SUGAR:

A HANDBOOK

FOR PLANTERS AND REFINERS.

PLANTATION OF BLACK TANNA CANES.

SUGAR:

A HANDBOOK

FOR PLANTERS AND REFINERS;

BEING

A COMPREHENSIVE TREATISE ON THE CULTURE OF SUGAR-YIELDING PLANTS, AND THE MANUFACTURE, REFINING, AND ANALYSIS OF CANE, BEET, PALM, MAPLE, MELON, SORGHUM, MILK, AND STARCH SUGARS;

WITH

COPIOUS STATISTICS OF THEIR PRODUCTION AND COMMERCE, AND A CHAPTER ON THE DISTILLATION OF RUM.

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PREFACE.

THE rapid rate at which successive editions of 'Sugar Growing and Refining' have been sold, points conclusively to the demand which existed for information on the all important sugar industry, and to the satisfactory manner in which the want was supplied. But no book of the kind, however complete, can keep abreast of the times without constant revision, and the introduction of much that is new in chemistry and mechanics. Improved machinery and novel processes, which lessen labour, or cheapen production, or increase returns, must command attention from all who would not be left behind in these keen competitive times, and these subjects cannot receive due attention and study except by means of a comprehensive volume furnished with a good index to facilitate reference.

After many years of unfair competition with bounty-fed sugar, there seems at last to be a prospect that the Colonial-raised article will be able to fight the foreign product on level terms. When this comes about, the Colonial sugar industry will take great strides, and many estates which have been abandoned as ruined will revive. The owners of these estates will, it may be hoped, recommence operations on a new basis, and instead of repeating the old-fashioned methods, which did well enough when competition was unknown, will adopt at once all the best and most recent processes and appliances for curtailing the cost and improving the product.

This again will drive the beet sugar-growers to seek, in improved methods of working, some compensation for the loss incurred by the removal of the bounties. So that there is a prospect of the whole sugar industry receiving an unusual impetus within a very short time.

The natural outcome of this will be a general brushing-up in the intelligence department, and a search for fresh information. To afford that information in an accessible form the present volume is written. The original book has served as a foundation and guide for the treatment of the subject, but much of the present volume is entirely new, and where the text of the earlier work has been followed, it has been because it was deemed to be accurate and appropriate.

THE AUTHORS.

INTRODUCTORY.

Definition and General Chemistry of Sugars.—The term "sugar" was originally employed and intended to classify all substances having a sweet flavour, and thus came to be used almost indiscriminately for cane-sugar, fruit-sugar, sugar (acetate) of lead, and other bodies possessing that property. At present, in a general sense, it is reserved almost exclusively to denote cane- and beet-sugar (true crystallisable sugar or "sucrose"). In chemistry, the word "sugar" is applied generically to a large class of organic bodies belonging to the group of "carbohydrates." The latter name is given to a group of compounds which contain in the molecule 6 or a multiple of 6 atoms of carbon, together with hydrogen and oxygen present in the proportion in which these elements unite to form water. The members of the sugar group are nearly allied to, and may be considered as derivatives of, the hexatomic alcohols ($C_6H_{14}O_6$), of which mannite may be taken as a type. Indeed, mannite, which can hardly be strictly classed as a true sugar, may be artificially formed from glucose ($C_6H_{12}O_6$) by treatment with sodium amalgam, the glucose thereby taking up 2 atoms more of hydrogen, and becoming converted into mannite :—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} + 2\,H = \underset{\text{Mannite.}}{C_6H_{14}O_6}.$$

Although the hexatomic alcohols are not to be regarded as true sugars, still, as several of them possess a marked saccharine flavour, and present some of the other characteristics of the true sugars, it will be convenient and instructive to include them in the subjoined tabular classification:—

THE SUGAR GROUP.

Hexatomic Alcohols. $C_6H_{14}O_6$.	Glucoses. $C_6H_{12}O_6$.	Saccharoses. $C_{12}H_{22}O_{11}$.
Mannite, mannitol.	Sucro-dextrose, dextro-glucose, dextrose, grape sugar, starch sugar.	Sucrose, saccharose, cane-sugar.
Dulcite, dulcitol.	Sucro-lævulose, lævo-glucose, lævulose.	Lactose, lactin, milk sugar.
Isodulcite, isodulcitol.	Galactose.	Maltose, malt sugar.
Sorbite, sorbitol.	Arabinose, pectinose.	Mycose, trehalose.
	Eucalyptose, eucalyn.	Melitose, eucalypton.
	Sorbinose, sorbin.	Melezitose.
	Inosite.	
	Scyllite.	

The properties by which the members of these groups may be distinguished are mainly:—(1) By boiling with acids (even dilute), the hexatomic alcohols and the glucoses are but little affected, while the saccharoses are converted into glucoses; (2) the varying powers possessed by many of their solutions, particularly the glucoses and saccharoses, in rotating the vibration-plane of a ray of polarised light; (3) the tendency of the glucoses to enter into fermentation, while the hexatomic alcohols are unfermentable, and the saccharoses are either unfermentable, or only partially fermentable and with great difficulty; most of the last, however, are converted into glucoses by the action of ferments, some of which, such as diastase (a principle formed during the germination of seeds) and synaptase (a principle found in almonds and other fruit-kernels), have special effects. The saccharoses are also converted into glucoses by the saliva, and by the juices of the stomach and intestines. Certain other ferments, such as *Torula cerevisiæ* and *Penicillium glaucum*, seem to possess the property of converting some saccharoses into glucoses, before promoting the special fermentations produced by their propagation. The fermentable sugars ($C_6H_{12}O_6$) which are capable of direct vinous fermentation are invert sugar (a mixture of dextrose and lævulose), dextrose, lævulose, and galactose.

The members of the first group (hexatomic alcohols) demand no further consideration here. The most important commercially is mannite.

Cane-sugar or sucrose is the variety of sugar which is extracted from the sugar-cane, a plant which grows only in tropical and subtropical climates, and which at one time supplied nearly the whole of the sugar consumed in Europe. It is extensively cultivated, and the manufactured product, under the name of "raw sugar," forms the staple produce of many of our colonies. Until recently, both the cultivation and manufacture of this most important article have been much neglected, and even at the present day some of the largest sugar-producing countries are exporting sugar, which, from its appearance and characteristics, has evidently been sadly spoiled during preparation. Sucrose is also extracted from the juice of the beetroot; it is apparently identical in chemical composition with the sugar extracted from the cane, and a considerable quantity is produced for consumption in Europe. More care is taken in the manufacture of sucrose from beet than from cane. Sucrose is likewise contained in the juices of many other plants, notably sorghum and several palms; its manufacture is, however, virtually restricted to the sugar-cane in the tropics, beetroot in Europe, sugar-cane, sorghum, and sugar-maple in America, and the wild date-palm in the East.

Sucrose is found associated with invert sugar in the juice of many fruits; the following table by Payen shows the percentage proportions:—

	Cane-sugar.	Total Sugar.
Pineapple (Montserrat)	11·33	13·30
Strawberry (Collina d'Ehrherdt)	6·33	11·31
Apricot	6·04	8·78
Apple, grey Reinette (fresh)	5·28	14·00
,, ,, (preserved)	3·20	15·83
,, English	2·19	7·65
,, Calville (preserved)	0·43	6·25
Plum, Mirabelle	5·24	8·67
,, Reine Claude	1·23	5·55
Orange	4·22	8·58
Lemon	0·41	1·47
Raspberry	2·01	7·23
Peach	0·92	1·99
Pear	0·68	8·78
,, St. Germaine (preserved)	0·36	7·84

The subjoined analysis of locust beans, from Cyprus, shows a considerable amount of cane sugar to be present in them, and largely accounts for their nutritive value:—

Moisture	12·06
Oil	0·42
*Albuminous matter	5·08
Cane sugar	24·00
Glucose	12·50
Woody fibre	8·60
Gum, mucilage, &c.	33·16
Ash (mineral matter)	4·18
	100·00
*Containing nitrogen	0·80
Equal to ammonia	0·97

Sucrose separates from a supersaturated solution in the form of monoclinic prisms, generally with hemihedral faces; its sp. gr. is 1·593; it is very soluble in warm water, but insoluble in ether and absolute alcohol. Heated to 160° C. (320° F.), it melts, and solidifies on cooling, but does not again crystallise. At higher temperatures than this, it suffers decomposition, losing water, and becoming converted into a mixture of dextrose and lævulosan; and at still higher temperatures, it is converted into caramel. Its concentrated solution can be kept exposed to the atmosphere for some considerable time without suffering any sensible amount of deterioration; in weaker solutions, however, the sucrose is gradually transformed into invert sugar, more especially if the sugar be at all impure, in which case it is very prone to undergo fermentation.

When sucrose is treated with concentrated sulphuric acid, it is transformed (with evolution of sulphurous acid and other volatile products) into a black carbonaceous mass. With bases, it forms a class of salts known as sucrates; the alkaline earths combine with it, and its optical power is reduced, not, however, proportionally to the quantity of the base, but to the concentration of the sugar solution. Its specific rotatory power, which does not vary with moderate changes in the temperature, is 73·8° for the transition tint. Various salts have the property of preventing sucrose from crystallising.

Sodium chloride forms with it a compound having the formula $C_{12}H_{22}O_{11}$, NaCl . $2H_2O$. Concentrated sugar solutions dissolve a large proportion of lime, forming thereby compounds containing one, two, or three equivalents of lime, which are readily decomposed by carbonic acid gas. There are several calcium sucrates formed by treating concentrated solutions of sucrose with calcium hydrate. As various methods have been proposed for manufacturing or refining sugar by the aid of these compounds, they may be shortly described. The monobasic sucrate ($C_{12}H_{22}O_{11}CaO$), prepared by precipitating a solution containing equal molecules of sugar and lime, with 85 per cent. alcohol, forms a white precipitate which, on drying, constitutes a brittle substance easily soluble in water. The bibasic sucrate ($C_{12}H_{22}O_{11}2CaO$) has been obtained by several methods; it is easily prepared by precipitating with alcohol of 65 per cent. a saturated solution of sucrose with excess of lime, and boiling; it is decomposed by water into the tribasic salt and sugar. Tribasic sucrate

($C_{12}H_{22}O_{11}3CaO$) is precipitated in flocks resembling albumen, when a sugar solution containing excess of lime is heated ; it is readily soluble in sugar-water.

The formation of the peculiar sucro-carbonate of lime, the so-called "sucrate of hydrocarbonate of lime" of Boivin and Loiseau, will be alluded to under Sugar-refining.

Sucrose is not directly fermentable, but first requires inverting. When its solution is mixed with yeast, it gradually becomes converted into invert sugar, and the latter subsequently splits up into alcohol and carbonic acid—

$$C_6H_{12}O_6 = 2\ C_2H_6O + 2\ CO_2.$$

Other compounds are also simultaneously formed, as shown by Pasteur, e. g. glycerol (glycerine) and succinic acid, amounting to nearly 5 per cent. ; so that the proportion of alcohol produced is only 51–51½ per cent. instead of 54·97, the theoretical quantity. The action of the yeast is not thoroughly understood. Mineral acids greatly retard fermentation, which is also prevented by salicylic, carbolic, and sulphurous acids.

Invert sugar ($C_6H_{12}O_6$) can be produced from crystallisable sugar by the action of acids, diastase, salts, &c. It is easily fermentable, forms salts with metallic bases, is found in the juices of many plants, and is present in very large proportion in the juice of unripe sugar-cane. Mixed with a solution of cane-sugar, it prevents nearly its own weight of that substance from crystallising ; with alkalies, it darkens in colour and forms soluble salts ; it reduces an alkaline solution of a cupric salt. The two bodies of which it is composed, namely dextrose or dextro-glucose and lævulose or lævo-glucose, differ in rotatory power, and in other particulars.

Dextrose ($C_6H_{12}O_6$) rotates a ray of polarised light to the right. It may be obtained in the form of needle-shaped crystals by the evaporation of an alcoholic solution ; when thus freshly prepared, its rotatory power is 112°, but after standing for some time, or immediately on heating, the rotation sinks to 56°, and remains constant; it is insoluble in ether, soluble in alcohol, and gives no coloration when mixed with concentrated sulphuric acid; with alkalies, on the application of heat, it turns brown; it reduces an alkaline solution of a cupric salt, and forms compounds with metallic bases; when heated to 170° C. (338° F.), it gives off one atom of water; by increasing the temperature, it turns brown, and is subsequently converted into caramel. Dextrose may be produced in several ways, of which the most important are as follows:—By the action of dilute acids on starch, dextrin, cane sugar (together with lævulose), or by treating linen rags and like vegetable substances with sulphuric acid. Dextrose is found associated with lævulose in honey. It also is present in diabetic urine. When separated by crystallisation from its aqueous solution, dextrose unites with one molecule of water, forming warty masses or tabular crystals, but from a hot concentrated solution it is often deposited in anhydrous prisms.

Lævulose is isomeric with dextrose, but rotates a ray of polarised light to the left; its molecular rotatory power, which varies with the temperature, according to Dubrunfaut, is $[a]$ j = $-53°$ at 90° C. (194° F.), and -106 at 14° C. (57·2° F.). It is a colourless, uncrystallisable syrup; on the application of heat, it behaves much in the same way as dextrose. It may be prepared by inverting cane-sugar with hydrochloric acid, and adding excess of calcic hydrate; the liquid after some time partly solidifies, and the solid mass, when pressed in a cloth, yields a solution of the calcium salt of dextrose together with calcium chloride; the cake, which consists of the calcium salt of lævulose, is then washed with water, and the lime is removed therefrom by means of carbonic or oxalic acids, when a solution of lævulose is obtained. It constitutes a syrupy liquid, which can be made with some trouble to yield an anhydrous amorphous solid. Lævulose is more soluble than dextrose, and its solution is much sweeter than that of the latter substance.

Milk-sugar, lactose, or lactine ($C_{12}H_{22}O_{11}$), an isomer of cane-sugar, is prepared from milk, which contains about 4 per cent., in the manner described hereafter; the product thus obtained can be further purified by passing its aqueous solution through animal charcoal, evaporating the water, and recrystallising. Milk-sugar crystallises in hemihedral trimetric prisms, of the composition $C_{12}H_{22}O_{11} + H_2O$; by heating to 130° C. (266° F.), the crystals melt and lose one atom of water; the anhydrous milk-sugar, which remains in the form of a liquid mass, solidifies into small crystals on cooling. Milk-sugar dissolves readily in weak acetic acid, and crystallises again unaltered; it is insoluble in absolute alcohol and ether, soluble in 5–6 parts of cold and 2½ parts of boiling water. A saturated solution in water has a density of 1·055, and contains 14·55 per cent. crystallised milk-sugar; when concentrated, this solution deposits crystals so soon as it has attained a density of 1·062; it then contains 21·64 per cent. milk-sugar. This change in solubility is accounted for by Hesse on the supposition that the size of the molecules of the two modifications of milk-sugar stand to one another as 3 to 2, so that by boiling, the β variety is produced, the molecules of which occupy ⅓ less space. The specific rotatory power for the a variety is $[a]_D + 80°$, and for β variety 52·7°. Milk-sugar is charred by warm concentrated sulphuric acid; heated with the diluted acid, its optical rotatory power is increased, galactose ($C_6H_{12}O_6$) being formed.

Milk-sugar ferments with yeast, but more slowly than grape-sugar or dextrose, yielding alcohol and carbonic acid; with many bases it forms well-defined compounds; it does not combine with sodium chloride. It forms two calcium compounds, one soluble and containing equal numbers of molecules of lime and sugar, the other insoluble, and containing a larger proportion of lime.

Maltose, according to O'Sullivan, is a body crystallising in fine needles, which become anhydrous at 100° C., leaving a residue of a very hygroscopic character. It is formed by the action of malt extract on starch; its specific rotatory power (150) is about twice that of sucrose. By boiling with dilute sulphuric acid it is converted into dextrose. Maltose is probably not susceptible of direct fermentation, but by the prolonged action of yeast its conversion into dextrose and fermentation occur almost simultaneously, yielding alcohol to the amount of 51½ per cent. of the maltose taken.

History of Sugars.—Etymologically, sugar would seem to be of Indian origin, the earliest forms of the word being *sarkara* in Sanscrit and *sakkara* in Pracrit. Thence it may be traced through all the Aryan languages, as *schakar* in Persian, *sukkar* in Arabic, *suicar* in Assyrian and Phœnician, *saccharum* in Latin, *azucar* in Spanish and Portuguese, *zucchero* in Italian, *sucre* in French, *zucker* in German, &c.

The precise product indicated by these various names is not always clear, and probably is not identical in all cases. The cultivation of the genuine sugar cane (*Saccharum spp.*) appears to have been common in China and India in very remote times, but there is no documentary evidence on this point earlier than that of Herodotus. Frequent mention of the "sweet cane" occurs in the Scriptures, but the plant referred to is doubtful. An Indian reed yielding honey is alluded to by Strabo, and a similar statement concerning an Egyptian reed is made by Theophrastus; while Dioscorides actually gives the name *saccharum* to a kind of honey obtained from reeds in Arabia Felix and India; both he and Pliny accurately describe the product as being white and brittle, and of a salt-like consistence. Later it seems to have been generally termed "Indian salt" among the Greeks and Romans, by whom it was obtained in small quantities at great cost from India, and used medicinally.

The introduction of the sugar-cane into the Mediterranean basin must have taken place at an early date; for it was found growing at Assouan, on the Nile, in 766, and was carried into Spain by the Moors in 714, while Sicily engaged in the culture about 1060–90. During the religious wars of the Middle Ages, the "sweet honied reeds," called *zucra*, which abounded in the meadows about Tripoli, were consumed by the Crusaders; and it is evident that sugar-making in that neighbourhood was conducted in a wholesale and systematic manner. From Cyprus and Madeira, the industry extended in 1500–1600 to most of the West Indies, where it was carried on by Spanish and British colonists; but there is strong evidence in favour of the supposition that several kinds of sugar-cane are indigenous both to the West Indies and to almost the whole continent of South America.

From the extensive growth of sugar in the Western Tropics, there ensued large importations of the raw article into Europe; and the introduction of tea and coffee about the same time created a general and wide demand for what had hitherto been regarded as a medicine rather than as a nutritive article of diet. Sugar-refining appears to have been copied from the Arabs by the Venetians, and refineries were established in England and Germany in the 16th century, and in Holland soon after.

Up to this time, cane-sugar was the only kind known in commerce. But in 1747, Margraf demonstrated the existence of about 6 per cent. of sugar in beetroot; and in 1795, Achard manufactured beet sugar on his farm in Silesia, and presented loaves of refined sugar to Frederick William III. of Prussia in 1799. About ten years later, Napoleon used extraordinary efforts to foster the production of native-grown sugar; and grapes, plums, maize, sorghum, carrots, &c., were also experimented on. The results obtained did not excel those from beet; and the first French factory for making beet sugar was founded at Lille, in 1810, by Crespel-Delisse. The sudden and great fall in the price of sugar caused by the Peace of 1815 crippled the native industry; but

Crespel-Delisse and a few others held on, and the production of beet sugar in France rose, through many vicissitudes, from 1000 tons in 1827 to 486,000 tons in 1886–7.

The artificial conversion of starch into glucose was first accomplished by Kirchoff, of St. Petersburg, in 1702. Of late years, this industry has assumed important dimensions in Continental Europe, England, and the United States.

As to the history of the other sugars obtained from the maple, sorghum, and various palms, little definite is known. The preparation of sugar or syrup from green maize stalks is due to the ancient Mexicans, and has been carried on with varying success in Southern Europe and in the United States; the extraction of sugar from melons is an American innovation of the last few years; and the separation of sugar from milk is an essentially Swiss industry. The saccharine secretions of bees and similar insects, as well as natural exudations such as manna, have probably been utilised from the very remotest ages, and are the subject of no particular preparation or manipulation.

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PLATES.

SUGAR:

A HANDBOOK FOR PLANTERS AND REFINERS.

CANE SUGAR.

CHAPTER I.

CULTIVATION OF THE PLANT.

The Plant.—The sugar-cane is a kind of gigantic grass, belonging to the genus *Saccharum*, though its external appearance would hardly lead the casual observer to this conclusion. Most botanists are inclined to ascribe all the varied sorts of sugar-cane now grown to a single species, called *Saccharum officinarum*, formerly *Arundo saccharifera*; this theory supposes all the forms which are at present met with to be merely varieties induced by the effects of cultivation. The best authorities are not absolutely agreed upon the subject, however; and as it is very questionable whether any of the canes now to be discovered growing in an apparently wild state in some of the oldest sugar-raising countries is truly wild, i.e. has never been subjected to artificial influences, it is probably impossible to arrive at a reliable decision, especially since the original home (or homes) of the sugar-cane remains unknown.

Varieties.—All practical ends are served by a knowledge of the characteristics which have been developed by education in the different varieties. Many of these have been raised to the level of distinct species, and have had botanical (Latin) names conferred upon them; but in view of the lack of evidence as to their being true species and not mere artificial varieties, and to avoid unnecessary complication, it will be sufficient here to give the colloquial names by which they are generally known to sugar planters, and their native names when they have no other.

1. The Bourbon cane appears to have been introduced into the West Indies from the Island of Bourbon, but it came originally from the coast of Malabar. There it was found growing spontaneously as a small-sized, but soft and juicy cane; but it was so much affected by the change of climate and soil, and the cultivation it received in Bourbon, and so increased in size, and richness of juice, that it was planted in preference to the old kind, and at length entirely superseded it throughout the island. Wray entertains a suspicion that it is in reality no other than the Tibboo Leeut of Singapore (generally called the Otaheite cane), somewhat altered by change of soil and climate.

2. The Otaheite canes are two; the yellow or straw-coloured, and the purple-striped or ribbon. The former and the Bourbon are so much alike in all respects, and have become so intermixed on West Indian estates, that it is a matter of great difficulty to distinguish them, if, indeed, they are not one and the same.

Considered as the same, one description will serve for the whole. With a good soil and favourable season, plants of the first year's growth often attain the height of 12 or 14 feet, measuring 6 inches in circumference, and with joints 8 or 9 inches apart, though this exceeds the average. Such plant canes commonly yield (in Jamaica, Bengal, and the Straits) 2½ tons, and not unfrequently 3 tons, of marketable sugar (including molasses) per acre. Planted at proper seasons, as will be treated of hereafter, they often attain maturity in 10 months, and very rarely exceed 12. Under certain circumstances, as in excessively rich land, or a wet season, it may be expedient to allow them even 14 months. They require a generous soil and attentive management. Many soils which suit other varieties are unfit for the proper development of these; whilst it is generally remarked, that they are more sensible of the injuries committed by the trespassing of cattle, sheep, &c., during their early growth, than other descriptions.

