢ per pound, for each degree over or under this test. Under the existing Reciprocity Treaty between the United States and Cuba, raw sugars from the latter country enter the United States

* See table on page 69.



Sampling Raw Sugar at Refinery

ufactured into a finished product and exported, the Government refunds approximately 99 per cent of the duty paid on the imported raw mate-

rial. This refund is known as drawback. For example, on refined sugars manufactured from duty-paid "raws" and exported, the drawback of approximately 99 per cent is applied. Further, the drawback is also applied on refined sugar used in the manufacture of candy, canned goods and other finished products where such refined sugar is made from raw sugar on which duty has been paid. Refined sugar is generally quoted for export at a lower price than for domestic use, the difference between the domestic and export price being approximately the amount of the drawback.



Unloading Raw Sugar at Refinery

at a preferential rate of 20 per cent less than the full duty, an arrangement which results in the present import duty of 1.7648¢ per pound for Cuban sugar of 96° test.

When a raw material is imported into the United States, man-

Discharging the Sugar Cargo **W**HILE the sugar cargo is being discharged the Government, the buyer and the seller are all represented on the dock. A representative for each takes a sample from every bag as soon as landed on the wharf, the buyer and the

seller alternating. The Government representative places his samples in separate tins and sends them to the Appraisers' Stores Laboratory for testing. The buyer and the seller jointly use other tins, large enough to hold samples from approximately 150 bags. The contents of these tins are mixed twice daily and three samples are taken therefrom and distributed to the buyer's chemist, the seller's chemist and to the New York Sugar Trade Laboratory, respectively; the average of the closest tests is the final purity basis on which settlement is made between the buyer and the seller.

The sugar is weighed first by the Government representative on electric automatic platform scales, and immediately thereafter, at the expense of the seller, by the merchants' or private weigher who, as a rule, uses either platform or beam scales. The weights obtained by the latter determine the quantity of sugar purchased by the refiner.

To secure the tare, or weight of the empty bag, the Government schedule of 2.5 pounds per bag may be accepted, or the importer may call for special tare when bags vary or when he is unwilling to accept the Government schedule. In the latter case, the Government weigher tares about 1 or 2 per cent of the empty bags and applies the average tare per bag, thus secured, to the entire cargo. The same practice is followed also by the merchants' or private weigher, who tares about 5 per cent of the cargo. This tare usually averages about 2.5 pounds per bag and is deducted from the gross weight. Thus is obtained the net weight of the sugar, which is the basis of settlement.



Weighing Raw Sugar on U. S. Government Scales

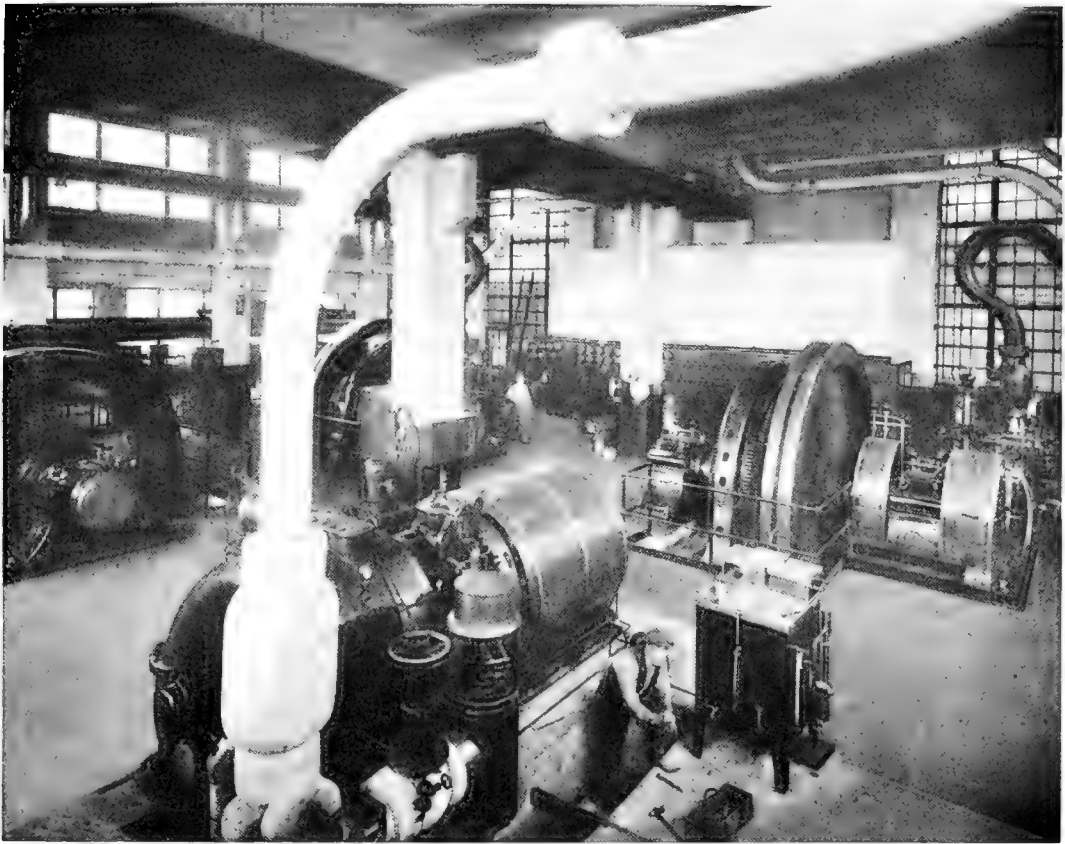


Raw Sugar in the Warehouse

The seller is given credit for the total weight of all samples drawn, except the Government samples, which are delivered to the buyer minus the comparatively small quantity actually used in the tests. In a 24,000-bag cargo, the Government will draw about 2,000 pounds of samples and the buyer and the seller together a like quantity. In all the tests made in a cargo of this size, about 100 pounds of samples will be actually consumed, this small quantity representing a loss to the buyer, as he pays for but does not receive this sugar.

The Government weighs and samples the sugar cargo independently of the buyer and the seller in order to determine the amount of import duty to be collected thereon. As the Revere Sugar Refinery secures its raws from the United Fruit Company, of which it is a subsidiary, it dispenses with this duplication of sampling and weighing and makes use of the Government figures.

In the discharge of the cargo the loose sugar, whether in the hold of the ship or on the dock, is carefully collected and is weighed both by the Government and the licensed weigher and is tested by the former. It is the usual custom for the buyer to accept and pay for all loose sugar or "sweepings" as clean sugar at approximately $\frac{7}{8}$ of the full weight, or a little less, according



Power Plant

to its condition. In other words, if a cargo outturns 30,000 pounds of loose sugar, the buyer accepts and pays for about 26,250 pounds, a loss of 3,750 pounds to the seller for dirt. It is therefore to the advantage of the seller to deliver sound cargoes, outturning a minimum of loose sugar. Raw sugar is usually discharged at the rate of about 1,200 bags per hour. Part of the cargo is stored in the refinery warehouse and the remainder sent to the melt house.

Usual Method of Refining **W**HILE the principles of sugar refining are comparatively simple, the actual operation is decidedly complex. As the processes are continuous, the work goes on day and night, usually in eight-hour shifts. Each step has to be controlled continually and carefully by means of tests made by the chemical laboratory, which also carries on a considerable amount of research work. All refinery calculations are conducted on the standard basis of 100 pounds of raw sugar.