The purple-striped Otaheite cane is very much like the ribbon cane of Batavia in appearance; but the former has broad purple stripes on a greenish-yellow ground, whereas the latter is of a blood-red on a transparent straw-coloured ground. It is often called the Otaheite ribbon cane, in contradistinction to the ribbon cane of Batavia. Its foliage is of a much darker colour than that of the yellow variety, whilst its leaves droop much less. It is a hardy and esteemed description, of large size, soft, juicy, and sweet; and yields sugar in equal quantity, though of a rather dark quality.

3. Batavian canes are of four descriptions, viz. the yellow-violet, the purple-violet or Java cane, the "transparent" or ribbon cane, and the Tibboo Batavee or Batavian cane of the Straits.

The "yellow-violet," so denominated in the West Indies, differs from the Bourbon in being smaller, less juicy, considerably harder, of slower growth, of much darker foliage, and more erect. When ripe, it is usually of a straw-colour, its skin or rind is thick, and the pith is hard; but its juice is rich and abundant. The yellow-violet contents itself with a soil of inferior quality; this renders it of much importance in planting out large tracts of land, some portions of which may be too poor for its superiors. The sugar manufactured from this cane is of a very fine quality, but considerably less in quantity than from the Bourbon. A very common custom of the old Jamaican planter was to mix the yellow-violet with the Bourbon plant cane, in certain proportions, for the purpose of "correcting" the juice of the latter, and to check "burning" during the boiling.

The "purple-violet," or large black cane of Java, is fully as thick as the Otaheite, with joints varying from 3 to 7 inches apart. In height it is usually about 8 or 10 feet, with leaves of a lighter green than the yellow-violet. The uppermost joints sometimes exhibit faint streaks, becoming imperceptible in the lower joints, which are of the darkest purple colour. Very frequently a white resinous film is seen encrusted on the joints of this cane, sometimes lying so thick that the purple of the cane itself is in some joints almost hidden. When in perfection, it yields a very sweet and rich juice. Being quite hard, it is difficult to grind, and affords a comparatively small quantity of juice, which is sometimes troublesome to treat. It is very hardy, thriving well in poor dry soils; in Jamaica, it is often planted in the outer rows of the cane fields, to stand the brunt of trespassing cattle. To other descriptions of cane, these ravages would be very serious indeed; but the purple-violet is so hardy that it quickly recovers, and springs up again with astonishing rapidity. It was introduced into the West Indies about the same time as the Bourbon, and is still much cultivated. In the Straits, the Malays term it Tibboo Etam, or black cane, and grow it around their houses, for eating.

The "transparent" or ribbon cane is much smaller than the Otaheite ribbon cane; is of a bright transparent yellow, with a number of blood-red streaks or stripes running the whole length of the stalk, and varying in breadth from ¼ to 1 inch. Its leaves are green, similar to those of the yellow-violet, but more erect. It grows from 6 to 10 feet high, with joints from 4 to 8 inches apart, and 4 inches in circumference. It is generally planted in light sandy soils, where no other cane will thrive; sometimes it is raised promiscuously with the yellow-violet. Although its rind is thick, and its general texture is hard, yet it yields a good quantity of juice of excellent quality, which is easily converted into fair sugar. Planters often grind this cane with the Bourbon, for the same reason as applies to the yellow-violet.

The Tibboo Batavee or Batavian cane is common in the Straits of Malacca, where it is cultivated by the Malays. In appearance, it is much like the yellow-violet, except in the peculiarity of its colour, which is rather greenish with a pink shade in parts; in some of the lower joints, this pink colour is very bright and pretty, whilst in the upper it is more faint and delicate. The joints are seldom more than from 3 to 6 inches apart. In height, size, and foliage, it closely resembles the yellow-violet; it differs from it in being much softer, more juicy, and less hardy in habit. In a rich soil, it is prolific, and ratoons well; its juice is rich, clarifies easily, and gives a fine sugar; but, on the whole, it is inferior to the Otaheite variety, while requiring an equally rich soil.

4. East Indian canes.—The large red canes of Assam are very juicy and sweet; the sugar produced from them is of an exceedingly fine grain and good colour; they are, moreover, strong in growth, and much less apt to fall over than the Otaheite, to which they are fully equal in size, as well as in quantity and quality of juice. They flower when only 8 months old; consequently they could be cut and manufactured in 10 months from the day of being planted.

In Lower Bengal (near Calcutta), and in the Straits of Malacca, a large red cane abounds, which bears a very close resemblance to the preceding variety.

The red cane of Bengal is a large and fine cane, much used about Calcutta for sugar manufacture; sugar made from it by the natives, in their own rough and primitive way, exhibits a grain of good size, strength, and brilliancy. The Malay name is Tibboo Merah.

The next large canes are the black and the yellow Nepal, large-sized and fine-looking canes, fully equal in appearance to the Assam.

The following three sorts of native canes are most cultivated in India:—the Kajlee, or purple-coloured cane; the Pooree, or light-coloured cane; and the Kulloor, or white cane. The first-named grows on dry land in Bengal, the second requires a richer soil, and the third grows best in swampy ground, which does not suit the other kinds. This last is the most generally cultivated.

Dr. Buchanan mentions four kinds common to Mysore—the Restali, which produces the native sugar of Mysore, can be planted only in the last two weeks of March and the two first of April; it completes its growth in 12 months, and does not survive for a second crop. The Puttaputti, which produces the best Bella or Jaggery; it can be planted at the same season as the Restali, as also at the end of July and beginning of August; it takes 14 months to complete its growth; but the stools produce a second crop, like the ratoons of the West Indies, which ripen in 12 months. The Maracabo and Cuttaycabo are very small, seldom exceeding half an inch in diameter; yet in some districts of Mysore, as about Colar, the last-named is usually cultivated, because it requires less water than the larger sorts. All these are inferior to our colonial kinds.

5. The Chinese sugar-cane possesses the advantage of being so hard and solid as to resist the forceps of the white ant and the teeth of the jackal—two great enemies to the East Indian sugar plantations. It is difficult to express the juice with the Bengal native sugar mill; but the cane bears drought much better than the sorts in general cultivation, producing a profitable crop even to the third year, while the common cane of India must be annually renewed. It is extremely hard and prolific; during very hot seasons, it remains uninjured in every respect, whilst other canes are all either burnt up, or eaten out of the ground by the white ants. As the rain comes on, the China cane springs up wonderfully, many roots having no less than 30 shoots, which, by September, become fine canes, about 12 feet in height, 3 inches in circumference, and with joints from 6 to 8 inches apart. These, cut in October, may be planted out during a tolerably

severe winter, the cold having little or no effect in checking their growth. These facts are sufficient to establish the China cane as a variety well suited to India, although it is very far inferior to the Otaheite, wherever that cane can be cultivated successfully. It was introduced into India in 1796, and is now common throughout Bengal, although the natives think it indigenous, from its having been so long amongst them. Its neglected cultivation during many years in India has caused it to degenerate very much. It is very small-sized, being rarely more than 1 or 1½ inch in diameter; but it is sweet, and makes fair sugar. The Chinese assert that it is better adapted than any other kind for making sugar-candy. It must not be confounded with the Chinese cane experimented with in Demerara in 1854–5, which was *Holcus saccharatus* (see Sorghum-sugar); though it gave 3 or 4 crops in a year, the aggregate annual yield fell short of that from the common cane.

6. The "elephant" cane of Cochin China has been stated to reach a height of 11 feet and a diameter of 7 inches in 6 months. This variety is only cultivated for eating or chewing, and might prove to be a good sugar-producing cane. But as varieties, especially in the case of sugar-canes, often improve by change of climate, perhaps this might succeed better elsewhere. The dimensions of diameter and height, to which this variety attains, depend on the length of time during which its growth continues. In a good soil, it requires 2 years to reach 10 feet in height. After 5 or 6 years, it will reach 16 to 32 feet; such specimens may be seen near native houses, where it is allowed to grow undisturbed as an ornamental plant. In the province of Mytho, this variety is cultivated in humid alluvial soils on a considerable scale, but simply for sale in the bazaars and for chewing. It has the peculiarity of possessing a very brittle epidermal layer, so that, instead of becoming pressed out, and giving up its juice, when passed through the wooden mills employed in Cochin China, it breaks up into small fragments.

7. The Straits Settlements grow eight kinds of sugar-cane, foremost among which is the Salangore, called by the Malays Tibboo Cappor or Tibboo Bittong Beraboo, and often termed "the Chinese cane" by the planters of Province Wellesley, from the simple fact of its having been cultivated there by the Chinese immigrants since a time long antecedent to the European occupation of the district. This is one of the finest canes known, attaining a weight of 25 lb., a length of over 13 feet, and a diameter of 3 inches, under favourable conditions. It is remarkable for the prevalence of setæ ("cane itch") on the portion of the leaf attached to the stalk. The leaves are very broad, deeply serrated, and have a considerable droop; they are some shades darker-coloured than the Otaheite, and adhere so firmly to the stem even when dry as to require taking off by hand. The cane "ratoons" better than any other kind in the Straits, and has been known to yield there 40 piculs (a picul is 133⅓ lb.) of granulated undrained sugar on 1 orlong of ground (an orlong is 1⅓ acre) as third ratoons. As "plant canes," they have given an average of 65 piculs of granulated sugar from each orlong, or 6500 lb. to the acre, sometimes increasing to 7200 lb. The Salangore cane grows firm and strong, remaining much more erect than the Otaheite; it affords an abundance of juice, which is sweet, easy of clarification, boils well, and produces a very fine fair sugar, of bold and sparkling grain.

The Salangore cane has been introduced into Brazil, and the British and French West Indies. In the former, it has been attacked by disease; but in the two latter, it is well spoken of, growing with great vigour under irrigation. Planted pretty wide apart (2 yards by 2 yards), and properly manured, in 5 or 6 months it forms such a thick vigorous growth as to keep down weeds, and greatly reduce the labour usually expended on their eradication. The clumps yield from 25 to 40 canes, thus producing a weight per acre much in excess of ordinary canes. As many as 16 clumps have been cut from 40 square yards, giving a net weight of over 800 lb. or at the rate of more than 80,000 lb. to the acre, while the ordinary canes vary from about 21,600 lb. to 32,000 lb. The "begass" of the Salangore cane constitutes so much fuel that only a small addition of straw is required to supplement it, while still leaving as much refuse on the ground as other kinds.

8. The South Pacific Islands are by some regarded as the original home of the sugar-cane, and they certainly produce a number of forms which are strictly local. Cuzent enumerates the following kinds in the Society Islands:—(*a*) To Uti: large stalk, of fine violet colour, pith of same hue, and rich in juice; it is cut at about 14 months. It is not indigenous, but was introduced from Batavia in 1782. (*b*) Rutu or Rurutu: stem of a clear violet, with white pith, the young leaves also violet-coloured. It comes from Cook's Archipelago. (*c*) Irimotu: large, green, fragile stem, which breaks with a straight fracture and no splinters, the pith being white; it is rich in juice, but is little cultivated, because of the pubescence (hairiness) of its stem, the hairs attacking both the skin and the respiratory organs during the harvesting operation. (*d*) Oura: the common "ribbon" cane, having a violet stem with longitudinal bands of bright yellow, the pith being white; it attains a great size, especially in humid soils. (*e*) Piavere: the Creole cane; it has a light-red stem, grows to a less size than the preceding, its internodes are less distant, its pith is white, and the juice is less rich than the other kinds, whence it is regarded as inferior. (*f*) Vaihi-uouo or Uouo: the stalk is white, and contains less juice than the average kinds, but the juice is richer in crystallizable sugar. It was introduced from the Sandwich Islands. (*g*) Avae: a yellow stalk banded with clear green, having some resemblance to the last-mentioned; the pith is white, tender, and very juicy, hence the natives chew it in preference to the others, but the sap is not very rich in crystallizable sugar. On the flanks of some of the mountains, two other varieties are met with. They are

both small, and are known collectively by the name To-Aeho; one, distinguished as To-Patu, is red, and contains more juice than the other, which is white. Canes growing in the Pacific Islands have been asserted to yield 25 per cent. more juice and 15 per cent. more crystallizable sugar than the bulk of the canes raised in our Colonies; but this statement requires confirmation: thus 15 per cent. more crystallizable sugar means a juice containing 2⅓ to 3 lb. of crystallizable sugar per gallon, whereas even 2 lb. would be an extraordinary figure. The Otaheite or Tahiti canes cultivated in the West Indies degenerate in course of time, and should be renewed by the importation of fresh stock from the Pacific groups, and perhaps New Guinea. The Sandwich Islands are accredited with 35 to 40 distinct varieties of sugar-cane. One of these varieties, called Puolleæ, grown on 30 acres of good land under irrigation, gave an average yield per acre of 12,000 lb. (6 hhds.) of No. 16 sugar. It is reported to be hardy, and to grow freely up to 2000 feet elevation in its native country. The Guingant cane, from Tahiti, blooms in June, is of vigorous growth, and gives a fair amount of sugar.

John Horne, Director of Gardens and Forests, Mauritius, calls particular attention, as a sugar yielder, to the Lahina cane. He was told when in the Sandwich Islands that this cane yields as much as an average of 6 tons sugar per acre, on areas as extensive as 100 acres; and 7½ tons per acre, on an average, over areas of 20 acres or less in extent. However, after the first ratoons it should be uprooted, as the second ratoons are nearly worthless. The variety Samuri is the favourite cane with the sugar planters in Fiji. It is hardy, grows rapidly, and yields sugar freely. While in Louisiana, Horne found that the Lahina cane, mentioned above, was under cultivation there, and was very favourably reported upon.

9. West Indian kinds.—H. Prestoe, the colonial botanist of Trinidad, has recently published an official report,

describing the 14 best varieties of sugar-cane, among 32 surviving kinds of a larger number sent from the Mauritius. Eighteen of them seem to be distinct varieties, and deserving of care and cultivation, as possessing characters that give them, in one way or other, a superiority over the two or three sorts at present in cultivation, and among which the yellow Otaheite takes by far the largest place. Some of the new varieties are peculiar for length of joint, and some for length of joint united with stoutness. One is remarkable for both, added to a very soft tissue. This sort is of a fine dark-claret colour, and is numbered 10 in the list. In common with many of the others, it also bears drought well, and is prolific. Two (Nos. 13 and 14), being extremely hardy and prolific, are recommended as fodder canes, to plant on poor, dry soils, unsuited for the better canes. They are much hardier than Guinea grass, and will yield a manifold greater weight per acre of surpassingly nutritious fodder. They are purple-striped. No. 8 resembles the best yellow Otaheite. No. 11, a dark-purple cane, perhaps a less luxuriant offshoot of same parent as No. 10, is also soft in tissue. All to No. 12 are described as stouter and more promising canes than the common Otaheite (planted in the same soil and under the same conditions), which was rarely 1½ inch in diameter. Only No. 4 was so small, Nos. 2, 6, 9, 11, and 12 being 1¾ inch, Nos. 1, 3, 5, and 7 being 2 inches, while the joints of the very handsome clean cane, No. 10, averaged 2½ inches in diameter by 6½ inches long. No. 5 has 6-inch joints, No. 9, 5½-inch, and Nos. 4, 6, 11, and 12 have 5-inch joints. Those of No. 1 are 4½ inches, of No. 3, 4 inches, and of Nos. 2 and 7, 3½ inches. No. 6 grows very straight canes. No. 7 retains a green foliage, and although short in joint, is stated to have a very fine habit. Having been grown on poor soil, the dimensions given indicate only the relative values of these varieties as compared with the yellow Otaheite, in fields side by side, and do not define the ultimate standards to which they may attain under more favourable conditions. A richer and moister soil will improve all. Purple and purple-striped canes are generally admitted to be preferentially adapted, by the hardihood of their habit, to the poorer drier soils; but it must be remembered that they have a strength of tissue which gives increased trouble in crushing. Nos. 10 and 11, however, are remarkable exceptions, and probably others of the list, when tried in really good soil, will assume a freer habit, and gain a larger size, than ever shown by the familiar yellow Otaheite. There is no reason to doubt that, with selection and nursing, superior and fixed qualities can be obtained in sugar-cane, as freely as they have been in beet and other agricultural crops in Europe and America.

An esteemed cane in Mauritius is the Diard, which does not bloom, and is suitable to dry country.

Purdie, the Government botanist in Trinidad, gives particulars of three new varieties of sugar-cane, which are provisionally named "Caledonian Queen," "Green Salangore," and "Violet Salangore." The Caledonian Queen is a pale- or greenish-purple cane, close jointed, and extremely vigorous. The leaves are remarkably broad, and their bases are nearly destitute of the setæ or "cane-itch" common to most canes. This cane is said to attain enormous dimensions in the East, and to be one of the most sacchariferous. The short joint is a feature which is generally considered objectionable, accompanied, as it usually is, by great hardness of tissue. In this respect, however, the Caledonian Queen is an exception, and the ready way in which both the length of joint and the diameter of cane are affected by manure (the natural soil at St. Ann's being of the poorest) indicates great variability of habit, and suggests gigantic growth under the influence of rich alluvial soil.

The Green Salangore is so named from its retaining a green colour on the cane much longer than usual, although, when fully ripe, the colour of the cane is yellow, but not so bright a yellow as that of a well-ripened Otaheite. This one is the freest-growing of all the varieties in the Gardens, except the giant Claret cane; and its erect habit is even more striking than in that sort. In respect of both length of joint and diameter of cane, it is equal to it, thus being the largest yellow cane grown in Trinidad. The foliage is large and heavy, as in Nos. 1, 2, and 6 of the former series, but completely deciduous, so that the operation of "trashing" is with it reduced to a minimum. The most striking feature in this cane, besides its size, is the broad white rim just below each joint.

The Violet Salangore has the habit of erect growth more strongly developed than is seen in any other of the canes enumerated, besides being distinctly the longest-jointed and tallest, with a full average diameter. The leaves are long and narrow, as compared with the well-known Otaheite.

The remarkably erect habit of growth in these two Salangores is a character which, considering the influences most conducive to a highly saccharine juice and a large yield of sugar per acre, is of importance; on this account, it is deemed desirable that they should be brought into notice, if only for experiment. It is generally admitted that the successful sugar cultivation of the future will mainly depend on an increased yield of sugar from a given weight of cane, just as the beetroot cultivation has become an established industry of immense importance mainly by an increased yield of sugar per ton weight of root, brought about, not only by improved tillage and manufacture, but by the propagation of roots (in this case by seed) which were found to contain most saccharine juice. One of the most commonly observed facts on a sugar-estate is that canes grown erect (and therefore enjoying full sunlight and air) are yellow, and "full of sugar," whereas canes lying on or near the ground (and thus deprived of light and air by their erect companions) are green and deficient in sugar. The erect or decumbent posture of the canes is in a measure dependent on the soil, and on the kind of culture they are treated to, especially when young; but, under any circumstances, a marked disposition to maintain an erect habit of growth is an obvious advantage in respect of the sugar yield. It would be highly instructive and doubtless encouraging, in the face of beetroot success, if every planter, judging himself to have a field capable of yielding 2½ or 3 hhds. per acre, were to test the saccharine contents of one of his best (most erect and yellow) canes and that of one of his worst (most decumbent and green) canes of such a field, then estimate the yield per acre by this best and this worst respectively, from the calculated weight of cane on the ground. Such a test seems to be one of the first steps towards increasing the percentage of sugar to weight of cane, and thereby the yield per acre, as has been accomplished in such a remarkable degree with the beetroot.

With regard to the several varieties of sugar-cane already introduced from the East, as well as the three varieties now newly brought into notice, there has not been, so far, any opportunity or proper means for testing their specific and individual characteristics in respect of their habit of growth and sugar yield under extended cultivation. It is most desirable that all the more promising kinds should be fairly tested, and their individual and distinctive features determined. To do this, it is indispensable that each variety be kept and treated separately, and experience has shown that it is a mistake for one person to deal with more than one variety when experiment is determined on. However intelligent and energetic the superintendence, it is next to impossible, with the assistance usually available, to maintain or even to plant, a collection of sugar-canes of several varieties without getting them mixed. Besides, ten or twelve stools grown under fair average conditions of the estate, are all that is required to accomplish a full and satisfactory experiment. Such stools, placed not less than 8 feet apart in a single row, and kept free from other plants, will furnish reliable material for analysis, and data for estimating yield per acre.

The judicious planter will make a selection of the two or three best sorts adapted to his estate, and will not confine his attention to a single kind, however superior its qualities may be; for it has been proved by experience that the growth of one class of cane, continued for successive seasons, and extending over many years, causes a material deterioration. The occasional exchange of new varieties therefore becomes imperative, in order to secure the maximum results that the land is capable of affording.

Structure and Development.—Bearing in mind the modified characteristics which cultivation has produced in the numerous varieties of sugar-cane described in the preceding pages, the following is an account of the structure and development of the plant.

A knowledge of the growth of cane roots being important to planters, the following experiments were made at Foulden Plantation, Mackay (Queensland), with a view of gaining some information on this point. The experiments were conducted by Mr. Henry Ling Roth, to whose kindness we are indebted for the following notes taken from the 'Proceedings of the Royal Society of New South Wales.'

"*A.* On 20th November, 1882, a cask 30 inches deep, with the bottom knocked out, and 17 to 22 inches in diameter, was filled with manured garden soil well mixed down to 12 inches from the bottom, and sunk into the ground so that the top of the cask was on a level with the surrounding soil. In the cask were planted, 4 inches deep, two Rose-bamboo plants with three good eyes in each.

"*B.* On the same date were planted a few feet distant from the above, two plants of the same variety of cane, with a like number of eyes and placed at the same depth. This plot trenched 4 feet square and 20 to 22 inches deep. The soil was a light black loam for the first 15 inches, then a heavier brown loam, which at 40 inches depth had merged into river sand. As far as has yet been ascertained, this sand extends down to beyond 6 feet. This plot was not manured.

"The cask was raised on 16th August and knocked to pieces, leaving a compact mass of roots binding the earth firmly together. The soil was removed by means of washing with water, but the roots were so fragile that in spite of every precaution many were broken off; in fact, from the quantity of rootlets collected in the water afterwards, I should say that fully one-sixth were dissevered. Fig. 1 will show the dense character of these roots. Some had spread out laterally, and not being able to extend beyond the cask had gone downwards; other roots, again, had gone down at once. As it was not imagined that any roots would have descended to a greater depth than 30 inches (the depth of the cask), no precautions were taken to prevent the sundering of any roots which penetrated below that depth. I afterwards found that almost all the roots had thrust themselves into the sand below the cask. The cane had been planted very late in the season, but had grown fairly well; the diameter of the canes reached 1½ inch, but the colour of the leaves was pale and unhealthy, having become and remained so after five months' growth, owing to the restrictions on the spreading of the roots by the cask. When taken out of the cask there appeared to be more roots than soil, and examined under the microscope, the fine root-hairs (trichomes) showed a diameter of 1–250th to 1–275th of an inch. Where the roots had come across a lump of manure they had formed a compact network.