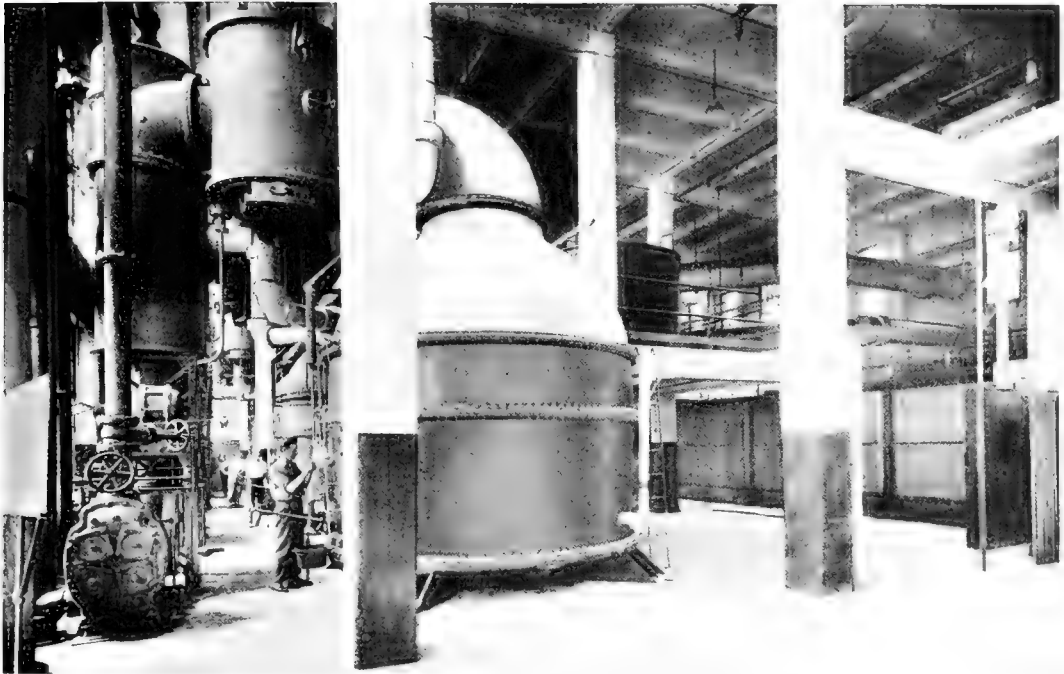
The Laboratory

The usual method of refining raw cane-sugar may be considered under the following heads:*

MELT HOUSE	{	Dumping
		Mingling
		Purging and Washing
		Melting
FILTER HOUSE	{	Clarification
		Bone Charcoal (Boneblack) Filtration
		Crystallization
PAN HOUSE	{	Separation of Crystals from Syrup
		Drying
FINISHING HOUSE	{	Screening
		Packing for Shipment

Melt House **A**T the refinery dump the bags are sampled and weighed, then cut open and emptied and the raw sugar is carried by conveyors to the storage bins at the top of the house. From here it is fed continuously into the minglers.

* See diagram of refining process (condensed flow-sheet) on page 70.



Vacuum Pans—Where the Sugar Crystals are Formed



"Purging" the Sugar in the Centrifugals



The Finished Product—Packed in Barrels and Bags

immediately below, which are simply scroll conveyors equipped with mixing flights. There the raw sugar is mixed with wash syrup to soften the film of molasses adhering to the sur-

face of the crystals. It is next sent to the centrifugal machines, of the type used in raw-sugar manufacture, where the molasses coating is separated from the crystals. These crystals are then washed with a measured quantity of cold water while the machines are rotating.

As refining consists in separating the pure sugar from its impurities, the removal of this molasses film, containing most of the impurities of raw sugar, may be considered as the first important step in refining operations. The products of this process of separation are two: first, a washed sugar of greatly improved color and purity; second, a wash syrup of comparatively low purity, which can be handled better separately.

The washed sugar is dissolved in about one-half its weight of hot water

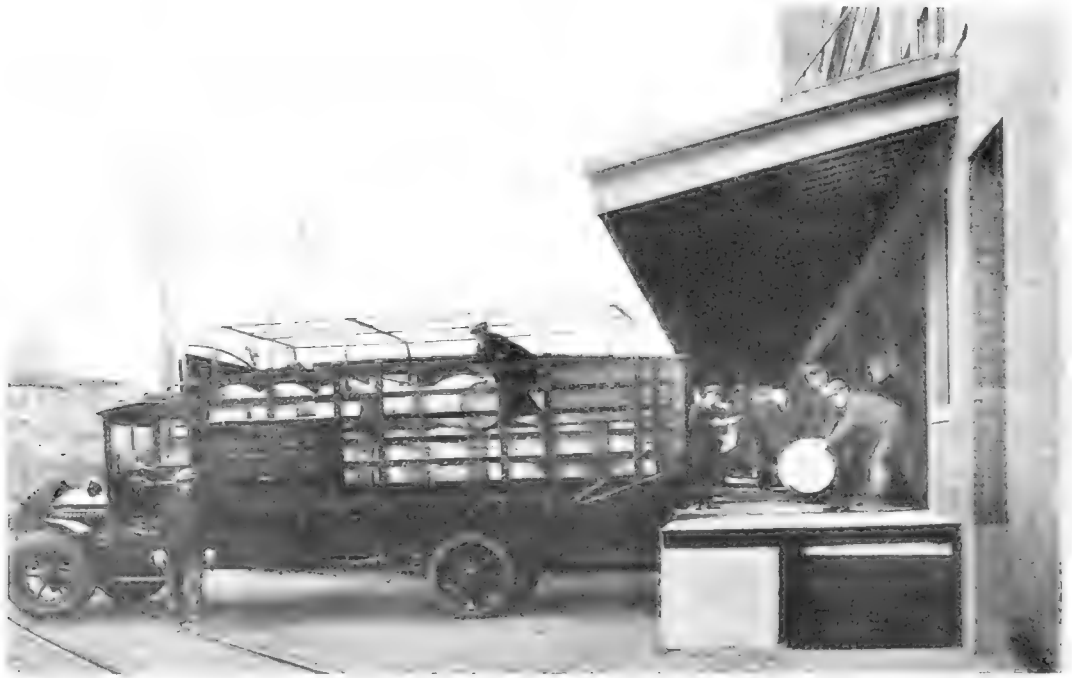


The Finished Product—Packed in Cartons

in tanks called “melting pans,” equipped with mechanical stirrers. The resultant solution, dark brown and cloudy, is pumped to the filter house for further purification. Some of the wash syrup is used for mixing with the raw sugar in the minglers—as previously explained—and the excess is sent to the filter house, where it undergoes much the same process as the sugar liquor.

Filter House **T**HE washed sugar liquor is pumped to the “blow-ups” where its temperature and density are adjusted, and some suitable porous filtering medium, as, for example, phosphoric acid and lime, infusorial earth or macerated paper pulp, is added to make the liquor more adaptable to filtration. These blow-ups are iron tanks fitted with steam coils for heating the liquor, and are equipped with conical bottoms to facilitate drainage. The sugar solution is next pumped through mechanical filters where the suspended impurities are removed. The filtered liquor, now of a clear brown color, is passed through char filters (large cylindrical tanks) filled with boneblack (animal charcoal, or bone char). These char filters remove the coloring matter and some of the soluble impurities, the process giving a sugar liquor as clear and colorless as the purest spring water.

The clear sugar liquor is followed on the boneblack by syrups from



Loading Truck with Sugar

which some granulated sugar has been boiled, and these in turn by other material of still lower grade, such as mechanically filtered wash syrup. From all these the boneblack removes color and impurities, in decreasing amounts as its absorbing power becomes exhausted.

The exhausted boneblack must next be "washed off," so boiling water is admitted to the filter. This displaces the sugar liquor and when the out-flow of the filter becomes dilute, the sweet water is diverted to the "sweet water" tanks. This sweet water is mixed with other similar solutions and is concentrated in evaporators, of a type similar to that used in a "central," and re-enters the blow-ups to begin the process over again.* When the sweet water from the char filters becomes so low in purity as to be worthless for further sugar recovery, it is run to waste. The washing of the bone char is continued several hours more to remove the impurities it has absorbed. Some of these, however, are so strongly held by the boneblack that water will not remove them and heat must be resorted to; accordingly, the boneblack is discharged from the filter, partially dried, then heated in special kilns.

* The evaporators in a raw sugar factory play a very important part in the process of manufacture, as all of the clarified cane juice goes through them for concentration. In a refinery, however, they do not have the same relative importance, being used only for concentrating the "sweet water."



Battery of Trucks Loaded with Sugar

These kilns are so constructed that the char passes through in a continuous stream, but air is excluded since an unregulated air current at this stage would be fatal to the life of the boneblack. This treatment, to a considerable extent, restores the purifying properties of the char and it is used and re-used until those properties are entirely exhausted.

Pan House **A**FTER char filtration has been effected, the sugar solution, or liquor, is pumped to the pan house. Here it is drawn into vacuum pans and concentrated at a low temperature under approximately twenty-six inches of vacuum until it has formed a magma, a mass of crystals mixed with a small quantity of syrup, resembling in character the massecuite of the raw-sugar factory. This crystallization is a very important stage of refining, as the temperature at which the sugar is boiled and the method of forming the grain determine the character of the finished product. The men who do this work, known as "sugar boilers," are of long experience and training.

The magma is purged in the centrifugals, the crystals being separated from the syrup and slightly washed with a mechanically controlled spray of purified water. The sugar is then automatically discharged from the machines



Cooperage Plant Exterior

and is passed through long revolving drums, called "granulators," and thoroughly dried in a current of hot air. The light colored syrups from the centrifugals are re-boiled with liquor to produce more granulated sugar. The darker syrups are either re-boiled to remove the remaining sugar, which is then re-melted and re-enters the process, or they are re-filtered through bone-black and boiled for a soft or brown sugar, which is sold as such. The final exhausted residue from the centrifugals constitutes refinery syrup. The latter is produced either as filtered syrup or as blackstrap, according to the demands of the trade.

Finishing House **T**HE dried granulated sugar is screened into various sizes and is packed in barrels, bags or cartons.

The work of packing is done almost entirely by machinery, the sugar flowing from overhead bins into the various containers. The barrels are first lined with paper by hand and are automatically shaken while the sugar flows into them. This shaking aids in filling them to capacity.