"The roots of *B* were raised on 20th August, 1883. In digging out the roots of this cane, which was grown under perfectly normal conditions, ample room was allowed for the lateral roots, which were found to spread to a distance of over 3½ feet. Having found these, I dug down and gradually approached nearer, until having excavated enough soil at a depth of 5 feet, I began to look for the tips of descending roots. The deepest root thus touched was a depth of 4¾ feet, being 5 feet 1½ inches long from its departure from the cane

FIG. 1.

Roots of Sugar Cane.

FIG. 2.

Tips of Sugar Cane Roots.

plant to its tip in the sand (Fig. 2*a*). Another root (Fig. 2*b**) was 3 feet 10½ inches long, and also grew almost perpendicularly downwards. Starting from above again, the roots

* To obtain a thorough idea of the roots, this figure should be examined through a magnifying glass; the tip of root (*b*) would thus be seen to advantage.

on the surface were not quite so dense as those in the cask, but were very close to a depth of nearly 2 feet, below which depth they thinned considerably. The cane, although, like the other, planted late, was fairly grown, with a good healthy colour in the leaves, about 18 inches higher than the cane in the cask, and the canes from $1\frac{3}{4}$ to $1\frac{7}{8}$ inch in diameter. In Fig. 2 the tip of the long root *a* was broken off in removal; but *b* shows the tip intact; its diameter at the broadest part was 5/16th of an inch. *c e f* are tips of roots found at various depths (*f* as deep as *b*); *d* are the surface or upper roots, the same as shown in Fig. 1. The two root stems *a b* look very naked; in reality they were not so, but in tracing them back to the planted pieces of cane, all the branches were broken off—their points of disconnection are plainly discernible; the rootlets were exceedingly brittle towards the lower end, and I feared that by attempting too much I might lose all. No roots tipped like *a* and *e* were found except with a downward tendency, that is to say, I found no lateral roots tipped like those. This, however, does not prove that the cane has two distinct classes of roots, for being very fragile, and being in the loam, which is not so easily disconnected as the sand, I may have missed them in consequence of the tips remaining in the soil.

"In the fields, young cane which has sprouted to only 6 to 10 inches above ground, will have fine roots going to the depth of 30 inches. All this would seem to indicate that cane, like other plants, requires plenty of room for the natural spread of its roots. Where there was plenty of food and the soil was loose enough to allow the roots to penetrate with ease, there the roots were thickest; where the soil was not in that condition, or there was no great quantity of food, there the roots were thinnest.

"Prof. Liversidge states that he saw at Maryborough, in Queensland, roots of the sugar-cane extending down from 8 to 10 feet, where they had been exposed by the cutting away of a bank, and was informed by planters that they had traced roots down to a depth of even 12 to 15 feet in light alluvial soil."

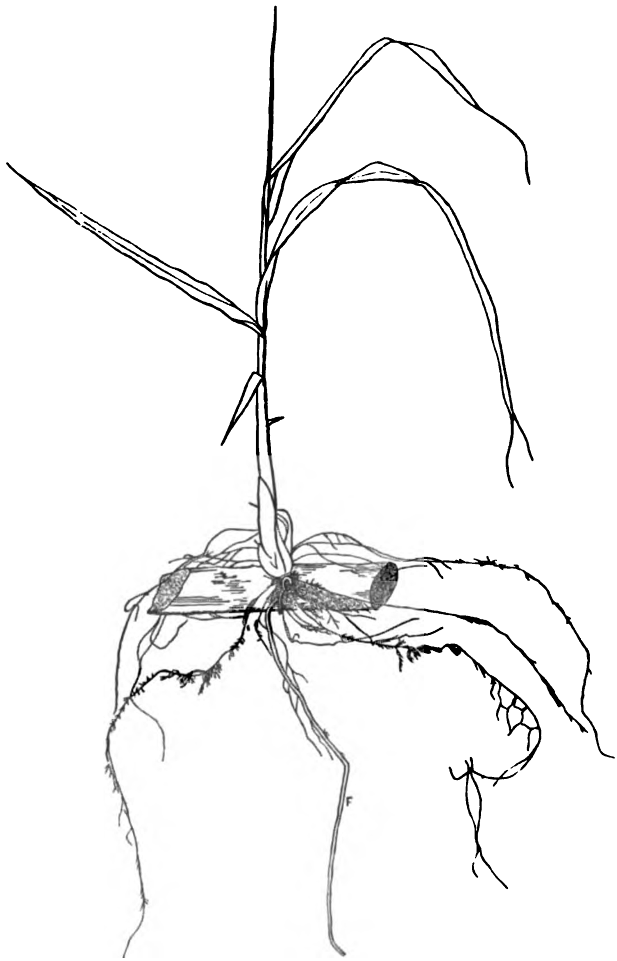
In order to find out something more about the fleshy roots discovered in the foregoing experiments, and their special functions, Roth made the following further experiments:—

"On the 2nd October, 1883, at Mackay (Queensland), after some good spring rains, when the soil was moist, warm to the touch, and otherwise in good condition, I planted two pieces of Rose Bamboo sugar-cane in two deep separate boxes.

"No. 1 was planted 3 inches deep in the soil, No. 2, 7 inches deep, both at the usual angle, and otherwise in the manner commonly followed by planters. The shoot of No. 1 appeared above the ground on the 20th of October, and that of No. 2 (the deeper planted) on the 25th of October. As usual, in both cases the soil was slightly raised by the pushing shoot shortly before any appearance of the green above ground. On the 2nd of November, both plants were carefully taken out: the boxes were put in a large butt of water, the sides knocked off, and by gently shaking the plants the soil was got rid of. An after examination of the water and soil showed that none of the roots had been dissevered. The plants were kept in water for twenty-four hours, to enable the roots to swell, and then photographed. The accompanying illustrations (Fig. 3, 4) were carefully drawn from the photographs. The weather during the period of growth was very favourable, and I may add that during the time which elapsed from their first appearance the sky was almost cloudless.

"When taken up, the shoot of No. 1 was 18 inches long, measuring from its point of departure from the parent cane. Besides numerous fine roots it had four fleshy roots, the longest of which was nearly 13 inches in length, while the others were less than 2 inches long. These fleshy roots appeared to spring from the point of growth of the shoot on the parent cane, and certainly had not come out of any of the starry points on the node.

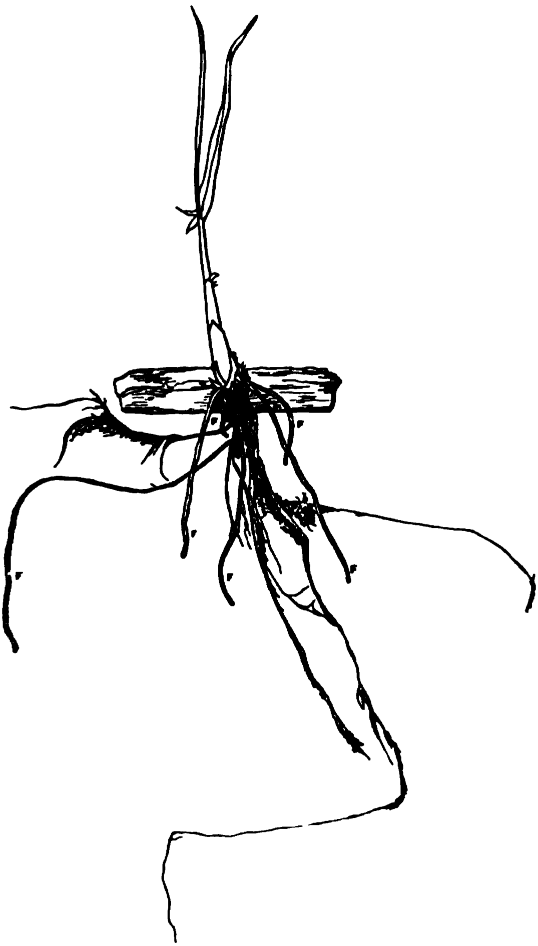
FIG. 3.



Sugar Cane Roots.

"The shoot of No. 2 was 12 inches long from its point of departure from the parent cane. This shoot was not so developed, nor were the roots quite so numerous or grown to the same length as those of No. 1. There were, however, seven

FIG. 4.



Sugar Cane Roots.

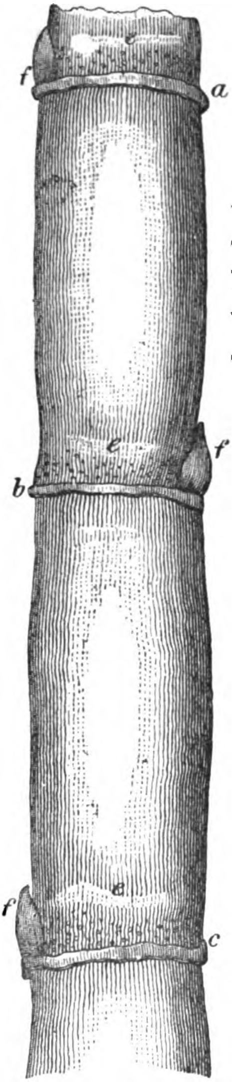
distinct fleshy roots, apparently also growing out of the bottom of the shoot; three of these averaged 6 inches in length, the others being much smaller. The fleshy roots are brittle and have a long tube running down the centre; occasionally they are pointed at the tip, at other times they are blunt. The surface is rough, and adhering grains of sand are distinctly visible without the aid of a lens.

"When these fleshy roots are found deep in the ground, that is to say when they belong to old canes, the tips only are succulent, the connecting portion being more or less shrivelled, and lateral smaller fleshy roots are thrown out at right angles at the tips. For its successful growth the cane requires a large amount of moisture, and it is very probable that these roots are thrown out at a period of its growth when the moisture contained in the parent plant is becoming exhausted. When plant-cane is put into moist soil it appears to swell, probably on account of the moisture it absorbs, and it does not shrink until the period of its function as a reservoir has ceased and decomposition sets in. On the other hand, when plant-cane is put into dry soil, the cause of the slowness of its growth (or rather the long dormant state) is due to the absorption of the moisture in the plant by the soil. Under ordinarily favourable conditions the functions of the fleshy roots would probably be to supply the plant with moisture.

"The experiments show that the root development of the cane is very great; they show also that when cane is planted deeply under ordinary circumstances, more time is necessary for the shoot to appear above ground; but that in the meanwhile the roots are not idle, for the fleshy ones, which in all probability form the mainstay of the future stool, develop very freely."

The number of joints on the stalk or cane proper varies from 40 to 60, sometimes even 80 in the Brazilian cane; but there are much fewer in the Otaheite, whose joints are farther apart, some of the internodes or so-called "joints" being 8 or 9 inches long, while the finer specimens of Brazilian are but 2 or 3 inches in length. The joints vary very much in their dimensions; they are short or long, large or small, straight or bulging; and several of these differences are sometimes found in the same cane. The knots of the canes, seen at *a b c* in Fig. 5, are not simple enlargements, but rings, from ⅛ to ¼ inch wide. Four or five rows of semi-transparent points occupy their circumference, and a circular semi-transparent line *e* very perceptibly divides the outer from the inner joint. At the upper part of this is a slight circular hollow, called the neck, which is terminated by the leaf belonging to the joint. The inner joint is entirely subordinate to the outer one in development and growth. It is destined to perform the most important function of the plant from an economic point of view, for in it the juice, after having undergone various modifications, arrives at the condition which gives it its value as a sugar-yielder. On every joint is a bud *f*, which encloses the germ of a new cane.

FIG. 5.



Cane Stalk.

The sap-vessels are abundantly large, and number more than 1500. They are both simple and compound, exhibiting, when cut transversely, one, two, three, or even four openings. The function of the proper or returning vessels is to separate the peculiar juices proper to the plant in the leaves, the rind, and the interior of the cane. At a point somewhat raised on the stalk, each sap-vessel divides itself into two parts, one continuing in a vertical direction, the other becoming horizontal; the latter grows interlaced with the vertical portion, and, after having formed a partition of about $\frac{1}{6}$ inch in breadth, they unite themselves into a bundle,which pierces the rind, and forms the bud that encloses the germ of a future generation. The buds always grow alternately on the opposite sides of the joints. The partition formed by the horizontal vessels separates the joints internally, and prevents all communication between them, as far as regards the peculiar function of each. The semi-transparent ring which forms a line of demarcation between the outer and inner joint is the weakest part of the cane, and where it is most apt to break. The space left between the sap-vessels, running from one partition to another, is filled by cells, which form the symmetrical disposition of the proper vessels.

The rind of the sugar cane consists of three distinct parts: the rind properly so called, the skin, and the epidermis. The rind is formed of sap-vessels, ranged in a parallel direction, on a compact circular surface. The skin, which is very thin, is at first white and tender; it becomes green and then yellow, as the joint approaches maturity, the period of which is shown by streaks of deep-red. The epidermis is a fine and transparent pellicle, which covers the skin. It is almost always white. At the upper part of the inner joint, the rind divides into two parts. The inner part forms the rind of the following joint. The sap-vessels of the outer part are joined by several others from the interior, with which they rise, supported by a reticulated tissue, and form the leaf, upon which the skin and epidermis of the rind are continued.

The first joint of the sugar-cane requires from 4 to 5 months for its entire growth, and, during this time, some 15 to 20 joints spring from it in succession; the same progression continues as, by degrees, each joint arrives at the period of its growth, which is ascertained by the decay of its leaf: this is the period of its maturation. When the leaves of the first 2 or 3 joints which appear out of the earth have died away, there are then about 12 or 15 leaves at top, disposed in the form of a fan. In its natural state, the cane has at this stage acquired all its growth, and arrived at the usual period of its flowering; if it blooms, the principle of life and generation passes entirely to the development of the parts of fructification. At this time, the joints which spring forth are deprived of their bud, and the sap-vessels, with which they were supplied, pass into the leaf; whence it happens that, as the number of these vessels is constantly diminishing, the joints in a similar proportion become longer, and their rind thinner. The last joint, which is called the "arrow," is 4 or 5 feet long; it is terminated by a panicle of sterile flowers, which are 18 or 20 inches high. If the period of flowering is delayed by cultivation, then the principle of life passes to the generation of new joints, and this continues till the sap-vessels of the stole become woody, and do not afford a passage to the watery juices. Under cultivation, usually very few of the canes flower at all; exceptions occur on some soils when the canes are planted early, and their vigorous growth is suddenly checked.

An excellent idea of the perfect plant may be gained from the frontispiece, which shows a plantation of black Tanna canes.

Range.—The sugar-cane has a wide range, succeeding in almost all tropical and sub-tropical countries, and reaching an elevation above sea-level amounting to 4000 feet in the South Pacific, and 5000 to 6000 feet in Mexico and South America. It is cultivated in many parts of the level country in India and China as far as 30° or 31° N. lat. Its exact geographical range may be more conveniently studied from the chapter dealing with the production, commerce, and local details of each country growing sugar.

Climate.—Climate has a very pronounced effect upon the commercial value of all plants whose secretion-products are sought to be availed of, and the sugar-cane forms no exception. This latter plant thrives to the greatest perfection in a warm moist climate, with moderate intervals of hot dry weather, tempered by refreshing sea-breezes. Its most luxuriant development is always to be observed on islands and sea-coasts, leading to the supposition that the saline particles conveyed to it by the winds are congenial to its taste; but perhaps a more weighty reason for the exuberance of the plant in such situations is to be found in the moisture which accompanies the sea-breezes, even in the hottest and driest weather. The cane attains its greatest perfection within the tropics; cold in any degree opposes its growth and development, hence it cannot be successfully cultivated in Europe, except in a very prescribed district of Spain. Even in Louisiana, the frost often sets in before the planters can gather the crop, and so affects the cane-juice that it can no longer be induced to crystallise, unless the canes can be cut and manufactured before a thaw occurs.

This singular change in the nature of the juice is occasioned by the fluid contents, the saccharine and the nitrogenised principles, of the various cells or organs bursting their bounds, and becoming intermingled the one with the other. While the frost continues, the low temperature prevents the possibility of fermentation setting in; but should a thaw intervene, the temperature of the air is raised sufficiently high to permit viscous fermentation taking place, which will altogether prevent the crystallisation of the juice if subsequently concentrated. If the thaw or period of comparatively warm weather has sufficient duration, this viscous fermentation continues until all the sugar contained in the juice is inverted, and the commingled fluids have resolved themselves into a viscid mucilaginous matter, possessing neither sweetness nor acidity. This will occur to the juice of the yet uncut cane; but it also happens to expressed juice under other circumstances. Juice which has become affected in this manner cannot be made into crystallisable sugar, and is valuable only for distillation to produce rum. In the upper districts of

India also, frost frequently does great harm to the cane crops.

It is obvious, therefore, that the sugar-cane is essentially a tropical plant, requiring the strong light and great heat which can only be found in the tropics. But these conditions alone are not sufficient for successful cane-culture. Rain at the proper season is equally necessary, though it may be to a great extent replaced by a proper system of irrigation ; on the other hand, rain at the wrong season, i. e. when the canes are maturing, if in great quantity, may do much mischief. As the canes are approaching maturity, 2 or 3 months of hot and fairly dry weather are exceedingly beneficial, bringing the juice to the highest degree of sweetness, and assuring a large yield of fine sugar ; slight showers at long intervals serve to maintain the vigour of the plant without appreciably weakening the juice. In the case of renewed vegetation being caused by rains after a drought, if it occur in a locality where frost is not to be feared, it will sometimes be advantageous to leave the canes on the ground much later than usual, as the juice will gradually become much richer than it can be immediately after the rain.

On the other hand, should an alternation of sunshine and rain, which for the space of 5 or 6 months has induced a luxuriant vegetation, be followed by a long-continued drought, the growth of the plants and ratoons will be prematurely checked, and they will often, under these circumstances, show a disposition to arrow. Should they now be cut, the juice will probably be found of good quality, and easily made into sugar, the only attendant evil being its deficiency in quantity, owing to the small size which the canes have attained. In such cases, it might be thought advisable to cut the canes, rather than permit them to remain on the soil ; but such a course is often impracticable, for the estate is not yet prepared for it, and even if it were, the planter would not be justified in thus running the great risk of a change in the weather at a season when long experience has taught him to expect it, and thereby jeopardise the whole year's labour, for with a return of rain, vegetation would immediately revive, and then the evil of having juice poor in saccharine matter would be added to that of unusually small canes.

When a drought sets in only a short time before the season for commencing to reap the crop, that is, after the canes have attained their ordinary growth, the effect is eminently beneficial, for it really causes an inspissation of the saccharine contents of the cells by the evaporation of their water. Cane-juice under such circumstances has a considerable density, and is often of great purity. But if the drought, at whatever age of the cane it may have commenced, should continue beyond the time necessary to produce the effects just mentioned, the leaves of the plant turn yellow, the stem assumes a red and scorched appearance, and not unfrequently splits, or becomes hollow from a contraction of its cellular structure. The canes then are said to be "burnt." The juice then obtained is greatly reduced in quantity, and its quality is considerably altered. In extreme cases, it is strongly acid, but it varies much in this respect. Frost will likewise cause canes to burst.

Soil.—The question of the suitability or unsuitability of a soil for producing a certain crop resolves itself into two distinct heads, one being the physical character of the soil, the other its chemical composition. The latter is best considered under the subject of manures, leaving the former only for discussion at the present moment. It is not too much to say that the first essential in a fertile soil is the capacity for absorbing abundance of air; at the same time, the friability or porosity of the soil must not be so excessive that no moisture is retained. Clay soils are objectionable from the former cause; sandy ones, from the latter. The decomposed granite formation so general in the Straits Settlements is always found to afford really desirable land for sugar culture, being well fertilised by a proportion of decayed vegetable matter. In both East and West Indies, there abounds a kind of soil called "brick-mould," which is considered the most advantageous of all for sugar-planting. It is composed of a mixture of sand and clay, in such proportions that air and water can penetrate to some depth with facility, thus constituting a marl which can be hoed, dug, or ploughed with comparative ease. Much depends upon the character of the clay present, and upon the amount of vegetable matter undergoing decay. A great deal of this "brick-mould" soil is in the best possible physical condition for agricultural purposes. Its property of retaining moisture, even in the hottest season, is quite remarkable, while in heavy rains, the water escapes quickly wherever drains exist; thus the soil is always moist without ever being wet. These qualities, added to the ease with which it can be broken up, and its constant power of recuperation from the air, render it esteemed and sought after before all others. But many an acre of rich heavy clay might be converted into equally valuable land by the application of sand: if sea-sand, so much the better. Deep black moulds are less suitable for cane culture, tending to produce exuberant plants, rather than a rich and plentiful juice. Some of the very best sugar is produced on limestone soils, though they do not promise great fertility.

In the Straits Settlements, Demerara, Louisiana, and other places, it often occurs that lands are strongly impregnated with saline matter, which causes the cane to grow most luxuriantly, but affects the juice (and consequently the sugar made from it) very prejudicially. In Province Wellesley, quite salt sugar has been produced in the first year from such land, and the soil of the Sunderbunds proved to be so very salt that the sugar estates had to be abandoned. In Demerara, also, infinite trouble and loss result from the same cause. Dr. Ure quotes an analysis of a sample of cane-juice from New Orleans, showing the following remarkable composition:

in 10 English gallons, of 231 cubic inches each, of juice, marking 8½° B., there were 5¾ ounces of salts, consisting of—

Sulphate of Potash	17·840	grammes	(= 15·44 grains each)
Phosphate of Potash	16·028	,,	,,
Chloride of Potassium	8·355	,,	,,
Acetate of Potash	63·750	,,	,,
Acetate of Lime	36·010	,,	,,
Gelatinous Silica	15·270	,,	,,
	157·253	(= 5·57 ounces avoirdupois)	

To the large proportion of deliquescent saline matter (of which one-half, he says, remains in the sugar), the analyst very properly ascribes the deliquescence and deterioration of the sugar, when kept for some time, or transported.

Where salt is present in the land, as from the overflowing of the tides, nothing can be done but making "bunds" to keep out the salt water, and establishing a good system of drainage. By these means, and by keeping the soil well turned up, the excess of saline matter will in a crop or two be carried off by the rains; also, in part, by the quantity taken away in the cane or other crop grown on the land. Of course, this will only be the case where the soil is not of so sandy and porous a nature as to admit of the salt or saltish water soaking up through it during spring tides. When once the cane has imbibed these undesirable salts, they become incorporated in its juice, and cause endless trouble and expense to get rid of them. The only course to be pursued with such land is, after bunding and draining it properly, to plant Indian corn, Guinea corn, or Guinea grass on it for 2 or 3 years, until the saline matters have become in a degree exhausted; then canes may be planted without fear.

The remedies for the physical defects of soils are thorough tillage and perfect drainage, without which heavy crops are an impossibility.

Tillage.—The question of tilling the soil is one which every cultivator is bound to study; and in a branch of agriculture which demands an enormous amount of labour carried on under conditions where labour is costly and rendered unusually arduous by a tropical climate, every contrivance which will facilitate the working of the soil and thus reduce the number of hands required on that score, should be welcomed by the cane-grower.

In the great development of steam agricultural machinery which has taken place in the last quarter of a century, the needs of colonial growers have not been neglected, and excellent machinery is in the market for dealing with the heavy soils usually found on sugar-cane estates.

Fallows and tillage may be considered together, as there is very little good in allowing land to lie fallow (unoccupied by any crop) without subjecting it to thorough tillage, so as to open it up, and expose it thoroughly to the action of the air. The importance of air to the soil has already (p. 28) been insisted on. Green-soiling is probably more beneficial than merely allowing the land to lie fallow.

Manuring.—Most intimately connected with the subject of soils is that of manures or fertilisers, the whole object of manuring being to supply to the plant those chemical constituents which the soil is deficient in. The sugar-grower must never lose sight of the end for which he is growing the plant, and his efforts must be directed to the production, not of the tallest and stoutest canes, but of the greatest possible quantity of crystallisable sugar. Extended experiments on this branch of the cane-sugar industry have yet to be made; but in the beet-sugar culture, as will be described farther on, prolonged trials have proved that it is by no means the finest roots which yield the most sugar.

Composition of the Canes.—To proceed logically, before commencing to discuss what cane-manures should consist of, it will be necessary to consider the composition of the canes which are to be grown, and the composition of the soils which are to grow them; having thus established what the requirements are, the next question will be the best and most profitable mode of supplying the deficiency. In this connection, the name of Dr. T. L. Phipson, of Putney, is known to all sugar-planters, from his valuable pamphlet on the Agricultural Chemistry of the Sugar-cane.

The average composition of the fully developed sugar-cane is fairly represented by the following analysis :—

Water	71·04	Derived almost wholly from the air.
Sugar	18·02	
Cellulose	9·56	
Albuminous matters	0·55	
Fatty and colouring matters	0·35	
Salts soluble in water	0·12	Derived from the soil.
,, insoluble ,,	0·16	
Silica	0·20	
	100·00	

Therefore 1000 tons of cane take up from the soil rather less than 5 tons of mineral ingredients, and if the soil cannot supply these 5 tons in a form capable of being assimilated, a full crop of sugar cannot be raised. About 1 ton of nitrogen is required to form the albuminous matter of 1000 tons of cane. Manures deal only with the matters supplied through the soil, except in supplementing the amount of nitrogen thus provided. The nature and relative proportions of these mineral ingredients, which are derived from the soil, are ascertained by analysis of the "ash" (the residue left after complete burning) of the full-grown entire cane. Much discrepancy exists in the various analyses of cane ash that have hitherto been made, the cause of which has been proved to lie partly in the different ages of the plants dealt with, and is perhaps due, in some cases, to variety of soil, and to omitting the leaves of the cane from consideration. Dr. Phipson gives the following as the rough average composition of the ash of the ripe cane and its leaves :—

Silica	43·0
Phosphoric acid	6·0
Sulphuric acid	8·0
Chlorine	4·5
Lime	10·0
Magnesia	6·5
Potash	18·0
Soda	2·0
Oxide of iron, manganese, and loss in analysis	2·0
	100·0

It may be well to compare the subjoined analyses of the ashes of 12 different specimens, by Dr. Stenhouse:—

	Trinidad.				Berbice.			Dem-erara.	Gre-nada.	Jamaica.		
	1	2	3	4	5	6	7	8	9	10	11	12
Silica	45·97	42·90	46·46	41·37	46·48	50·00	45·13	17·64	26·38	52·20	48·73	54·59
Phosphoric acid	3·76	7·99	8·23	4·59	8·16	6·56	4·88	7·37	6·20	13·04	2·90	8·00
Sulphuric acid	6·66	10·94	4·65	10·93	7·52	6·40	7·74	7·97	6·08	3·31	5·35	1·94
Lime	9·16	13·20	8·91	9·11	5·78	5·09	4·49	2·34	5·87	10·64	11·62	14·36
Magnesia ..	3·66	9·88	4·50	6·92	15·61	13·01	11·90	3·93	5·48	5·63	5·61	5·30
Potash	25·50	12·01	10·63	15·99	11·93	13·69	16·97	32·93	31·21	10·09	7·46	11·14
Soda	..	1·39	..	..	0·57	1·33	1·64	..	..	0·80	..	..
Chloride of potassium ..	3·27	..	7·41	8·96	..	..	..	10·70	11·14	..	16·06	0·84
Chloride of sodium ..	2·02	1·62	9·21	2·13	3·95	3·92	7·25	17·20	7·64	4·29	2·27	3·83

The first seven were all fine canes with the leaves; No. 8 had no leaves; No. 9, but few leaves; No. 10 was in full blossom, and had been manured with pen manure; No. 11 were old ratoons, manured in the same way; No. 12 were young Mont Blanc canes, manured with pen manure, guano, and marl.

By comparing these elements together, it will be seen that the largest figures are those of silica, potash, lime, and phosphoric acid; but sulphuric acid and magnesia appear to have their importance also, whilst chlorine and soda, though represented by comparatively small figures, are usually present as chlorides of potassium and of sodium to the extent of 4 or 5 per cent. The principal substances, therefore, required to be provided in an available state in a cane soil are potash, silica, phosphoric acid, sulphuric acid, lime, and magnesia, besides a certain amount of nitrogen beyond what the plant can secure from the atmosphere. The oxides of iron and of manganese are, perhaps, also essential.

The relative importance of each substance in particular is a difficult problem to solve. Experience shows that the composition of the ash of any plant varies considerably with the period of the year at which the plant is cut, and the parts of the plant that are burnt for analysis; so that it is by no means an easy task to state with scientific accuracy what substances any plant takes in largest quantities from the soil. But it is a fact of the greatest interest that, for a given plant, the mineral ingredients derived from the soil are constantly found in the same relative proportions; and this law holds good for the various portions of a plant, when considered in a state of maturity, i. e. when each portion has done all the work allotted to it. Dr. Phipson is undoubtedly right in saying that the analyses of the mineral ingredients of plants burnt after they have arrived at maturity, no matter where they have been grown, must generally coincide, and can alone teach with accuracy what any plant takes from the soil. He found that the analysis of the ash of some Virginian tobacco grown in the Royal Botanical Society's Gardens in London, presented precisely the same composition as that grown in America; so that neither change of soil nor of climate had influenced the relative proportions of mineral matter and organic matter, nor those of the principal ingredients: the plant had taken from the soil of London the same materials, and in the same relative proportions, as from the soil of Virginia. But it must not be forgotten that the sugar-cane possesses a power of absorbing an abnormal quantity of salts when such are presented to it in the soil, a quantity far in excess of its needs, and to the detriment of its juice. This has been already referred to under Soil (p. 30), and is illustrated in Nos. 3, 7, 8, 9, and 11 of Dr. Stenhouse's examples (p. 33).

Composition of Cane Soils.—The next question is the composition of cane soils. In illustration of this, reference may again be best made to Dr. Phipson's analyses of two West Indian soils, one (A), from a new estate in Jamaica now under canes for the first time; the other (B), from a plantation in Demerara which has been worked for more than 15 years consecutively. A valuable lesson is to be learnt from these analyses alone, but some others are given farther on. To the eye of the most experienced planter or chemist, there was scarcely any appreciable difference in the aspect of these two soils: the sample A was merely a clay of rather darker colour than B, but nothing in their external appearance could have indicated their widely-different composition:—

TYPES OF CANE SOILS.

	A.	B.
Moisture	12·25	18·72
Organic matter and combined water	15·36	6·03
Silica and insoluble silicates	48·45	68·89
Alumina	13·80	2·50
Oxide of iron	6·72	2·60
Lime	0·99	0·08
Magnesia	0·29	0·25
Potash	0·11	0·10
Soda	0·70	0·09
Phosphoric acid	0·10	0·03
Sulphuric acid	0·30	0·03
Chlorine*	0·51	trace.
Oxide of manganese, carbonic acid, and loss in analysis	0·42	0·68
	100·00	100·00
Nitrogen (in organic matter)	0·31	0·05

Persons accustomed to discuss analyses of soils can easily see that A possesses everything that is requisite to grow canes for a considerable number of years, whilst B is a soil fast approaching exhaustion. Dr. Phipson calls attention to the greater amount of organic matter (humus), nitrogen, lime, and phosphoric acid in A, and to the important fact that the quantity of lime (0·08) in B is far below that of the magnesia (0·25). This he has ascertained to be a very bad sign in cane soils, and it will probably be found to be so in soils devoted to the cultivation of almost any other plant. Indeed, he deduces from the results of a numerous series of analyses carried on in his laboratory for some years past, that the degree of exhaustion which a cane soil has undergone can to

* The quantity of chlorine is unusually high, which is accounted for by the proximity of a salt spring.

a great extent be ascertained by comparing the relative amounts of lime and magnesia yielded to analysis. In support of this, he gives analyses of four samples from the same estate in British Guiana, taken from various portions :—

	Cultivated			
	10 to 15 years.		Upwards of 60 years.	
Lime (per cent.)	0·43	0·64	0·11	0·40
Magnesia	0·32	0·50	0·36	0·51

These suffice to show how the lime has disappeared (from the same soil) by prolonged cultivation of the cane, whilst the magnesia has remained pretty much as it was. In fact, it is quite possible in some cases to judge very approximately of the number of years a soil has been under canes, by a careful analysis of the soil, more especially when the analysis can be compared with one made of the same soil from some uncultivated spot on the borders of the plantation.

Dr. Phipson states as an axiom in cane culture that when the quantity of lime has diminished so much by prolonged culture as to be present to the extent of only 0·1 per cent., and then amounts to no more than ⅓ of the magnesia present (knowing that originally the lime was not only equal to, but higher than, the magnesia), we may rest assured that the crops of cane on this soil will fall off year by year, and that the most careful system of manuring will be necessary to place it again in its former lucrative condition.

This is a state of things which actually exists over a very considerable portion of the cane soils of our colonies. The annexed table (p. 37) of the composition of soils from numerous plantations, analysed by Dr. Phipson, is very interesting.

R. H. Harland has recently published an analysis of a soil from the Camarines Sur district of Luzon, in the Philippines, where the cane grows luxuriantly often to a height of 12 feet, one stool producing 4 or 5 canes, and giving sugar of

ANALYSES OF CANE SOILS.

	Demerara.								Barbados.		Queensland.
	A	B	C	D	E	F	G	H	I	J	K
Moisture	26·00	23·00	26·70	14·12	25·00	13·88	22·64	16·00	19·00	13·00	23·10
Organic matter and combined water ..	5·90	5·30	8·30	6·17	8·86	32·39	7·06	7·88	9·11	10·50	12·56
Silica and silicate of alumina	61·68	64·44	58·02	68·08	57·49	46·50	68·00	68·22	65·00	60·00	41·42
Lime	0·64	0·11	0·47	0·17	0·28	0·48	0.45	0·22	0·25	0·30	0·56
Magnesia	0·50	0·36	0·50	0·37	0·36	0·30	0·31	0·30	0·30	0·47	0·26
Sulphuric acid	0·01	trace	0·01	0·16	0·04	0·04	0·20	0·12	0·03	0·03	0·04
Phosphoric acid..	0·08	0·05	0·19	0·07	0·09	0·03	0·16	0·10	0·07	0·06	0·06
Potash and soda..	0·11	0·10	0·12	0·54	0·26	0·24	0·30	0·10	0·10	0·16	0·20
Chlorine	trace	0·02	0·01	...	0·01	0·06	0·05	trace	trace	trace	0·02
Oxide of iron, alumina, manganese, &c.	5·08	6·62	5·68	10·32	7·61	6·08	0·83	7·06	6·14	15·48	21·78
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

OBSERVATIONS.—A, B, and C are soils in adjacent plantations of the same estate. A has been in canes about five years; C for a somewhat longer period—10 to 15 years; and B for about 60 years. D and E are from adjacent estates, far distant from the former; they have been in canes 20 to 25 years. F is a new soil, now growing ferns only. It is about to be planted with canes as an experiment. This soil, when it has been dried, burns like peat. G and H are from plantations only separated 100 feet from each other by a canal. G is new soil; H has been in canes about 15 years. I and J are good average specimens of Barbados soils, and K is a sample of red clay soil from Queensland, Australia.

superior quality. This soil is extremely fertile, as shown by its composition:—

Silicious matter	53·39	per cent.
Alumina	13·16	„
Oxide of iron	4·80	„
Oxide of manganese	0·10	„
Oxide of magnesia	0·42	„
Potash and soda as chlorides	1·14	„
Lime	1·60	„
Sulphuric acid	0·09	„
Phosphoric acid	0·25	„
Carbonic acid	traces.	„
Organic and volatile matters	25·05	„
	100·00	
Moisture in sample before drying	6·79	

This does not materially differ from Dr. Phipson's sample A, except that the essential ingredients are present in still greater quantity; hence the wonderful fertility of the district, where canes are grown for years in succession without manuring.

That soils in hot countries, especially in tropical climates, contain more organic matter than those of our latitudes is a common supposition; but it is evident from the analyses that such is not the case with cane soils. The figures which include organic matter and combined water owe a great deal to the latter, which is driven off by heat with the organic matter. In fact, putting aside soils of a peaty nature, it is rare to meet with cane soils yielding more than from 2 to 4 per cent. of humus or vegetable mould. The loss of this organic matter has produced sterility in Java, by causing a want of porosity, of nitrogen, and of carbonic acid. Hence the danger of applying lime to these soils, much as most of them require it, since it tends to destroy the humus in a very short time. In European climates, lime is always backed up by a liberal supply of organic manure; and this latter is even more essential in the tropics than with us.

Manures obtained from Foreign Sources.—The clays of

Java and Demerara, when properly drained and worked, will yield good crops of canes without manure for at least 10 or 12 years. In Jamaica, the same kind of clay will yield well for about 15 years; and the red porous clay of South Australia, for 15 to 20 years. After these periods, the yields will become less and less each season; and for some years past, it has been customary to dose the soils with sulphate of ammonia and Peruvian guanos, which will usually raise the produce for the two or three seasons immediately following, but after this, their stimulating effect will cease almost completely, and the soil will be then in a worse condition than before. Generally, it is preferable to try and restore these partially-exhausted soils by a rational system of culture, rather than take in new land farther from the boiling-houses.

The following useful information on sugar-cane manures occurs in a report by Dr. Morris, of Jamaica:—

1. Manuring the sugar-cane with only the mineral constituents of manures is useless, the cane not having the power, as stated by Ville, of assimilating free nitrogen from the air.

2. The addition of readily available nitrogen to the purely mineral manures produces large increases in the weight of canes grown; but excessive dressings (over 3 cwt. of sulphate of ammonia to the acre) cause a marked decrease in the richness and purity of the juice.

3. Under the climatic conditions existing at the Dodds estate during the years 1885, 1886, and part of 1887, and upon the soil of the experimental fields, nitrate of soda was decidedly inferior to sulphate of ammonia as a source of nitrogen.

4. The addition of superphosphate in moderate proportions to manurings of nitrogen and potash, causes a very great increase in the yield of canes, and in the available sugar in the juice per acre.

5. The addition of superphosphate in quantities beyond that capable of supplying about 75 lb. of "soluble phosphates" per acre (equivalent to about 16 per cent. of "soluble phosphates" in the ordinary manuring of one ton to five acres of commercial sugar-cane manures), does not produce a corresponding increase, and if applied in very large proportions may even reduce the produce below that obtained from manuring with nitrogen and potash only.

6. The addition of potash to manurings of superphosphate and nitrogen, may not increase the yield of total produce to any very marked extent, but from its tendency to increase the development of the canes causes a larger increase in the amount of "available sugar" in the juice per acre.

7. The presence of potash in the manures in rather high relative proportions apparently tends to increase the amount of sucrose in the canes. This point is worthy of further investigation.

8. The presence of an excess of potash in the manures does not injuriously affect the purity of the juice by increasing the glucose, or appreciably the amount of potash salts contained in it.

In the selection of artificial manures, the Barbados planters have shown much interest. During the last two years, under the direction of Professor G. B. Harrison and Mr. J. R. Bovell, superintendent of Dodd's Reformatory, a series of practical trials have been carried out to ascertain the relative value of the different fertilisers used for the sugar cane, and the results obtained have been most carefully reported upon by them to the Barbados House of Assembly.

One particularly interesting group of trials was arranged to show what form of nitrogenous manure can most profitably be used.

The following extract shows what manures were applied and the results :—

		Cutting.	Produced* available lb. of Sugar.	Net pecuniary result.
		$		$
94 lb. soluble phosphates, 6 lb. reverted ,, 30 lb. potash +	50 lb. nitrogen from sulphate of ammonia.	13·83	7517	profit 4·77
Do.	75 do. ..	18·01	7812	,, 4·28
Do.	100 do. ..	22·21	7789	loss 0·21
Do.	50 Nitrogen from nitrate of soda ..	14·03	7368	profit 2·64
Do.	75 do. ..	18·31	7111	loss 4·77
Do.	100 do. ..	22·61	7087	,, 9·39
20 loads of farmyard manure	.. ..	40·00	8372	,, 10·71
89 lb. soluble and assimilable phosphates, 22 lb. potash, 30 lb. nitrogen,	applied in the form of Ohlendorff's early cane manure and dissolved Peruvian guano	12·62	8292	profit 15·67
		PER ACRE.		

"The following points in these results are worth carefully noting—viz., that by augmenting the doses of sulphate of ammonia an increased yield was obtained, but not sufficient to compensate for the extra cost; that nitrate of soda as a sugar cane manure proved, in accordance with previous experience, inferior to sulphate of ammonia, and when applied in large doses gave a decided loss; that farmyard manure produced the largest crop, but, owing to the high cost of applying such a bulky manure, resulted in a heavy loss; that the most favourable result was produced by Ohlendorff's early cane manure and dissolved Peruvian guano, which with the moderate outlay of $12.62 gave a net profit per acre of $15.67. The individual canes grown with these manures were the largest, and contained only 9·84 per cent. of fibre, while the average is over 12 per cent.

"A very important point gained by the early manuring of the cane with suitable manure, is that by so doing, the healthy growth of the young plant, upon which the future crop so much depends, is ensured, and if a drought ensues in March, April, May, and June, it will be found that such plants will withstand its effects much better than the unmanured ones.

* Available lb. of sugar per acre means the number of lb. of crystallisable sugar per acre indicated by the polarisation of the juice, less 1½ times the lb. of glucose formed by chemical analysis.

"Following is an analysis of Ohlendorff's early cane manure: sample drawn from 100 tons ex *Atlantis*, Nov. 8th, 1886:—

Moisture	13·24
a Ammonium sulphate	8·42
b Organic matter	22·28
Sand and silica	4·46
Monocalcium phosphate	11·53
c { Equal to tricalcium phosphate rendered soluble	(15·29)
c { Reverted phosphates	3·59
Insoluble phosphates	·99
Calcium sulphate	21·96
d Alkaline salts, &c.	15·53
	100·00

a Contains Nitrogen 2·00 = ammonia	2·43
b ,, ,, 2·06 = ,,	2·50
a and *b* contain nitrogen (total)	4·06
Equal to ammonia	4·93
c Assimilable phosphates	18·88
d Contains potash	8·34

"Next we will consider the selection and application of the artificial manure to be given in June, July, and August. As at this period of the year the cane has well developed its roots, and is in a state of very active growth, we require a much more soluble and active manure than that used at an earlier period.

"The manure should contain a fair proportion of phosphates and potash, one with a larger amount of the latter being chosen if the earlier manuring has not supplied it. In selecting the manure great attention should be paid to the fineness of its particles and their intimate state of admixture, as well as to the complexity of its composition; the regular and even distribution of the manurial plant-food at this season being of the very greatest importance. Avoid the mistake of throwing the manure into the cane bunch. It is useless there, nay, even injurious, until it has been washed into the surrounding soil. The young cane roots, by the extrēmities of which absorption of plant-food alone takes place, are now away from the middle of the bunch, and are finding their food in the banks of the holes.

"Chemical or artificial manures must at all times be applied with the greatest care; they should, preferably, be first thoroughly mixed with two or three times their bulk of dry earth, so as to facilitate their uniform application and distribution, and should be used in comparatively small quantities, say 2 cwt. at a time. You will get a far better return by applying any good artificial manure in two dressings of 2 cwt. each, than in one of five, and you will have the additional advantage of saving some 12*s.* to 15*s.* per acre in the cost of manure. You may object that it will cost more to apply manure in two dressings than in one. I reply that in this island labour is cheaper than manure.

"The following is a detailed analysis of Ohlendorff's dissolved Peruvian guano, which well illustrates its complex character:—

Soluble in Cold Water.	
Moisture	9·058
Sodium chloride	1·540
a Potassium chloride	1·305
b Potassium nitrate	·085
c Potassium sulphate	2·639
Magnesium sulphate	4·464
d Monocalcium phosphate	15·570
e Ammonium sulphate	30·341
f Organic matter	·348
Soluble in Ammonium Citrate, sp. gr. 1·09.	
g Tricalcium phosphate	2·217
Iron peroxide	·368
Calcium sulphate	20·235
Magnesia	·172
h Potash	·055
Silica	1·138
j Organic matter	2·402
Insoluble in Water and Citrate.	
Tricalcium phosphate	·571
Iron peroxide	·107
Magnesia	·027
k Potash	·024
Silica	5·329
l Organic matter	2·005
	100·000

a and *g* equal to assimilable phosphates	22·847
a, *b*, *c*, *h*, and *k*, total potash	2·367
a contains nitrogen..	·011
e ,, ...	6·440
f ,, ...	·170
j ,, ...	·636
l ,, ...	·157
a, *e*, *f*, *j*, and *l* contains total nitrogen	7·414
Equal to ammonia	9·000"

Amongst the larger manufacturers of fertilisers specially designed for sugar-cane, Messrs. E. Packard & Co., of Ipswich, stand in the front rank. Mr. George Hughes, formerly chemist to the Agricultural Society of Barbados, is now associated with this firm in the manufacture of sugar-cane manures, and they have thus the very great and exclusive advantage of Mr. Hughes' scientific knowledge and long practical experience in cane cultivation in the West Indies at their disposal. Mr. Hughes annually visits these colonies, and is willing to investigate the properties of the soil of any planters desiring it, and will send out to them manures especially suitable to the requirements of their soil. Hughes' improved sugar-cane manures, as manufactured by E. Packard & Co., are well known in the West Indies, and are well suited to any sugar-growing colony.