Cooperage Plant—Interior

Each barrel of sugar is headed and weighed separately and the weight is marked thereon. It is then sent by a conveyor to the shipping room or the warehouse. A single machine automatically fills a bag with the required amount of sugar, sews the mouth and discharges the full bag into a chute leading to the shipping room.

The carton-packing machine automatically fills, weighs and seals the two and five-pound packages of granulated sugar, operating at the rate of thirty per minute for the former and twenty-six for the latter. For powdered sugar, which is generally packed in one-pound cartons, the machine performs the additional work of inserting a lining of wax paper before the sugar is admitted into the cartons. Cubes and tablets are made by a process of pressing moist granulated sugar into molds and then drying them in ovens.

Cooperage **I**T is evident that a refinery, requiring containers in such quantities for its products, cannot risk dependence upon the usual sources of supply in the open market. Consequently, a well-equipped cooperage plant is operated as an

adjunct to the modern refinery, producing all the barrels and wooden cases necessary for the packing of its sugars. Elm, gumwood and other semi-hard woods are largely used, the bulk of the supply coming from Kansas, Missouri, Mississippi and Louisiana.

Marketing **T**HE sugar product of the refineries is sold to the confectionery and other manufacturing trades and to wholesale grocers and jobbers, either directly or through brokers, for domestic use, or through brokers for export. The wholesale grocers and jobbers sell to the retail trade, which in turn supplies the individual consumer.

The filtered syrups and blackstrap are sold either directly or through brokers, to blenders, exporters and jobbers. The syrups are sold on the basis of their color, clarity and chemical analysis and are used for human consumption. The blackstrap is used for the same purposes as the final molasses of a raw sugar factory, i.e., it is either distilled into alcohol or used as feed for live stock.

Delivery **A**RAILROAD siding furnishes facilities for the shipment of full carload lots and a fleet of automobile trucks makes prompt delivery in local and adjacent territory.

Disposal of Empty Raw-Sugar Bags **T**HE empty jute bags, after being washed in hot water to remove all adhering sugar particles, are sold as second-hand bags and eventually find their way into the potato, coconut and other trades. Only in times of extreme shortage of new bags are these washed bags mended and re-shipped to Cuba to be used again as raw-sugar containers. They prove unsatisfactory for this purpose, as the washing weakens the fibre.

It is interesting to note that the Revere Sugar Refinery makes it a practice not to wash the best of the empty bags. These are mechanically dry-brushed for the recovery of any adhering sugar, mended by sewing machines, baled and returned to Cuba to be used a second time by the United Fruit Company for shipping its raw sugar to Boston. This practice has proved highly economical and efficient as, when the bag is dry-brushed, the fibre is not weakened.

Conclusion **A** SUGAR refinery operates on the basis of the difference between the cost of its raws, including the import duty, and the selling price of its refined sugar.

On this narrow margin it must pay all manufacturing expenses, including the loss due to the impurities in raw material, as well as the cost of packing and selling. It is essential that a refinery have deep water for directly receiving its raw-sugar cargoes. Moreover, its location should afford a good supply of labor, coal and water, in addition to adequate rail and highway transportation for the delivery of its products. All these factors, together with the increasing number of fancy grades of refined sugar demanded by the public, have resulted in the concentration of the industry in a few large refineries, situated for the most part at the large Atlantic seaboard centres, with daily productions ranging from 1,000,000 to 5,000,000 pounds.