Sulphate of ammonia, applied by itself in large quantities, acts as a poison to plants; in smaller doses, its action is that of a powerful stimulant. Much the same remarks apply to nitrate of soda. The plant receives a momentary stimulus, only to suffer the greater relapse in a short time afterwards. Moreover these nitrogenous manures do great harm in another way, by increasing the albuminous matters in the cane-juice, to the double detriment of the sugar, first by reducing the amount of sugar in the plant, and next by destroying a portion of the sugar in the already-extracted juice during the process of manufacture. The elucidation of this action of nitrogenous matters in the juice will receive attention in another place; it must suffice here to state the fact.

No references to manures obtained from foreign sources would be complete without attention being called to the fertilisers derived from the sea. Peruvian guano and preparations thereof, as is well known, are composed largely of the excrement of birds, whose only food is fish; and cargoes of this once famous fertiliser have proved themselves of late years to be very irregular in quality. The chemical composition of the fish itself never varies; reliance in this respect may therefore with confidence be placed upon its uniform value. The production of guano and fertilisers from this source has never been attempted upon anything approaching the large scale attained by Messrs. J. Jensen & Co., Limited, of Brettesnæs, Lofoten, Norway. The mass of fish which, as "raw material," annually comes to their hands for manipulation, may be imagined from the fact that, according to Professor Huxley's computation, there are no less than 120,000,000 cod fish in a square mile of the shoals which frequent the Norwegian coast in the fishing season. The herring exists in the same waters in far greater numbers, and Messrs. Jensen manufacture guanos from both these fish.

From their organic and highly concentrated nature Jensen's guanos are well suited as fertilisers for the sugar cane. According to Professor Harrison, of Barbados, the best results are to be obtained by their use during the earlier stages of the canes' growth, at the rate of 4 to 5 cwt. per acre, and for plant canes on light soils.

Without giving details of the intermediate steps of the analysis (which are not really required by the buyer or user of manures), the following percentages of the manurial elements necessary for the perfect fertilisation of the sugar cane are found in Jensen's guanos:—

	"C. P." Brand.	"H. P." Brand.
Ammonia	6½ to 7½	7 to 9
Phosphate of lime ..	20 „ 22	10 „ 12
Potash	7 „ 8	7 „ 8

The first-named brand is manufactured from codfish, the second from the herring. Both articles contain under 5 per cent. of moisture and under 1 per cent. of insoluble non-fertilising ingredients. These guanos are natural fertilisers, and not artificial manures; and they are not "dissolved" or treated with acid in any way. The nitrogenous organic particles of which they are composed dissolve gradually under the influence of moisture, and as such dissolution takes place the plant is fed. A soluble and rapid-acting manure is not only unnecessary but is positively harmful to the sugar cane, which requires its supply of manurial properties to be gradual.

It will be noticed that the percentage of potash in the above brands singularly coincides with the desideratum mentioned by Dr. Morris, of Jamaica, in his seventh paragraph on page 40 of this work.

Generally speaking, sugar planters cannot do better than by placing themselves, as regards manures, in the hands of the manufacturers named.

Manures Produced on the Estate.—So much for the manures which are derived from foreign sources: now for those which are produced on the sugar estate itself. The one object of the planter is to obtain the sugar from the cane. The cultivation of the plant is merely the end by which this object is attained; it is necessary to feed the plant in order that it may live long enough to secrete a highly saccharine juice; this done, the whole plant (excepting the small proportion of sugar yielded by it) becomes a waste product. To go a step farther, this sugar is not derived from the soil at all, but from the air. Consequently if the whole of the waste products are returned to the fields as manure, the soil, with the aid of proper tillage, should theoretically increase in richness, and produce heavier crops every year. The waste produced on a sugar estate consists of the following materials:—
(1) The "trash," or dead leaves which are stripped from the canes during growth, as well as the "tops," which are not

used for planting; (2) the "begass," or crushed cane from which the juice has been (more or less perfectly) extracted; (3) the "feculencies" collected in the clarifiers, &c.; (4) the "dunder," or wash-waters, containing salts in solution and other matters. To these must be added the night-soil and dung necessarily accumulated on an estate employing many men and cattle.

First, with regard to the "trash." Wray goes so far as to say that he feels quite convinced that if all the trash and begass were ploughed into the soil while yet in a fresh condition, the cane would require no further manuring. This is rather overstating the fact, but the advantage of such a proceeding is undoubtedly very great. The leaves should be hoed in as fast as the trashing proceeds; the operation is described on a subsequent page. This, however, could not be done in localities frequented by the white ant, as the fermenting mass of vegetable matter in the soil would immediately form a nest for that destructive insect. In such cases, the vegetable matter must first be fermented in tanks under sufficient moisture to repel the ants, and may then be ploughed or trenched in between the rows of canes. The same applies pretty much to the cane tops which are not required for planting new ground.

Touching the begass, Wray recommends it to be carried back to the fields by the same carts which bring in the canes, and would have it immediately ploughed or trenched into the soil. In practice, this is very rarely done, despite the volumes that have been written in support of the plan. The reason for this apparent anomaly is sufficiently simple. The sugar factory consumes a very large quantity of fuel, and fuel in the shape of coal or wood is usually very dear and scarce in sugar-growing districts. Hence has arisen the generally-accepted custom of using the begass for fuel, and returning only the ashes (which it leaves behind when burned) to the soil. In this way, a portion of the salts is certainly conveyed back to the soil, but the act of burning has reduced them to an insoluble condition, and their value is thereby greatly diminished. An advantage in burning is the destruction of insect larvæ, and it has sometimes to be resorted to on that account; but it must always be at the expense of the manurial value of the material burnt.

This question of returning the begass to the soil just as it comes fresh from the mill cannot be decided off-hand, as it will depend upon circumstances. These circumstances are that the estate requires both manure and fuel, that the fresh begass will afford either one or the other (but not both), and consequently that the one which is not so supplied must be derived from other sources. The point that then arises for the planter to settle is, which of the two materials (manure and fuel) can be best procured by exterior means. The conditions of each estate will determine the best course to pursue. In any case, the canes must be brought to the mill, and their bulk implies the expenditure of considerable labour in carrying them back to the fields, just at a moment, too, when all hands are fully employed. Viewing the improvements which have lately been made in the preparation of cane manures, and the highly-concentrated form in which they are now supplied, there is little likelihood of planters departing from the old way; and should success attend the newly-invented furnaces for burning undried begass (described on a later page), there will be still greater inducement to adhere to the current custom. This being so, only the ash of the begass can be counted on as manure. This will amount to about 5 cwt. from each 100 tons of cane crushed and burned, and its manurial value will not exceed 8*s*. per cwt. It should be preserved with the other waste under a shed out of the rain till used. There will probably be an additional 5 cwt. of ash from other sources (trash, wood, &c.), worth about 6*s*. per cwt.

Next, the feculencies from the clarifiers, and the skimmings, say together equal to 6 tons (from the 100 tons of cane), should be pressed as soon as collected, and would yield 3 tons of juice and 3 tons of cake; this cake, rich in nitrogen, should be dried, with or without previous fermentation, and would yield half a ton of dry nitrogenous manure, worth 3*l.* The sediment of fermenting-vats, also containing some nitrogen, would weigh say 4 cwt. when dry, and would be worth 10*s.*

Lastly, the "dunder." This, to the extent of two-thirds, being used over and over again daily in making up the wash, would leave one-third to be dealt with as manure. This third would amount to 800 gallons or 4 tons (from the 100 tons of cane). Whether it would be better to take it on to the fields in its liquid state, or first to dry it completely or partially, remains to be ascertained. It would dry to about half a ton, and would contain half of the mineral matter of the crop and some nitrogen (as ammonia), and would be worth about 3*l.* Sooner or later, legislation will step in to prevent the contamination of streams by the present common system of running this liquor into a pond or the nearest brook. Efforts should be made to utilise it for irrigating purposes, or its suspended and dissolved impurities should be precipitated and recovered before it makes its escape to the river.

Green-soiling, Rotation, and Fallows.—There remain to be described the various other methods which modern agriculturists have adopted for maintaining the fertility of the soil.

"Green-soiling" consists in planting beans, peas, lucerne, indigo, or other plants, between the cane-rows (when canes are first planted), and ploughing them into the soil whilst they are green and succulent; this has a powerful effect in fertilising land, and when performed by agricultural implements, may, even where labour is costly and scarce, be practised without any great expense. Indigo is a very valuable plant for such a purpose as this, and may be planted by a drill (in regular lines), just at the commencement of the rains, and, in 2 months after, be uprooted, laid along near the roots of the young canes, and moulded over. The only part of these operations necessary to be performed by hand labour is the uprooting and placing the plants evenly along the cane rows, so that the plough following may cover them over completely and neatly. If the indigo plants are cut to within a few inches of the ground, when they have attained a good height and show a fair bush, instead of being rooted up, they will again spring forth remarkably soon, and furnish another fine bushy plant before the end of the rains; this may then be rooted up and moulded over as the first. This latter plan presents the advantage of two crops being afforded to the soil instead of one, at the cost only of the cutting, which, when the labourers have sharp sickles, is very quickly and neatly performed, and cannot entail any great expense. The indigo plant so applied furnishes a very rich manure for the cane, for which object it is generally appropriated by the natives of India, although not until the colouring matter, forming the indigo of commerce, has been extracted, and the plant becomes partly decomposed. In the Straits, the Chinese who cultivate indigo first extract the colouring matter from the plants, then take them at once, all dripping with moisture from the vats, to the cane patches, where they lay them carefully along the roots of the canes, and then mould over them. Wray states that he has seen Chinese in this manner produce excellent canes, from land so sandy and otherwise unfertile that no European planter would think of growing canes on it. Thus it is in Province Wellesley that, wherever a Chinaman cultivates indigo, he always grows a patch of canes also.

It may be well to mention that indigo must be planted either at the commencement of the rains, or be frequently and plentifully watered at other seasons; hence, wherever the means of irrigation are available, this green-soiling may be practised all the year round. Wray considers it a very cheap and ready means of keeping up the fertility of cane soils; and says it is more especially deserving of the planter's consideration in cases where the begass (from whatever cause) is used for fuel instead of being returned to the soil. Indigo, to grow luxuriantly, requires a generous soil, consequently will only answer expectations where so planted; after the land has been manured, it will spring up vigorously and luxuriantly.

A great variety of plants may be used in the same manner as indigo; but it is very essential to remark that the greatest good can only result from ploughing in the plants whilst quite green and succulent, and that the best time for performing the operation is just before they begin to blossom. In Demerara, the castor-oil plant (*Ricinus communis*) is highly esteemed for green-soiling; and the same may be said of the pigeon-pea (*Cajanus indicus*) in the West Indies and Australia.

Rotation of crops as a means of refreshing the soil has long been known and applied in European agriculture, where experiment was forced upon the farmers at an earlier date by reason of the inferior fertility of their land. In the rich soils of our tropical colonies, exhaustion was longer in making its appearance, and hence has arisen that disposition to adhere to a single class of crop as long as the ground is capable of affording anything like a remunerative return. Some sugar-planters have at last appreciated the advantages to be derived from a judicious rotation, and have benefited much thereby, while their neighbours who persist in extracting a crop of canes from the same field every year are gradually ruining the land beyond all hope of recovery within a reasonable time, and are engendering all kinds of disease in their canes by excessive and ill-advised manuring. In Mauritius, it is now becoming the general custom, after the land has borne canes for 2 seasons, to plant it with maize (Indian corn), arrowroot, manioc (cassava), or peas, allowing a period of 3 years between the cane crops.

Laying-out an Estate.—The laying-out of a sugar estate is a much more complicated affair in Guiana than almost any-where else, as it generally includes provision for drainage and irrigation on a far more perfect scale than is common elsewhere. An account of the operation as conducted in British Guiana will therefore be most valuable. Here the plantations are on a uniform plan. They are generally narrow rectangular strips of land, with a frontage on the coast, a river, or a canal, varying from 100 to 300 Rheinland rods (the Rheinland ruthe or rod is about 12⅓ feet). Exceptional cases occur where extra "façade" (water-frontage) has been allowed, giving the estate more of a square form. Every estate is bounded by four dams: the front dam excludes the sea, river, or canal; the back dam, parallel to the former, excludes the bush-water, which, in heavy weather, is very considerable, and would inundate the cultivation. The clay thrown out in forming the adjacent canals or trenches affords the material of which the dams are formed. Along each of the remaining sides, runs a dam from front to back. These are usually termed "side lines." They serve two contiguous estates, and prevent the influx of water from the sides. Thus the very long rectangular strip of land is surrounded with dams, which, when kept free from bush, answer the purpose of a road round the estate; but the produce is brought to the buildings (often situated in front) by canals. In fact, water transport of produce is universal. The arrangement of the navigation system is very simple. From front to back, through the centre of the estate, there runs a dam called the middle walk, with a canal on each side of it. These are termed central canals, and are wide enough to admit of two punts passing each other. The dam forms a path for the cattle that draw the punts. At regular and comparatively short intervals, branch canals strike off at right angles from the central canals, and proceed to within a rod of the draining or side-line trenches, which are parallel to the side dams before described, and adjacent to them. These branch canals constitute the transverse boundaries of the fields, and navigation canals thus lie on three sides of every field, and admit of canes being carried by a short path to the punts. On some estates there is only a single central navigation canal.

These canals are principally supplied by rain, but in protracted droughts, and especially when they are shallow, they are liable to run short of water: hence, whenever access can be got to creek-, lake-, or bush-water, it is brought from behind to supply the navigation system. In other instances, salt water has to be taken in from the front, when a cane crop cannot otherwise be got off the ground. The drainage of the estate is equally simple. From back to front, and immediately adjacent to the side-line dams, run the two main draining trenches, generally dug considerably deeper than the navigation canals. The small drains, again, cut at distances of 2 to 3 rods apart, commence within a bed of the middle-walk side of the field, and terminate in the side-line draining trenches, being dug with a fall in that direction. The small drains are thus at right angles to the main draining trenches. In the front dam, the sluices or "kokers" are placed. Sometimes there is only one on an estate, but generally two, one at the end of each draining-trench. The main draining trenches are generally connected together by a trench running along behind the front dam.

The different operations and their cost are as follows:—

The area of cane to be grown is assumed as 100 acres, the land having a water-frontage of 100 rods, and being a good clay soil, with a certain amount of bush and sand-reef upon it. The dams are commenced at the beginning of September, calculating by the end of October to have planted the tops, and thus have the advantage of the coming wet season for bringing them on, so that they might be ready for cutting in November of the following year, when the "arrow" would be well off, and the canes sweetest. Operations open with cleaning off the rough grass and weeds on one of the sides of the 100 acres, say the middle walk side. Here a space of 7 rods outside (or on the savannah side) of the

100 acres is lined out. On the 33 rods of bush land, the wood is cut by the cord. Having everything cleared off 300 rods × 7 rods, all the grass and rubbish being packed in a line on the savannah side, so as to form a kind of stop-off to keep any of the little water remaining in the savannah from flooding the work, the next consideration will be making up the dam on the middle walk side. This dam will be 24 feet wide at the bottom, with a top of 8 feet, a height of 5 feet, and a gradual slope on each side of 10 feet, and containing nearly 1200 cubic feet per rod. From the savannah side, 48 feet are lined out; in the centre, line pins are placed so as to form two spaces of 24 feet each, the space on the savannah side being for a trench, 20 feet × 5 feet × 12 feet, which will provide the ground to make up the dam. The other space will be the dam proper. To proceed with this, the blind trench is commenced with, which must be lined out 5 feet × 5 feet, exactly in the centre of the intended dam; all the dirt coming out of this is packed on the empolder side, so as not to be in the way of the men digging the trench. The bottom of the blind trench, 5 feet below the level of the savannah, is thoroughly shovel-ploughed, one shovel of clay lying over the other in perfect rotation.

In commencing to dig the trench 20 feet × 5 feet × 12 feet, the first shovelful of earth must go against the foot of the dam, great care being taken not to allow any to go into the blind trench. Having got rid of this, which is mostly roots mixed with a little clay, the trench can be sunk, all the clay that can be got being thrown into the blind trench. When about a foot of clay is in the blind trench, it should be rammed down tightly, and so on as each fresh foot of clay is thrown in, until the level of the savannah is reached, after which, the centre of the dam 5 feet wide is rammed until it is 5 feet above the savannah. The dam is pared and shaped off, making it 8 feet wide at top and with a slope of 10 feet on each side.

The side-line dam will be the same in every way as the middle walk side one; but digging the side-line trench will give some ground to make up part of the dam with, having cleared off 6 rods wide of grass and roots, in the same way as on the other side. The side-line trench is lined out 14 feet at top. From this, a space of 1 rod is left from where the edge of the side-line will fall, and then the dam is lined out 24 feet wide; the blind trench is dug of the same dimensions and in the same manner as on the middle walk side.

From where the space for the dam stops, a trench is lined out 14 feet × 3 feet × 14 feet. In digging the side line, all possible slope is thrown on the dam side, so that when it is finished there is only 9 feet of bottom; this is quite sufficient to drain 100 acres, and by having a long slope, the edges of the side line are not so liable to fall in. The two side-line trenches afford sufficient ground to make up the dam to 1200 cubic feet.

The side dams being complete, there is now only the back dam to finish to take in the new land. The back dam will be exactly the same as the middle walk dam. The dam-bottom is lined out 24 feet, then 24 feet more (allowing 4 feet from edge of trench to bottom of dam) are taken for the trench, so as not to dig a cross canal in the first field, No. 1, but bring out all the canes on the main navigation trench and the canal between Nos. 1 and 2. Thus the back dam is not weakened by having a trench dug exactly in front of it; this plan also to a great extent prevents the dam from leaking, as when a canal is dug in front of a dam, the first bed of canes suffer very much from the leakage from the dam, and from the navigation water swelling up and overflowing the bed. The trench behind the dam, 20 feet × 5 feet × 12 feet, affords sufficient ground to make up the back dam.

In joining the middle walk and side-line dams to the back dam, the back dam blind trench must be carried through the whole width of the side-line and middle walk dams, so that there may be no division between them, but that they dovetail into one another. In making up the back dam, a space of three rods should have been left opposite to the main navigation trench, to facilitate putting in the back dam koker to supply the navigation with water. The koker is 4 feet × 4 feet × 28 feet long, and has six frames containing 36 cubic feet 9 inches. The gallows-post, windlass, &c., &c., contain about 13 cubic feet 7 inches; the foundation timbers, piles, caps for back of koker, wings, &c., in front, contain 76 cubic feet 2 inches; or a total cubic contents of greenheart timber for koker = 126 cubic feet 7 inches. In addition, there are 300 feet of greenheart slabs, for pauling off wings, back of koker, and foundation: 17 pieces greenheart, 28 feet × 12 inches × 2 inches, for frame, boarding up, &c., and door; 50 lb. 4-in. spikes, small ⅜-in. chain for door, sheaf for hoisting door, &c. If the door of koker is placed 18 feet within the dam from the savannah side whenever it is desired to repair the koker, or in case of an accident, a stop-off in front 8 feet wide can be put in, and will still be in a line with the dam, so that it will have an equal pressure with the rest of the dam, and cost next to nothing in comparison with making up a stop-off if the koker came up to the foot of the dam.

Lining out the middle walk trench is commenced by lining out a space 20 feet wide from the foot of the middle walk dam. On this space, all the ground from the middle walk trench is thrown, so as to form an extra or company dam for navigation purposes, as, if the mules were allowed to travel on the outside savannah dam, it would soon be trodden out of shape and become weak, and any leakage from the dam, with the mules walking about on it, would soon increase, and cause the dam to "shove" down into the trench. This extra dam will also greatly strengthen the outside dam. The middle walk trench is made 14 feet × 4 feet × 12 feet.

The ground from this trench makes up a dam 18 feet wide and about 3 feet high. This must be added to the outside dam in such a manner that no space shall be left between; that is, the two dams, having been pared off, form only one large dam, with no perceptible joining.

Before commencing to dig the cross canals, the wood in field No. 4 is cut and corded, amounting to 200 cords. The 9 cross canals are lined out 12 feet × 4 feet × 12 feet. On the side line, the digging of the canals is stopped 2 rods from the trench, so as to prevent leakage. "Turns" at the canal heads lead into the main middle walk trench.

The small drains are dug 2 feet wide and 3 feet deep. Commencing in field No. 1, 3 rods are measured off from the back dam, and there the first drain is lined out, and so on, placing the drains 3 rods apart. The drains are dug only 98 rods long, leaving 2 rods on the middle walk side of the field, so that the water may not leak out from the middle walk trench. The drains, when finished, are 2 feet on the top and 1 foot at the bottom, having a gradual slope of 1 foot on each paring. In the sand reef, field No. 5, a 4-foot or "tracker," is lined out 4 rods from the middle walk trench, so that it may carry off the water from that side of the field; sand reefs require more digging than other lands, and hold the moisture more.

Appended (see following page) is a table of the cost of the operations.

Drainage.—The proper drainage of a sugar estate is one of the most important matters for the consideration of the planter.* This is especially the case in localities which possess no natural means of taking off the surplus water, as, for instance, the flat lands of British Guiana. In Demerara, few subjects of late years have attracted more attention, or excited more discussion among planters, and those connected with the cultivation of sugar, than the proper drainage of the

* See 'The Drainage of Fens and Low Lands by Gravitation and Steam Power,' by W. H. Wheeler, M.I.C.E. London: E. & F. N. Spon; 1888. 12*s*. 6*d*.

DESCRIPTION OF WORK.	Number.	Price paid.	Local coin.	English equivalent.
FOR MIDDLE WALK DAM.		$ c.	$ c.	£ s. d.
Clearing off 7 rods grass in savannah	267 r.	0 48	128 16	26 13 8
Cutting 20 cords wood from 33 r. bush land	..	0 40	8 00	1 13 4
Digging blind trench, 5 ft. × 5 ft..	300 r.	0 40	120 00	25 0 0
,, trench in savannah, 20 ft. × 5 ft. × 12 ft.	300 r.	3 20	960 00	200 0 0
Ramming blind trench	300 r.	0 40	120 00	25 0 0
Shaping off and paring dam	300 r.	0 48	144 00	30 0 0
Incidental expenses, making up dam	300 r.	0 12	36 00	7 10 0
FOR SIDE-LINE DAM.				
Clearing off 6 r. grass in savannah	300 r.	0 36	108 00	22 10 0
Digging blind trench	300 r.	0 40	120 00	25 0 0
,, trench in savannah	300 r.	1 00	300 00	62 10 0
,, side-line trench	300 r.	2 00	600 00	125 0 0
Ramming blind trench	300 r.	0 40	120 00	25 0 0
Paring off and shaping dam	300 r.	0 48	144 00	30 0 0
Incidental expenses..	300 r.	0 12	36 00	7 10 0
FOR BACK DAM.				
Clearing off 5 r. grass in savannah	103 r.	0 30	30 90	6 8 9
Digging blind trench	103 r.	0 40	120 00	25 0 0
,, trench in savannah	103 r.	3 20	329 60	68 13 4
Ramming blind trench	103 r.	0 40	41 20	8 11 8
Paring off and shaping dam	103 r.	0 48	49 44	10 6 0
Incidental expenses	103 r.	0 12	12 36	2 11 6
Putting koker in back dam, materials, labour, and superintendence	..	..	273 18	56 18 3
Digging main navigation trench	300 r.	1 44	432 00	90 0 0
Shaping off empolder side of middle walk dam	300 r.	0 24	72 00	15 0 0
Cutting 200 cords wood, No. 4	..	0 40	80 00	16 13 4
Transporting 200 cords of wood to navigation trenches	..	0 08	16 00	3 6 8
Digging 9 cross canals, each..	98 r.	1 00	882 00	183 15 0
Making turns of cross canal heads into main trench, 9 canals, each	..	0 64	5 76	1 4 0
Digging small drains	100 a.	9 00	900 00	187 10 0
,, 4-foot in sand reef	30 r.	0 12	3 60	0 15 0
	..	..	6192 20	1290 0 6

soil. Looking at the vast extent of valuable land occupied by, and the large amount of money yearly spent in cleaning out, the open drains at present in use on almost all the sugar plantations in the colony, it requires no great research to discover the reasons for the interest which this subject has attracted to itself. Attempts have been made to establish the system of tile drainage, and had these been attended with success, nothing would have been left to say on the subject; but planters continue to use the old system.

As a rule, the crust of the earth in the colony of British Guiana is composed of a stiff impermeable sort of clay, streaked with layers of fine sand or "caddy." Now, it is well known that all clay soils in their natural state resist the passage of water through them, and therefore it will be seen that, in the case of a heavy fall of rain, the most natural way of drainage will be from the surface. The water in running off the surface flows into open drains. These drains are generally 3 rods apart, seldom less than 2, and scarcely ever more than 4. The bottoms of these drains are usually from 4 to 8 feet below the level of the land, while the tops vary from 3 to 9 feet in width (by this is meant the distance from the lowermost cane root on the one bank to the nearest one on the other). These drains run along the whole length of a field, dividing it into beds of 3 rods wide, and issue into what is called a side-line or main draining canal, which is generally about a foot deeper than the drains. The water from this side line, in the case of an estate having natural drainage—i.e. where the river or sea which is the receptacle for all this water is (at ebb tide) on a lower level than the side line—is discharged through a koker generally from 4 to 6 feet in diameter, and, in the case of very low-lying estates, is thrown out by means of what are called draining-engines. This latter method entails, in wet weather, a great deal of expense in the way of fuel, and, considering the immense outlay to procure such apparatus as is required for this one item, the profits for the cultivation of sugar would need to be enormous.

It has been said that the present system is one of surface drainage—i. e., the rain does not thoroughly penetrate the soil, but almost immediately runs off into the drains. For this purpose, the beds between each drain are rounded off, being high in the middle and sloping at each end; drills are also dug, commonly 1 foot deep by 2 feet wide, crossing the bed from drain to drain in order to facilitate the flow of water. Of course, this is all very well in a continuous wet season, where the only object is to get the water off as quickly as possible; indeed, it would seem that this is the only advantage in drains of this sort. But in the stiff clay lands of this colony, where the want of porosity is very great, and therefore the absorption of rain very small, it is probable that the benefit which would accrue to the soil from a good heavy shower of rain in a dry season (and it is then it is most wanted), is, in the present state of drainage, reduced to a minimum.

This, however, is not the only disadvantage in open drains. The greatest, and assuredly the most hurtful to a planter, is the great extent of land they occupy. Take a field, say, of 10 acres. This measures 100 rods from middle walk to side line, by 30 rods in breadth, and consists of 10 beds of 3 rods each, measuring from the middle of one drain to the middle of another. Take the width of the drain, say, at 4 feet. Thus there are between each two beds intervals of 4 feet, which in 9 drains, without counting a middle cross tracker, would be 36 feet, or nearly 3 rods. Thus we have 3 rods × 100 = 300 square rods* = one acre, or, on an estate of 500 acres, no less than 50 acres are lost on drains alone, and this is no exaggeration.

Besides this, these open drains are constant sources of annoyance, as they are perfect nurseries for grass and weeds, and, however well constructed, are perpetually having their sides slipping in, forming "stop-offs" across them, and greatly preventing the flow of water. Another disadvantage is the inability to use the plough or tilling machine, which would render planters a great deal more independent of immigration than they are at present. The last, but by no means the

* These are the old Rheinland rods or ruthe before referred to (p. 52). An English acre contains 43,560 sq. ft.; 300 square rods would be equal to 43,200 ft. if the rod is reckoned at 12 ft., or 45,633 if at 12¼ ft.

least disadvantage, is the loss of the great amount of fine earth which is being continually swept into the drains during rainfalls.

Mention has already been made of the futility of tile drainage in this colony. The failure may be attributed in the first place to the great distance (36 feet) which the drains are placed apart. In England and Scotland, where the land is of a clayey nature, tile drains are seldom placed at more than 15 to 20 feet from each other, and there the rainfalls are much less heavy than in British Guiana. In the second place, it is a question whether water can gain access to the pipes in sufficient quantities by means of the small chinks between them, and especially where the surrounding layer of clay will tend to stop up the interstices altogether. Of course, on an estate where the soil is very porous, there is no doubt that tile drainage, if the drains are placed sufficiently close (say 24 feet apart), would be the proper thing; but the only method which seems adequate to the wants of this colony, is that of stone drains. The great and only difficulty will be the immense outlay of money requisite, but in a very few years the advantages of it will doubly compensate for the expenditure. Of course, there is no question but that covered-in drains, if able to draw off the water, are more profitable than open ones. The kind of drain advocated is what is called a "box" drain, and which is often used in Scotland with thorough success, in soil exactly similar to that in this colony, and where it is considered that tiles, which are, no doubt, much less expensive, would be wholly ineffective.

In the first place, it is assumed that the old open drains will be used as trenches in which to place the stones, as it will not be necessary to incur more expense by digging new ones nearer together. Operations are in this case commenced by digging the side line to the utmost depth that the koker will allow; the old drains should then be neatly dug to a depth of about 1 foot above the bottom of the side line. While this is going on, the stones should be brought in punts, and laid along the drains on the bank; after the old drain has been properly cleaned out, the stones, which should be formed flat, should be placed, the largest and flattest (say 1 foot square), at the bottom, smaller ones (say 8 inches square) at the sides, and similar ones to those in the bottom will serve to go on the top as covers, the whole forming an open drain. The fragments, or what has been chipped off the stones in order to bring them into shape for the sides, &c., should be placed on the top to a depth of 6 inches, and the whole covered over with earth. Of course, this can only be done where new land is to be taken in, or the fields to be replanted, as the beds adjoining the drains will have to furnish the earth which is to be backed on to the top of the stones.

In the case of a Dutch bed field, where the drains run into a tracker, it would be advisable to leave the tracker open. Where the drains run from middle walk to side line, there might be a cross open tracker in the middle of the field, into which all the drains in the first half of the field would fall, with an open drain running thence to the side line. The drains in the remaining half of the field would be quite independent of, and unconnected with, those in the first part. This plan of keeping open two "4-foots" would probably be a great advantage in case of heavy weather, when the kokers or draining-engines are unable to take off the water fast enough, and it would be no hindrance to the use of the plough, which could be run on each side alternately.

As to the question of what sort of labour is to be got for this work, it will probably be necessary to have recourse to Chinese.

Appended is an estimate of the cost, which will undoubtedly be the chief obstacle in putting this system into practice. Stones of the quality required cost, say, $2 or 8*s.* a ton, landed on an estate. A drain will require, say, 6 cwt. per rod, or, in a drain of 100 rods, 600 cwt. = 30 tons, or 24 tons per acre. Thus—

	Per Acre.
24 tons stone, at $2*	$48 00 (10*l.* 0*s.* 0*d.*)
Filling into punts, at 8 cents a ton	1 92 (0*l.* 8*s.* 0*d.*)
Throwing out, at 8 cents	1 92 (0*l.* 8*s.* 0*d.*)
Breaking stones, and placing in drain, at 8 cents a rod	8 00 (1*l.* 13*s.* 4*d.*)
Cleaning out drain before stones are put in, at 2 cents a rod	2 00 (0*l.* 8*s.* 4*d.*)
Backing in earth and filling up drain, at 48 cents a rod for both sides	48 00 (10*l.* 0*s.* 0*d.*)
Total	$109 84 (22*l.* 17*s.* 8*d.*)
Or, on estate of 500 acres	$54,920 00 (11,441*l.* 13*s.* 4*d.*)

To show against this, on an estate of 500 acres, if the open-drain system is done away with, there are 50 acres of extra land; say this gives 2 hhds. of sugar an acre, and a corresponding quantity of rum:—

	Yearly.
100 hhds. sugar at $80	$8,000 0 (1666*l.* 13*s.* 4*d.*)
50 puns. rum at $50	2,500 0 (520*l.* 16*s.* 8*d.*)
Yearly cleaning out and deepening of open drains (which would now be done away with) at $2 50 an acre	1,250 0 (260*l.* 8*s.* 4*d.*)
Total gain yearly	$11,750 0 (2447*l.* 18*s.* 4*d.*)
Expense of stone drains	$54,920 0 (11,441*l.* 13*s.* 4*d.*)
Interest for 10 years at 4 per cent.	21,960 0 (4572*l.* 0*s.* 0*s.*)
Cost of keeping up drains per year at $100	1,000 0 (208*l.* 6*s.* 8*d.*)
	$77,880 0 (16,225*l.* 0*s.* 0*d.*)
Yearly gain of .. .. .. $11,750 × 10 =	$117,500 0 (24,479*l.* 3*s.* 4*d.*)
Or a gain in 10 years of	$39,620 0 (8254*l.* 3*s.* 4*d.*)

The chief disadvantage is the scarcity and consequent expense of stones; but were planters to adopt this system on a large scale, more labour would be employed on quarries in

* The Guiana dollar is 4*s.* 2*d.*, the cent ½*d.*

the interior, and in a few years the supply would increase so much as to reduce the cost to a minimum. It may be objected that the drains should not be 36 feet apart, when that is the chief cause of the failure in the tile drains. But the size of the stone drains is so great as compared with that of tiles, that the stone drains are quite capable of holding the water that runs into them even from a distance of 18 feet on each side. The advantages, on the other hand, are many. The additional acreage of itself would be enough to compensate for a great outlay of capital. Then there is the saving of all the fine soil which in open drains is washed away with a heavy rainfall, the avoidance of all labour and trouble after the drains are once formed, and the great benefit of being able to use the plough.

Lastly, all soils, and especially those in which clay forms a principal part, possess the property of contracting when dry and expanding when wet, so that, after the upper water has sunk into the drain, a very great contraction takes place, especially in a dry season, causing innumerable cracks and fissures in the soil, sometimes extending to a considerable width and depth. Now this cracking of the soil is of the very highest importance in draining land; in fact, it is very doubtful whether it would be possible at all to drain clay lands by covered-in drains without it. The tendency of drainage is to increase this cracking action, and it will always be observed that the main fissures commence at the drains and spread from them in almost straight lines into the subsoil, forming so many minor feeders all leading to the main drain. When these cracks are once formed, the falling of loose earth into them, and the action of the water which passes through, prevent them from ever closing so perfectly as to stop the passage of water. Thus the subsoil is pervaded by a perfect network of small drains which, in case of covered-in drainage, are always being filled up with the fine rich mould carried down by the rain on its way to the main drain, and this probably constitutes by far the greatest advantage of covered-in drainage. Not only is the mould not swept away to fill up the drains and side lines, but it is permitted to filter through and permeate the stiff soil below, altering it for the better year by year, turning the clay into the consistency of a fine loam, and, from the richness and consequent fertility imparted by it, forming a new soil, which, in a very few years, will pay the planter doubly for his outlay.

*Irrigation.**—Closely related to the subject of drainage, is that of irrigation, a matter of at least equal importance to sugar-planters, but one of which they are mostly ignorant. The apathy which has been manifested in this respect is the more remarkable, since, in a tropical country, the subject appears in a stronger light than in the temperate and humid climate of England. Hence, many proprietors of sugar estates, who have never been out of the United Kingdom, cannot conceive the loss that is sustained by their fields not being irrigated during dry weather.

Whilst in the greater part of Upper India, it is impossible to cultivate even the common native cane without constant irrigation, in the West Indies, the Straits Settlements, and many other parts, the cane is grown altogether without other moisture than that obtained by the rain. In Singapore, fine seasonable showers usually occur every fourth or fifth day, so that the soil is kept quite moist, and in a condition highly favourable to vegetable life; but even in this favoured spot, spells of dry weather happen, and do considerable damage to the sugar-canes. Malacca is very similar to Singapore in regard to frequent showers and occasional periods of hot, dry weather; while Penang and Province Wellesley are much more subject to spells of dry weather, which also are of far longer duration. But there is not one estate in Province Wellesley which could not irrigate every field, by merely

* For an account of many methods of raising water, consult 'Spons' Mechanics' Own Book' (E. and F. N. Spon, 125, Strand, London). Price 6*s*.

raising water from a depth of from 6 to 10 feet, in the very driest weather.

In the West Indies, long periods of dry weather very frequently occur, when the planters are in despair at the ruin and destruction of their crops; but few appear to recognise irrigation as their great and only safeguard.

In the matter of irrigation, very many estates have the facilities already existing, awaiting only the application of labour to turn them to proper account; others are in a position to create facilities, by digging wells, &c.; whilst some are so situated that irrigation would be next to impossible. In the first case, the methods whereby the water may be conducted and distributed over an estate can be easily arranged, if once the determination be formed to make it available; in the second, the grand question is the depth to which a well would have to be sunk, in order to secure sufficient water for the purpose required. In a very great number of instances, the depth would be moderate, consequently the expense would be limited, and the undertaking such as could with great propriety be carried out; but where the depth is extreme, and the expense necessarily very great, of course it could not be entertained.

The application of water to a cane-field must be viewed (1) in respect to the manner in which it renders soluble the constituents of the soil, and in that form presents them to the plants, (2) in regard to the oxygen that it contains in solution, which acts on the organic and alkaline constituents of the soil, and converts them into alimentary substances for plants, and (3) in relation to the various other substances which it holds in solution, and consequently supplies to the soil. In these two latter respects, the waters used in irrigation must be extremely variable.

River-water generally contains silica, potash, oxygen, and other substances conducive to fertility, independent of the extra matters contributed during heavy rains. During the dry season, when irrigation is so necessary, the water would only supply those substances ordinarily held in solution. The sugar-cane thrives luxuriantly in marshes, argillaceous soils, streamlets, and other places, where the change of water constantly renews the supply of dissolved silica. The potash abstracted is also restored to the soil by annual irrigation. This is found to be of such advantage, that in some places the fallowing of the land is superseded by inundation.

In irrigation during hot dry weather, there is another feature which most materially influences the plant; this is the vapour which a strong sun causes to rise from irrigated lands. This vapour, as it leaves the ground, passes up through the foliage of the canes, in order to escape into the air; but in its passage, it is powerfully attracted by the leaves and other green parts of the plants, and its moisture is made use of. When the air is exceedingly dry, the creation of this moist atmosphere around and amongst the growing canes must be highly beneficial, as the external organs of assimilation are thereby supplied with the means of exercising a more vigorous action, to the refreshment and corresponding improvement of the whole plant. Hence it is apparent that irrigation benefits the plants both by the food which it supplies to their roots, and the nourishment that it affords to their leaves and other green parts.

The rough and ready methods of irrigation practised in India, Egypt, Arabia, Persia, and China, deserve passing mention.

On the Nile, the irrigating machines mostly consist of an endless band, with a number of wide-mouthed earthen pots tied on it at intervals; this band works over a drum-wheel having spikes or teeth, fitting into holes in the band, so as to catch and carry it round; while the drum-wheel shaft is moved by a large cog-wheel fitted on a vertical shaft, worked by animals of various descriptions. On the Euphrates, the same kind of machine is used, as well as the Persian wheel. In China, bamboo wheels, endless bands, and what is termed the "Chinese pump," are in constant use in the dry season.

The methods pursued in India are chiefly three. The first is by means of an upright pole placed in the ground, the top of which is forked to receive another pole, fixed by means of a pin, forming the axis on which the cross pole works. The short end of the cross pole carries a large stone, sufficiently heavy to counterpoise the receptacle, which is attached by a rope to the other end of the pole.

The second Indian plan is performed by the aid of baskets. In this case, the water of ponds is usually availed of. The basket used is round, closely woven, and very shallow; to it are attached four strings, two on each side, about 4 or 5 feet long. Steps are cut in the bank about 6 or 7 feet above each other, with little channels running from the top of one to the foot of the other; two men take up their positions at each of the steps, and bale up the water with their baskets. About 2½ feet above the level of the pond, places are cut for the two men to stand, having the water between them; they then take the basket by the strings (each man having one in either hand), and giving it a swinging motion, just skim the top of the water, filling the basket, and jerking its contents cleverly on to the top of the first elevation or step. Here it is received in a kind of bed with raised edges, and having grass laid at the bottom to prevent loss by splashing. From this, it runs along to the foot of the next step or elevation, whence it is raised as in the former case; and so on to the next elevation, until it reaches the general surface of the land. By this method, 6 men are required to effect the elevation of each basketful of water to the surface of the land, which may be reckoned at from 18 to 21 feet above the level of the pond.

The third Indian mode is by a "moat" (a hide bucket holding about 12 gallons) and a pair of bullocks. Over the well is erected a rude but strong framework, with a wooden shaft running across, bearing a small revolving drum-wheel. Into this, the rope is dropped, and the cattle being attached, the moat is let down into the well and filled with water; the cattle then run down an inclined plane, of the same length as the depth of the well, and draw up the moat, which is immediately emptied by the man stationed on the well for that purpose. To work the moat all day requires four bullocks, three men, and one boy; these will, according to native calculation, irrigate one-third of a pucka beegah in that time.

A smart set of bullocks and driver may make one trip a minute, delivering 12 gallons of water, which would amount to a distance of about 7½ miles travelled in the day, and of water raised about 7200 gallons. This, together with its distribution over the field, would only cost about 1*s.* 2½*d.*, making for the irrigation of an acre, according to this plan, the sum of 5*s.* 4*d.*

The utilisation of the wind as a motive power for working pumps is of the greatest importance in this connection, wherever it can be successfully accomplished.

Next to having proper means of raising water, the important point is to have a regular and well-devised plan for conveying the water on to the different fields to be irrigated. This leads back to the subject of laying out an estate in the first instance (see pp. 51–57), in a methodical and properly arranged manner. Where this is done, the various roads situated at regular distances would also form the tracts or lines along which the water-courses would run, each cross road having its water-course, into which the water supplied at given points could be directed as might be necessary.

The estate should be cut up into fields of from 30 to 50 acres each, in order that a properly-sunk well may be allotted to each field, in case no river or pond be at hand. Where possible, the fields should have some regular form, so that the well may be made in the centre. The next point is to conduct the water pumped up from the well, so that little or none of it is lost during its transmission. This object may be gained by laying down common drain-pipes (of whatever diameter may be found necessary), say in four regular lines about 260 feet apart. By this method, 30 acres of land may be permanently laid down at a small expense, as not more than 5500 pieces of piping would be necessary. Each pipe should be 1 foot 3 inches long, one end having a shoulder, and being large enough to receive the end of the other pipe to the extent of 3 inches. At intervals of from 40 to 50 feet along the line of piping, a good-sized naud (earthen vessel) is sunk in the ground, so that the ends of the pipes fit into it about 2 or 3 inches below the rim exactly opposite each other, and are made water-tight by the application of a little mortar. These vessels serve as receptacles for the water, from which it may be distributed over the field, either by tossing it out with wooden shovels or brooms, or by a small pump irrigating-machine, and so throwing a jet of water over the land as far as the power of the machine will carry it. These receptacles also serve as points from which the water can be drawn into any branch-piping or mud-channels in the fields; and they are of much utility in detaining the mud, sand, or other matters which might otherwise lodge in the piping, and obstruct the free course of the water.

Of pumps, it may now be said that their name is legion, and it would be quite impossible here to attempt a description of even the most noteworthy forms. Nor is it necessary, as they figure in most engineers' catalogues. The planter should always choose the simplest.

Propagation of the Plant.—It has more than once been stated that the sugar-cane is in some localities reproduced from seed, but the statement has originated in a misconception, there being no kind of sugar-cane known to regularly perfect its seed. Propagation is therefore effected exclusively by means of cuttings from the stems. For this purpose, none but the healthiest and most vigorous canes should be selected;

neglect of this point will result in disease and deterioration, and even with every care, it cannot be continued indefinitely

FIG. 8.

FIG. 6.

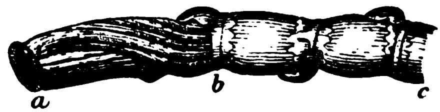
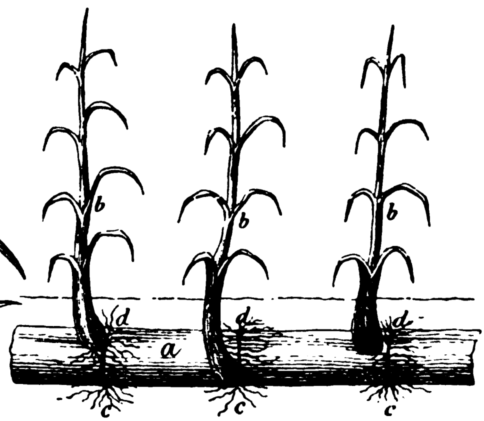
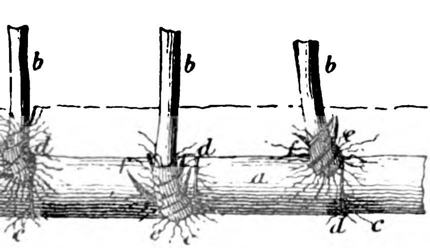


FIG. 7.