* See page 55

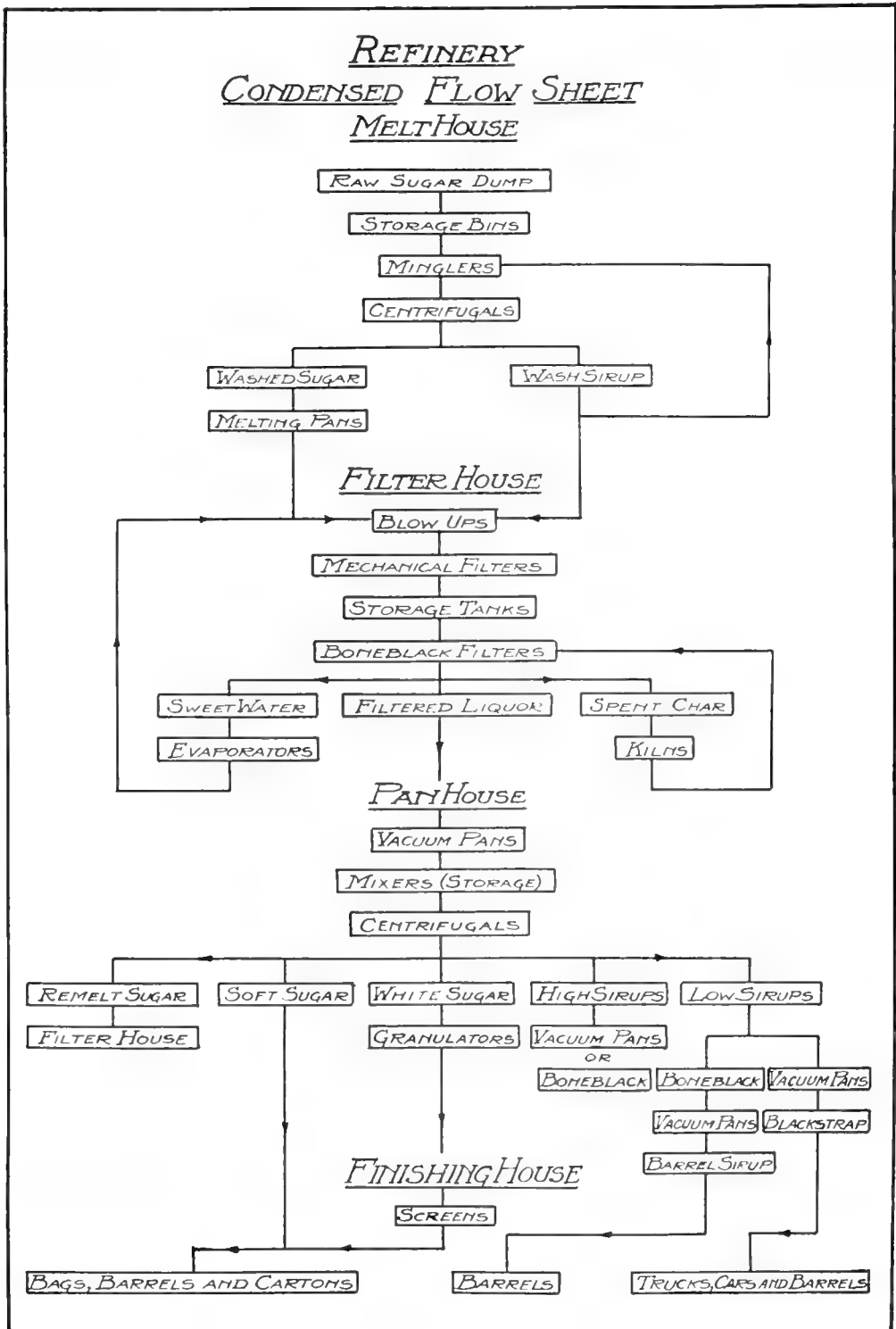
TABLE OF ALLOWANCES AND DEDUCTIONS FOR RAW SUGAR POLARIZING ABOVE AND BELOW 96 DEGREES, RESPECTIVELY

Effective with crop of 1919—1920

<i>Price per Pound</i>		<i>Allowance per Degree</i>		<i>Allowance per Degree</i>	
		95 to 96		Above 97	
<i>C and F</i> <i>Cents</i>	<i>Duty Paid</i> <i>Cents</i>	<i>C and F</i>	<i>Duty Paid</i>	<i>C and F</i>	<i>Duty Paid</i>
5.00— 5.999	6.00— 6.999	10 pts.	12 pts.	5 pts.	7 pts.
6.00— 6.999	7.00— 7.999	11 “	13 “	5½ “	7½ “
7.00— 7.999	8.00— 8.999	12 “	14 “	6 “	8 “
8.00— 8.999	9.00— 9.999	13 “	15 “	6½ “	8½ “
9.00— 9.999	10.00—10.999	14 “	16 “	7 “	9 “
10.00—10.999	11.00—11.999	15 “	17 “	7½ “	9½ “
11.00—11.999	12.00—12.999	16 “	18 “	8 “	10 “

Fractions of a degree in proportion.

For prices higher or lower than those that appear in this table, the allowance to the seller on sugars over 96 degrees (but not exceeding 97), and to the refiner on sugars under this figure, increases or decreases one point (1 cent per 100 pounds) for each cent of increase or decrease in price. The rate of allowance to sellers for polarization over 97 degrees increases or decreases one-half point (½ cent per 100 pounds) for each cent of increase or decrease in price.



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