Cane Cuttings.

with impunity, and sooner or later new plants have to be introduced.

Every part of the cane stem having a perfect "eye" or bud will put forth a new plant, and it sometimes becomes necessary to take advantage of this circumstance, and utilise every portion of the sound canes for this purpose. Where there is room for choice, however, preference is usually given to the few upper joints nearest the leaves, usually termed the "cane top." But this is not the case in Louisiana, where preference is given to the main stalks, and tops are used only for economy's sake. An ideal cutting from the cane top is shown in Fig. 6. The part included between the letters *a b* is a portion of the top stripped of its leaves; the part included between the letters *b c* embraces one, two, or three of the uppermost "joints" of the cane.

When planted, the eyes at the joints commence to spring forth, and at the same time a number of roots are thrown out around the whole of each joint; these roots serve to supply the young plants with the means of subsistence till they are advanced enough to put forward roots of their own. Fig. 7 shows the condition of a cutting with three eyes at this stage; *a* is the cutting, *b* are the young shoots springing from the joints, *c* are the roots from the joints, supplying nutriment to the young shoots, *d* are the joints whence the roots and shoots originate.

As the development of the shoots advances, the parent cutting gradually dies away and decays, while the young shoots become furnished with perfect roots of their own. This stage is illustrated in Fig. 8; *a* is the cutting, *b* are the young shoots springing from the joints, *d*, *c* are the remnants of the old roots on the joints of the cutting, *e* are the new roots thrown out by the young shoots themselves, and forming their support independent of the now decaying parent cutting, while *f* are the fresh buds or eyes which appear on the joints of the young shoots (now become good-sized plants), and which also develop into plants.

Planting.—After the estate has been properly laid out and drained, the next operation is to bring the soil into a perfect state of tilth, which is effected by the usual routine of ploughing, harrowing, hoeing, digging, &c., as for any other crop, and demands no special description here. The land being in a fit condition to receive the cuttings selected, planting is the next operation to be described. This naturally divides itself into several distinct sections, such as preparing spots for the reception of the cane cuttings (termed "lining-out" and "holing"), setting out the cuttings in their places, &c.

Lining-out and Holing.—For facility in carrying on all the operations incidental to raising a crop of sugar-cane, it is essential that the estate be laid out in a regular and systematic manner in the first instance. When this is done, all subsequent steps are much simplified. Perfect regularity in the rows of cane is very important. This is attained by "lining-out" the fields with great care, by means of long lines and poles. Each field, varying in size usually between 5 and 25 acres, is first divided up into convenient sections by tall poles, placed say 100 feet apart on each side. Between these are stretched long tapes carrying pieces of conspicuously-coloured rag, fastened at the distance apart which the holes for the canes are intended to be. Small stakes are then driven in at the rags by a gang of labourers following the tape, each stake occupying the centre of the hole to be dug.

The distances apart at which the holes are situated, as well as the dimensions of the holes themselves, are subject to no absolute rule. Very often, the holes are made 2 feet apart in rows 3 feet asunder, but much depends upon the soil and climate. Common dimensions for holes in the West Indies are 15 to 18 inches square, and 8 to 12 inches deep; in Guiana, they may be said to average 3 feet square at the top, diminishing to 14 inches at the bottom, and about 8 inches deep. Since ploughs have come widely into use in tropical agriculture, there has been a growing disposition to replace hand-dug holes by furrows turned by the plough, the latter effecting a great economy of labour. Ploughing is universal in Louisiana. In this case, it is generally necessary to retain the lining-out, as only the most experienced ploughmen will preserve perfect regularity in the intervals between the rows without some guide.

Setting-out the Cuttings.—The number of cuttings to be placed in each hole, or in each 2 feet of trench, varies between 1 and 4, according to their degree of vitality and the prospects of their striking root. With good sound cuttings, 2 placed at about equal distances from parallel sides of the hole will amply suffice; when 3 are set out, the same sort of disposition is generally adhered to, the 3 pieces lying parallel with each other and with 2 sides of the hole; when the cuttings are very poor, and 4 are considered necessary to ensure a plant from each hole, they are more commonly arranged in a square, corresponding with the sides of the hole. The usual plans of setting out in trenches are (1) to place the cuttings end to end at a little distance apart in one continuous straight line, (2) to allow them to overlap each other in a somewhat zigzag fashion, and (3) to lay them side by side obliquely across the trench. It is preferable to plant too heavily rather than too lightly, as the former evil can be easily remedied by subsequent lopping, while the latter entails a filling up of the gaps with new cuttings, which can rarely be done without in some degree disturbing the adjacent plants.

The natives of Bengal have a peculiar method, which is often adopted by European planters there. This consists in burying the cane-cuttings in a pit until they sprout, when they are carefully removed and planted out in the fields. In placing them in the pit, great care is taken to have them in regular layers, with wet straw and a little mould between the layers; and the most delicate manipulation is needed in removing them, or the white and tender shoots will be broken off. It is a useful way of keeping cuttings over for a time when waiting for the fields to be ready for planting, and plants succeed very well when set out in moist hot ground; but they are quite unfit to be transferred to cold damp situations, or even to hot land which is also dry.

In any case, the cane-cuttings when laid in position in the holes or trenches, are covered with a thin layer (say 1½ to 2½ inches) of earth. They thus lie sheltered from direct sun-heat at the bottom of a more or less deep hole, which forms a natural receptacle for rain or any other moisture that may be supplied.

The time for planting will of necessity be governed by the character of the local seasons, and no absolute rule can be laid down for it.

Moulding and Banking.—In about a fortnight, young sprouts push themselves up through the covering of earth: these are immediately "moulded" round with some of the soil still remaining from the hole or trench. This moulding operation is repeated at intervals, as the plant grows, till the hole or trench is filled up, and is further continued till the stem of the cane is "banked up" for a certain distance, to ensure its retaining as far as possible an erect position.

Weeding and Trashing.—Simultaneously with the moulding and banking, the land should be thoroughly weeded with a hoe. As the plants progress, "trashing" will also become necessary. This consists in removing from the stem every dry and fading leaf which has ceased to perform its functions. In rich land, it requires to be frequently resorted to during the wet season, but may be done at longer intervals when the rains are over. The importance of constant trashing cannot be too strongly insisted upon, as it admits to the plants that abundance of light and air which is absolutely essential to the production of a heavy crop of sugar. At the same time, green and living leaves must on no account be removed, as they form part of the vital system of the plant, and their destruction necessarily acts injuriously upon its development. Equally demanding removal when too numerous, are the suckers thrown up by the roots; yet among Louisiana planters these are encouraged all possible. Both the leaves and suckers should be buried in trenches dug or ploughed between the cane rows, and covered over with a thin coating of earth; there they decay, and form excellent manure for the growing crop.

Ratooning.—In describing the operation known as "ratooning," it is necessary to refer the reader to the section on the propagation of the plant (pp. 70–72) and the illustrations relating thereto (Figs. 6, 7 and 8). Bearing in mind the method in which the cane-cuttings put forth new shoots, it must now be explained that the first crop obtained from newly-planted cuttings is called "plant" canes; when these plant canes have been cut and carried, the stole or stool, remaining in the ground, in due course sends up another growth of canes, which are termed "ratoons." The first crop of ratoons (i. e. the second crop of canes from one planting) are designated "first ratoons," and the succeeding crops are numbered progressively in the same way.

It is found that ratoons annually diminish in length of joint and circumference, the first being larger than the second, and so on in a deteriorating progression. The roots of the buds, being fewer than in the original plant, and nearer to the surface of the earth, supply less nutriment to the ratoons, and the ground about them cannot be so effectually loosened and manured, as when the cane is freshly planted and the roots are deeper in the soil. These unfavourable circumstances attendant on the vegetation of the ratoons, limit their number, and retard the vigour of their growth.

On some soils, it is found best to depend chiefly on ratoons. A very general practice is to plant a certain proportion of the cane lands (commonly one-third) in annual succession. The stoles are allowed to continue in the ground, and as they become thin and impoverished, the vacant spaces are supplied with fresh plants. But if this method is adopted, great care must be taken to assist the development of the bud by judicious treatment. The earth round the stoles should be loosened, and cleared from weeds; and as soon as the ground has been refreshed by rain, the stoles should have manure placed round them, which, if covered with cane trash, to prevent its being dried up by the sun, will be found at the end of 3 or 4 months to be incorporated with the mould. At this period, the ratoons should again be well dressed, after which, very little care is requisite, until the canes are fit for cutting. Colonel Martin, of Antigua, advises, as soon as the canes are carried to the mill, to cut off, by a sharp hoe, all the heads of the cane stoles, 3 inches below the surface of the soil, and then to fill up the hole with fine mould; by this means, all the sprouts rising from below will derive more nutriment, and grow more equally and vigorously.

By the method of constant ratooning, the produce of sugar per acre, if not apparently equal to that from plant canes in newer soils, yields, perhaps, in the long run, quite as much profit to the grower, if the relative proportion of the labour and expense attending the two methods be taken into consideration. The very small average produce of sugar per acre (about 12 cwt.) in Jamaica is due to the system of permanent ratooning there prevailing, the plants that fail being replaced yearly one by one. The expenses are thus very small, and the risk of losing a field of young plants by drought is avoided, but the yearly yield is necessarily much curtailed, and a rotation of crops is rendered impossible.

As soon as the canes are cut, the land intended for ratoons requires the attention of the cultivator. If the rainy season be near at hand, all the field-trash, consisting of decayed leaves, should be buried with other manure about the roots of the plants, the earth around being well loosened and cleared of all weeds, either by the plough or hoe.

In some countries, such as Bengal, really good ratoons are never met with. In this case, first ratoons may be allowed;

but it is an absolute loss of time, labour, and money to attempt second or third ratoons. It is also found that white ants swarm in the old roots of the ratoons, and do immense mischief to the growing canes; whereas when planted yearly, or even every second year, the good stirring up which the land receives goes far to break up their abodes, disturbing and destroying them. Constant ploughings, which include the preparation of the land, and subsequent cleanings, mouldings, bankings, &c., have an excellent effect on these terrible enemies to the cane; and they have been known to vacate, in a great measure, land that had been continually disturbed by ploughing.

The cost of replanting land in India is so small, and the increased return so much greater, that Wray thinks no planter could hesitate a moment in deciding in its favour; especially as his great enemy, the white ant, is so much distressed, and the land so greatly improved, thereby. In British Guiana and some of the West Indies, it is held to be a good rule to replant when ratoons give only 1 to 1½ hhds. of sugar per acre.

In replanting, the old roots should all be burnt, and the cane-top cuttings be planted between the rows of the former crop, so that they do not occupy the same place as the old roots did. When it is determined to allow the ratoons to continue another crop, it will be advisable to cut down the banks (around the roots) and roots, so as to make the field quite level. This last can best be performed with sharp hoes, and when cleverly done, causes no injury whatever to the stools. Irrigation must be resorted to (as in the case of plant canes) throughout the hot season; and probably they may also require a liberal watering after the banks and roots are cut down, as it will have the effect of making them spring up again vigorously. This may be calculated on, if the former canes are cut in November or December, as the land is at that time generally pretty dry; but if a good shower falls in those months, the necessity of irrigation is removed.

Harvesting.—When the canes are ripe and ready for the harvest, they are cut with hatchets as close to the stole as possible; thus new vigour is given to the ratoons that are to spring from the old root, while the juice from these lower joints is the richest the cane contains. The top is discarded. It may perhaps be sufficient to cut off only one joint of the cane, with the cane top, from those canes which grow on very dry soils; but otherwise, two should be cut, for if they be not sufficiently matured, their juice will only injure the sugar, instead of augmenting its quality. All leaves are also stripped off.

Those canes which are rat-eaten, or otherwise damaged, must be sorted from the rest, and not be sent with the others to the mill, as they would probably sour the juice.

The canes, being cut, are tied into bundles for the convenience of taking them to the mill. On the mountains, they are carried by mules. In some parts, the bundles are rolled down the steep places, or shot down wooden spouts. In the plains, they are conveyed in carts, drawn by oxen, mules, or road engines, to enclosures near the mills; and in Guiana, in flat-bottomed boats or punts, by means of navigable trenches, which intersect the plantations for this purpose.

Figs. 9, 10, 11 and 12, obligingly furnished by W. Carrington, 72, Mark Lane, engineer to the owners of the wire tramway patents, illustrate the arrangement of a wire tramway for sugar-cane carriage, showing the cane being fed direct on to the cane traveller as is done in many places; also the arrangement of three tramways driven at the mill, and radiating in different directions, delivering their cane on to the carrier of the mill.

These wire tramways have been largely and successfully used for sugar-cane carriage in the West Indies, Guatemala, Mauritius, and Queensland. In Mauritius alone, there are some 60 miles at work, where, on many estates, by means of this system, plantations on high grounds are utilised, which

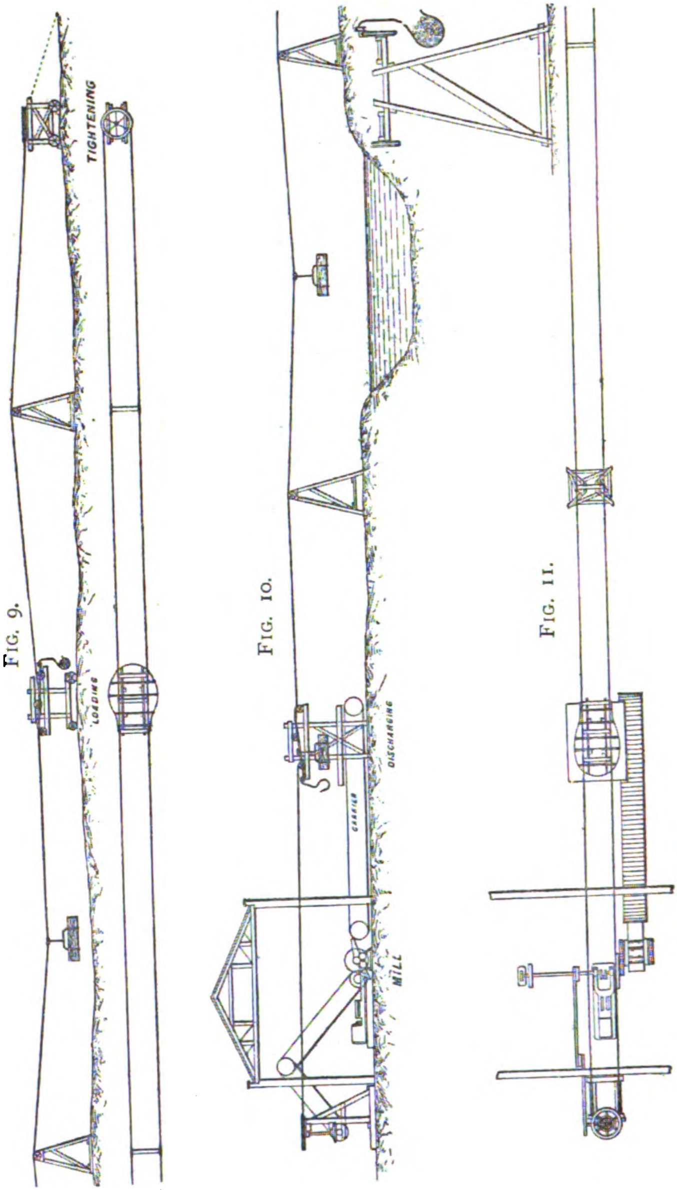


FIG. 9.

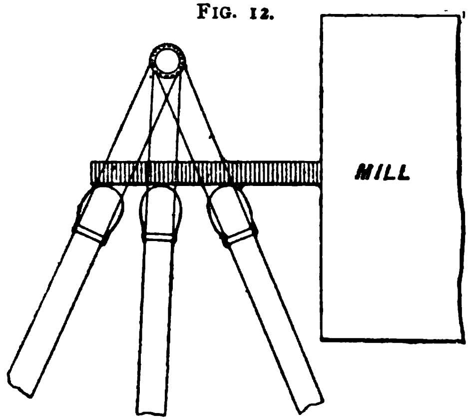
FIG. 10.

FIG. 11.

Wire Tramways.

are beyond the reach of any other system of transport. The cane is carried in a crook, which is hung from the rope by the usual patent saddle, and travels with the rope at a speed of 3 miles per hour. The cane is put on to the tramway by

FIG. 12.



Wire Tramway.

means of a travelling shunt-stage, which is moved from end to end of the tramway, and on the shunt-rails of which the carriers run from the rope, are loaded, and placed on the return wire-rope to go to the mill with their load. Thus only the portion of the tramway rope between the mill and movable shunt-stage is employed in carrying the loads. When necessary, the terminal of the tramway can be mounted on wheels, and the driving gear arranged to allow the tramway to radiate to any portion of a circle, so as practically to reach any point of a field.

The wire tramway presents great advantages in being able to cross any rivers or dykes in the plantation, or between it and the mill; it can also ascend or descend inclines as steep as 1 in 3, and can thus easily reach any spot of an estate, however inaccessible to other systems. Its use does not damage the ground over which it runs by compressing it and rendering it bad for cultivation next year. Another advantage

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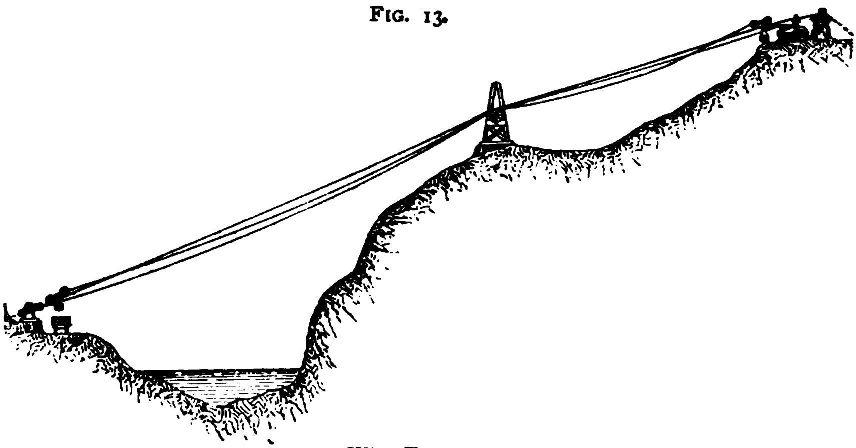
is found in its providing a regular continuous feed of freshly-cut cane to the carrier, never making accumulations of cane outside the mill, but being easily regulated to deliver exactly the quantity which the mill can take.

The posts are either made, as shown, of timber, or are a portable form of iron post, which is light, and easily moved about and regulated as to height.

These wire tramways can be made to carry from 50 to 500 tons per 10 hours, and can be constructed for from 200*l.* upwards per mile, including all machinery and rolling stock.

Fig. 13 shows the arrangement adopted when the country is much broken.

FIG. 13.



Wire Tramway.

Windrowing.—In some countries, frost greatly interferes with the progress of the harvest. The ill effects of frost and subsequent thaw upon the cane-juice, have been already alluded to (see p. 26). To such a degree is this evil felt in Louisiana, that special precautions are there needed, and have resulted in the adoption of a method of keeping the cut canes uninjured, which has been termed "windrowing." This method will now receive attention.

The usual method of windrowing is by throwing into 1 furrow from 2 to 4 rows of cane, in such position that the tops of the last thrown down will always cover the butts of the preceding. This plan will do well enough for protection against frost while the cane is waiting to go to the mill; but seed cane should never be windrowed in so careless a manner, as is almost universally done, with only the addition of a furrow of dirt thrown on from each side. The proper way to windrow cane for seed is *first* to throw to the centre of the water-furrow 1 or 2 furrows of dirt from each side; a harrow is then run over that, so as to pulverise it thoroughly, and give the cane a soft bed to lie on; and the bed is made of such an elevation that the cane cannot be injured by water standing upon it during the wet winter months. Upon the cane, 2 to 4 more furrows of dirt are thrown, to protect it from the cold. Of course it is very difficult to plough and harrow between rows of heavy cane, but the importance of keeping seed cane in a sound condition justifies all the time necessary for this method; and if the cane is crooked, or otherwise interferes with the team passing between the rows, a sufficient quantity of the cane may be cut away to make room. In this way, there is no difficulty in keeping seed cane.

There are strong arguments in favour of "round mats," or standing the canes upon their butts on a dry piece of land, and throwing dirt around the outside to the height of 3 or 4 feet. The cane from about half an acre is usually put in each mat. This method, however, is but little used. The addition of a square wooden tube, running up through the centre for ventilation, prevents dry rot. The "flat-mat" method of preserving seed (laying down as in windrowing, in beds about 15 feet wide, on elevated ground, to the depth of 2 to 4 feet, then lightly covered with earth) is much more common and popular; but either round or flat mats require more time than most planters are willing to give. The losses of seed cane might be so easily prevented by the plan of elevating the ground upon which it is to lie in windrow, that when once known it will doubtless be generally used.

Diseases and Enemies.—Like every other growth, whether vegetable or animal, the sugar-cane is subject to attack from various enemies and diseases. Some of these are common to the wild cane and cultivated cane, but others are so conspicuously developed upon the latter alone, that there can be no room for doubting that they have originated in defective systems of culture, improper or insufficient manuring, or unsuitable conditions of climate or soil. Diseases of this latter and most serious kind can only be combated by removing the cause, whatever that may prove to be.

Rats.—Rats are one of the most troublesome pests to the cane-planter, as they gnaw the standing canes, thereby admitting air to the interior of the plant, and setting up fermentation and other destructive changes in the juice. Some planters have successfully rid their estates of rats by rearing numbers of that useful animal the mungoose; it will thrive in any climate that will grow sugar-cane, and is moreover a great enemy to snakes. On this subject, a most interesting communication from Mr. D. Morris, of the Botanic Gardens, Jamaica, was published lately in the *Field*, and is here reproduced verbatim.

"While collecting information for a report on the agricultural products of Jamaica, I was lately led to investigate the results of the introduction of the mungoose (*Herpestes ichneumon*) into the island for the purpose of destroying the plague of rats, which have always more or less infested sugar estates and caused considerable loss by their ubiquitous depredations. As a consequence, rat-catching has been an important item in all sugar estate expenses not only in Jamaica, but in all the West Indian islands, and for the last two hundred years numerous suggestions have been made to cope with an evil, which, in spite of rat-catchers, dogs, traps, baits, and poisons, has remained as great as ever.

"The rat-catchers on estates are mostly Africans (negroes), who pursue their calling accompanied by a troop of dogs, and use traps of a very primitive fashion. These consist of a bow made of tough wood, with a small basket at one end to hold the bait, and just large enough to admit a rat's head. The string, attached to the bow, is formed into a loop inside the basket, and held ready for action by a small peg, on which the bait is fixed. The rat, on touching the bait, loosens the attachment of the string, which suddenly tightens round its throat and kills it. Besides traps, poisons prepared from phosphorus are largely used.

"The common brown and black rats of Europe, introduced, no doubt, by ships, are common everywhere; but the most destructive to the sugar cane is the 'cane-piece rat,' which Gosse has named *Mus saccharivorus*—distinguished by its large size and white belly, a truly formidable creature (drawn by Robinson in his MS. volumes, iv. 13), measuring 20 inches in length, of which the tail measures one-half. This rat is also known as the 'Charley Price rat,' from an impression—proved, however, to be erroneous—that it was introduced by Sir Charles Price for the purpose of destroying the black and brown rats. Naturally, one of the first thoughts of an Englishman plagued by rats, and beyond the power of cats and dogs, would be the introduction and naturalisation of the European ferret.* It appears, however, that the ferrets when introduced were rendered useless by their inability to overcome the attacks of the Chigoe flea, which infests the lowlands, and becomes a serious pest to most imported animals. 'Under these circumstances, Sir Charles Price bethought him that, if he could find an animal in the country of the Chigo, corresponding to the weasel of Europe, he would accomplish the naturalisation of a rat destroyer with instincts capable of counteracting the plague of the parasitical insect. He ac-

* Although cats have been introduced and encouraged on estates, it appears that they have not contributed largely to diminish the plague of rats. There is an impression in the island, which I give for what it is worth, that the negroes are addicted to eating cats, and thus frustrate the efforts of the planter; but whether from choice or as an antidote to Obeahism is not stated.

cordingly procured something from South America, that, in the eyes of the negroes, had strong rat characteristics, but which was no rat. It was of large size. Several were set at large about the house at the Decoy in St. Mary's, and at Worthy Park, to establish themselves how they might. It would seem that nothing came of the scheme, for no animal allied to the musteline group quadrupeds has been found in the colony.'* The appearance of the large 'cane-piece rat' in the island about this same time was no doubt connected by the natives with the animals introduced by Sir Charles Price, hence his name remains associated with the rat instead of its destroyer.

"The introducer of the native ant of Cuba (*Formica omnivora*) was more fortunate. This is said to have been Thomas Raffles, who, in 1762, brought over this formidable hymenopteron to prey on the young rats; and, strange as it may appear, the 'Tom Raffle ant' has remained to this day a firm friend to the sugar planter, and a foe to all pests of rats and vermin.† To aid the 'Raffle ant,' another foe to rats was adopted in the 'Agua toad'—an enormous South American amphibian, some 7 inches from the muzzle to the coccygeal extremity, and as broad as long. This was introduced by Anthony Davis in 1844. These gigantic toads had been considered in Martinique and Barbadoes very important auxiliaries to the planter by their pursuit and destruction of young rats. They had no doubt been introduced in the first instance from Cayenne and the intertropical parts of South America, where they are said to be indigenous, and to abound in great numbers. The dispersal of these strange animals in Jamaica, caused at first considerable commotion. The oldest inhabitant never heard such hoarse bellowings from the ponds and pastures as suddenly saluted their ears when this 'Bull

* Gosse, 'Naturalist's Sojourn in Jamaica,' 1851, p. 447.

† In some districts where specially abundant, the "Raffle ant" has been known to attack the young of both cats and dogs, and to severely injure them, especially in the eyes. Calves have also been similarly affected.

frog' became common. Its note, to use the words of the late Richard Hill, is a 'loud sort of modulated snoring noise,' and he evidently thought little of it as a rat catcher, for he adds, 'they are now (1847) eradically established among us, and are to be added to the miscalculating delusions which gave us "big rats" to devour "little rats," and the ant of Cuba to rid us of the accumulated pest of rats and vermin, and to become a more intolerable scourge than all the other plagues put together.' *

"It appeared, however, that both the Raffle ant and the Agua toad had had their day, for up to 1872 the rat pest continued as great as ever. In some of the moister parishes of the island, depredations by rats were estimated to cause the loss of nearly one-fifth the produce of a large estate, while the cost of rat-catching, poison, &c., amounted to more than 200*l.* per annum.

"Taking the number of sugar estates and their returns as given in 'The Jamaica Handbook' for 1881, it appears that there are at present in the island some 216 estates, containing in the aggregate 39,505 acres under canes, and yielding about 31,400 hogsheads of sugar, and 20,700 puncheons of rum. Taking sugar at 15*l.* per hogshead, and rum at 11*l.* per puncheon, this would represent an annual value of 700,000*l.* While some dry districts, such as Ven in Clarendon, are comparatively free from rats, others, such as St. Thomas in East Portland, and Westmoreland, have always suffered very severely from their depredations.

"It would be almost impossible to estimate, with any degree of certainty, the annual loss caused by rats on sugar estates; for, although planters in nearly all cases could give the number of cartloads of rat-eaten canes ground for the still

* The "Bull frogs" (as they are called by the negroes) are said to commit depredations on ducklings in ponds, and to be terrible enemies to beehives. I can understand that to a confirmed insectivore like a toad, our stingless and easily accessible bee must be a veritable *bonne bouche*.

house, the fact that these canes give a return in rum somewhat lessens the loss.

"It is, I know, currently reported that some estates in the Swift River Valley (Portland), such as Paradise, Eden, Elysium, and Shrewsbury were actually abandoned, owing to the destructive depredations of rats. This may not have actually been the case. It is a fact, however, that portions of estates and cane pieces bordering on woods and near rocks, affording shelter to rats, have been finally abandoned on account of their depredations; and even in the case of whole estates, 'the damage caused by rats has no doubt been one of those large "leaks" that has helped to sink them.'

"From a careful series of returns received from planters in all parts of the island, I am led to believe that the loss caused by rats in rat-eaten canes, up to a recent date, could not be less than 50,000*l.* per annum; while the expenses incurred in rat-catching, rebuilding walls pulled down to catch rats, poison baits, and rat-traps, would reach nearly 5000*l.* per annum. This, however, only applies to sugar estates. Cane pieces cultivated by settlers, coffee, cacao, coconuts, corn, sweet potatoes, arrowroot, fruits, peas, vegetables, and numerous other crops, appear to have suffered equally from depredations by rats, so that the total loss caused by rats in Jamaica, apart from the discouragement which they have caused to many minor industries, might very safely be estimated at not less than 100,000*l.* per annum.

"As examples of the distribution of rats, and the destruction caused by them in the island, the proprietor of an estate in Trelawny informs me that 'the annual number of rats destroyed and paid for on one estate was over 20,000 at the rate of one penny per head, exclusive of what was destroyed by poison and dogs.' Another in Portland writes: 'I lost fully 20 to 25 per cent. of the entire sugar crop by the ravages of rats, and could never grow corn, sweet potatoes, or peas. The cost of catching rats was over 200*l.* per annum.' A large proprietor in St. James's reports that he paid in a district not remarkable for the depredations of rats, on an average 70*l.* per annum for rat-catching, and the destruction of canes by rats may be moderately estimated at 200*l.* per annum. Another reports: 'On this estate we lost frightfully by rats; fully one-third of the crops were often destroyed.'

"With these facts before us, it will not be a matter of surprise to learn that the rat question has continually cropped up and pressed itself with more or less vigour upon the proprietors of all estates, and especially in the moister districts. The 'Tom Raffle ant' had either lost its initial vigour, or had gradually disappeared from districts in which it had proved of service.* The 'Agua toad,' if it ever was of service, was quite unequal to the formidable task of cleaning out some hundreds of thousands of 'cane-piece rats.' A new rat enemy was therefore in urgent request, and the mungoose was thought of.

"As long ago as 1816, Lunan, in his article on the sugar cane, 'Hortus Jamaicensis,' vol. ii. p. 206, drew attention to the capabilities of the mungoose as a rat catcher in the following words:—'There is an East Indian animal called "mungoes" which bears a natural antipathy to rats; if this animal was introduced here, it might probably extirpate the whole race of these vermin.'

"It appears, however, that until some twenty years ago no attempt has been made to introduce the mungoose into the island, and even then the results were unsatisfactory or fruitless.

"Among the earliest importers of the mungoose into Jamaica were the Hon. William Vickers, Westmoreland; Mr. De B. Spencer Heaven, of Ramble; Wm. Bryce Watson,

* On this point a correspondent remarks, "Formerly this estate (Swanswick) was swarming with ants commonly called 'Tom Raffles,' and they kept the cane fields quite clean of rats; but within the last ten years or so, these useful little creatures have almost disappeared."

of London; Hon. J. W. Fisher, Mahogany Hall; Mr. Shortridge, of Hollands Estate; and Mr. Burgess, of Mount Eagle. Most of the animals introduced by these gentlemen were, however, obtained from London, and having been bred in captivity they were, to use the words of one of the introducers, 'literally afraid of a rat.' The first importer of the mungoose direct from India appears to have been Mr. William Bancroft Espeut, of Spring Garden Estate, Portland, who, by the interest of Government, with the aid of Mr. Anderson, Agent-General of Immigration in India, obtained four males and five females by the cooly ship *Merchantman* in March 1872. Mr. Espeut paid 9*l.* for their expenses in transit, and at once turned them out on different portions of his estate. From these nine animals nearly, if not quite, all the mungooses in the island at the present time have been obtained. Hence, among the natives, the mungoose is becoming known as 'Massa Espeut ratta,' just as the animals supposed to have been introduced by Sir Charles Price were called 'Massa Price ratta.'"

"The negroes in the neighbourhood of Spring Garden Estate appear to have caught and sold thousands of mungooses to planters in other parishes. One who went actively into the trade is said to have received over 300*l.* for animals supplied to estates in other parts of the island.* All these were doubtless the progeny of the nine introduced by Mr. Espeut in 1872. Their powers of reproduction must therefore be very great. They are now firmly established in the neighbourhood of Kingston and in every parish in the island; and even in the mountains at elevations from 5000 to 6000 feet, with a minimum temperature of 45° Fahr., they are becoming quite common. That they can swim and dive with great

* Numbers of animals have also been supplied to Cuba, Porto Rico, Barbadoes, and Santa Cruz; while Mr. Espeut himself has undertaken to ship some to Australia and New Zealand for the purpose of putting down the rabbit pest of those countries.

facility has often been noticed, and thus streams and lagoons offer no hindrance to their dispersal. After just ten years' experience with the mungoose in Jamaica, it is an interesting question both for the sugar planter and the naturalist to discuss, What are the practical results of the experiment?

"The introduction and complete naturalisation of an animal possessing such strong predatory habits and remarkable powers of reproduction as the mungoose must have an important influence on all indigenous and introduced animals capable of being affected by it. As is well known, the mungoose, although shaped like a weasel, belongs to the civet-cat family (Viverridæ), and its disposition is as sanguinary as its habits are predatory. Its natural food consists of birds, snakes, lizards, rats, mice, and last but not least, the eggs of both birds and reptiles. In India the destruction which it often causes amongst poultry is well compensated by the incessant war which it wages against snakes and vermin. Even the lethal cobra falls a victim to the agility of the mungoose, which, according to Eastern tradition, is said to possess an antidote, by means of which it can withstand the venom of the most deadly reptile.

"I have been at some pains to learn what the general opinion in the island at the present time is with regard to the influence of the mungoose, and, at the risk of being deemed prolix, I will give a summary of the information which I have gleaned from persons representing all kinds of industries.

"In the first place, there can be no doubt that on sugar estates the mungoose has fully realised the hopes held out respecting its powers as a rat-catcher, and sugar planters all over the island speak in the most unqualified terms of the good it has done in destroying the rapacious 'cane-piece rat,' and reducing the expenses of rat-catching in all its phases.

"On an estate where the mungoose had only been introduced in 1878, the attorney speaks of its usefulness as follows:—'In comparing the expenditure on an estate where I lived for some years, I find the present yearly expenditure for rat-catching shows 8*l.*, as compared with 80*l.* spent in catching and poisoning rats, and rebuilding walls pulled down to catch rats. I take this from averages for five years before the introduction of the mungoose, as compared with last year's expenditure. This amount does not include the cost of poisons, baits, and traps, which would average fully 20*l.* a year, making 100*l.* as compared with 8*l.*

"'In comparing the quantity of rat-eaten canes destroyed before the introduction of the mungoose, I take the number of gallons of rum canes ground during the crop preceding the introduction of the mungoose, and compare it with the quantity ground last year. This shows 14,850 gallons rum cane ground before 1878 to 7425 gallons ground in 1881, which, compared at the rate of seven loads of canes to a siphon of 450 gallons, shows eleven and a half hogsheads of sugar spoiled before 1878, compared with five and three-quarter hogsheads spoilt in 1881—taking twenty loads of good canes to the hogshead, or a destruction of 10 per cent. as compared with 5 per cent. under existing circumstances.' Again: 'Some of the best cane lands on the estate I have just mentioned had to be thrown out of cultivation for years, owing to the impossibility of saving the canes from rats. This land is now being taken up again and put into cane cultivation.'

"A correspondent on the eastern portion of the island reports that—'On the four estates on the north side of the Plantain Gardens river, they (the mungoose) have made a saving of 75 per cent. in the expense of catching rats; and it is only in public places, where the traffic of man and beast is about sixteen hours out of the twenty-four, that the ravages of rats continue. In the sequestered parts of the estates where there happen to be any stone walls or buildings affording favourite residences for the mungoose, as they did formerly for the rat, and where the ravages of rats used to be greatest, I may say the decrease of rat-eaten canes is at least 90 per cent.' And he adds, 'In a word, as a sugar planter, I feel most grateful to the mungoose and his importer.'

"Another in St. Mary's writes :—'The mungoose has fully realised the objects sought by its introduction, and it has saved on this estate 50*l.* in rat-catching expenses, and at least 20 hogsheads of sugar (of the value of 16*l.* per hogshead) per annum.' A proprietor in St. James states that 'the annual actual saving in rat-catching expenses and in rat-eaten canes on my estates, consequent on the introduction of the mungoose, has averaged from 50*l.* to 200*l.* at least on almost every estate under my charge, according to locality.' A correspondent in Trelawny writes :—'I used to lose annually from 20 to 25 tons of sugar, viz. 500 cartloads of canes (rat eaten) were ground and sent to distillery. Last year, after the introduction of the mungoose, only *one cart load* was so used. On two estates of mine in St. James similar results ensued.'

"A large proprietor in Westmoreland writes to the same effect, stating that after the introduction of the mungoose 'rats have almost disappeared from my estates. The annual expenditure for rat-catching and poison was over 300*l.*; it is now *nil.* The rat damage to canes was very considerable; it is now inappreciable.'

"These extracts might be extended, to include nearly every estate in the island, and with similar results as regards the benefits which the mungoose appears to have conferred upon the cultivation of sugar. The annual saving to sugar estates by the introduction of the mungoose might fairly be put down at 90 per cent. of the rat-catching expenses, and at 75 to 80 per cent. of rat-eaten canes. This, according to the estimate given above, would represent a total saving to the island of nearly 45,000*l.* per annum.

"Hence for sugar estates, the rat question appears, for the present at least, to have been fully solved. With regard to other industries, the question is not so clear, nor, perhaps at first sight, so satisfactory. For instance, rats, especially the black and brown species, have always caused considerable loss to coco-nut plantations by attacking the young nuts on the trees, and destroying them, sometimes in mere wantonness, in immense numbers. With the spread of the mungoose, I am informed that more rats than formerly have taken refuge in coco-nut plantations, apparently driven away from sugar estates by the mungoose; and, as the latter cannot climb, the rats are apparently quite safe. This, I fear, will always be the case, especially with the black rat, which nests in trees, and is a splendid climber. It is only in the open, where cultivation is carefully kept up, and the rats have no special shelter or trees to climb, that the mungoose is a successful rat-killer. Coco-nut planters are now, however, protecting their trees when grown up by placing strips of tin around the stem, about 6 feet from the ground, after effectually clearing out the rats and their nests from the trees. Bats, here called 'rat bats,' probably do quite as much harm in some districts to young coco-nuts as rats, and to depredations of this kind there would appear to be no remedy.

"The cultivation of cacao will no doubt ultimately benefit by the introduction of the mungoose to a considerable extent. The peasantry have hitherto suffered so severely by the depredations of rats, that this cultivation has never been taken up by them on a large scale. Owing to the introduction by Government of the best varieties of cacao from Trinidad, and the energy displayed by several large planters in establishing plantations, cacao is likely to prove a very important industry in the island.

"The following table will show the rapid increase which has taken place in the export of cacao from Jamaica since 1874:

Year.	Quantity Exported. cwt.	£
1875	311	873
1876	459	1,286
1877	375	1,051
1878	1694	7,832
1879	2153	6,631
1880	3304	10,918

"Where large areas are planted with cacao, and where the ground is kept clean and open, the mungoose must prove of great service in checking the depredations of rats, and the trees being small and low rats would be unable to make a permanent lodgment in them.

"Similarly with coffee, which has hitherto suffered most severely from their depredations. The proportion of 'rat coffee' on some estates is probably one-twentieth of the whole crop, and it would be larger still if it were all carefully gathered and cured. The actual damage done to coffee by rats has been estimated as high as 15,000*l.* per annum, and probably this is not far beyond the mark.

"In some districts the greater yield of coffee and cacao, in recent years, has been attributed more to the influence of the mungoose than to the increased area under cultivation. Certainly the large increase of our exports in cacao during the last five years cannot be accounted for alone by the increased area devoted to this culture.

"The actual benefits conferred by the mungoose on the cultivation of corn, arrowroot, sweet potato, peas, and those ground provisions cultivated by the negroes, cannot be estimated at present. 'Where the cultivation is neglected, and grass allowed to grow plentifully, from my own experience,' says a planter, 'with the growth of corn the mungoose is of little or no advantage; but when the land is kept clean, and the mungoose has free action to see and dart upon its prey, I am of opinion it is of immense advantage to corn, &c.'

"Turning now to another phase of the subject, viz. the injuries said to be inflicted by the mungoose on poultry and other domestic animals, the general opinion amongst the negroes and those who have not suffered severely by the depredations of rats is of a character decidedly unfavourable to the mungoose.

"It is but natural that an ichneumon should eat eggs and destroy chickens when other supplies fail; but from my own experience (and I have some 150 fowls running freely about the yards) I cannot recall a single instance in which eggs or chickens have been actually destroyed by the mungoose, and it is, and has been, for some time, very prevalent in the neighbourhood. Many of my correspondents, however, state the fact, and on this account the negroes destroy the mungoose whenever they find it. The evil, as yet, is not of a serious character, whatever it may eventually attain, and certainly not greater in most districts than that formerly caused by rats before the mungoose became common. At present there would appear to be no diminution in the supply, or increase in the price of either poultry or eggs. It is said that the mungoose will not trouble any fowl-house near which a dog is kept, and, as it is a day walker, its depredations in these respects are likely to be kept within comparatively reasonable limits.

"From the naturalist's point of view, the acclimatisation of the mungoose is likely to cause a disturbance in the distribution of many of our indigenous animals, which is much to be regretted. For instance, quail, wild guineafowl, and most ground-hatching birds, are rapidly diminishing.

"Sea and water fowl are also being attacked in several of their nesting places, with the evident result of their being gradually reduced. The yellow snake or boa (*Chilabothrus inornatus*), itself a good rat-catcher, and the "meek-faced" ground lizard (*Ameiva dorsalis*), are also becoming daily more scarce.

"The diminution and probable extinction of animals, in no sense dangerous, but, on the other hand, highly useful, may hereafter considerably alter the conditions of animal life in the island. For the present, however, we can only note the facts as they present themselves to us, leaving it to the naturalist of the future to draw his own conclusions.

"One view is, that when the mungoose has attained its maximum distribution, and its food supply is diminished, it will, like the Raffle ant and Agua toad, become less felt in the economy of life, and find its natural place with the rat—but both in diminished numbers. While on this subject—the due balance of animal life—I may mention that it is the opinion of one trustworthy correspondent that the Agua toad, when it swarmed over the island, by destroying the predatory insects which held the ticks and grass lice in proper check, brought upon us the present tick infliction of the colony. If this view be correct, then we may hope that, now the toad is diminishing we have also seen the worst of the tick plague. Truly a consummation much to be wished."

Ants.—In some localities, white ants are a great nuisance. Wray records the fact that their antipathy for petroleum is so great that tops or cuttings soaked for a few minutes in water tainted with petroleum will never be attacked by them. Where the soil is impregnated with petroleum, white ants are unknown.

Pou blanc.—One of the greatest scourges of the sugar-planter is the *pou blanc*, or more properly, *pou à poche blanche*, a collective name applied to two species of "louse," scientifically known as *Icerya sacchari* and *Pulvinaria gasteralpha*. The ravages of these insects are sufficiently familiar to the planters of Mauritius and Bourbon, and specimens of one of these species have recently been discovered in Queensland, upon canes grown from joints newly imported from Singapore.

In dry and hot weather, these insects frequent the roots of the canes, and do much injury to the fresh rootlets, thereby greatly retarding the growth of the plants. The young insects are very active, and run about on the green shoots and leaves until they find a suitable spot where they may fix themselves for life. They are armed with a sharp probe as long as the body, which they introduce into the new sap-wood, and suck away the juices of the plant, sometimes till they have quite destroyed it.

These insects spread very rapidly, and are exceedingly tenacious of life, notwithstanding the greatest extremes of temperature. Dr. Icery, who studied them in Mauritius, found that washing the canes with alcohol killed the insects at once, and he further recommends a solution formed by boiling a mixture of sulphur and lime in water. It should be borne in mind, however, that the insects rarely appear on healthy and well-developed canes, and though these remedies may prove useful for checking their ravages for the moment, complete extermination of the pests will only be secured by proper attention to all the conditions required by the plants.

W. Bancroft Espeut, of Spring Gardens, Jamaica, believes that the "rust" described further on (p. 102) is caused by these insects, being in fact abrasions produced by the young feeding on the surfaces of the leaves. The "waxy" powder which is usually described as coating the fully-matured insects is ascribed by this writer to the saccharine juice of the cane, and he states that it does not seem to appear until the insects attack the cane itself, extracting the sweet sap, and exuding the sugar in a liquid or crystalline form from orifices in their skins. It is this exudation which forms the great attraction to the ants, in quest of which the latter scrape the lice incessantly with their mandibles. Pike even asserts that the ants tickle the lice with their forefeet while feeding, and cause the latter to disgorge what they have imbibed (which the ants then greedily devour), till they die of starvation. In any case, ants are the great natural enemy of the lice.

Borers.—The term "borer" is applied generically to the caterpillars or "grubs" of a number of species of moths, beetles, and other insects; they are sometimes (especially in America) also called "worms," which is a misleading name, from its being correctly and more generally applied to a distinct class (*Vermes*).

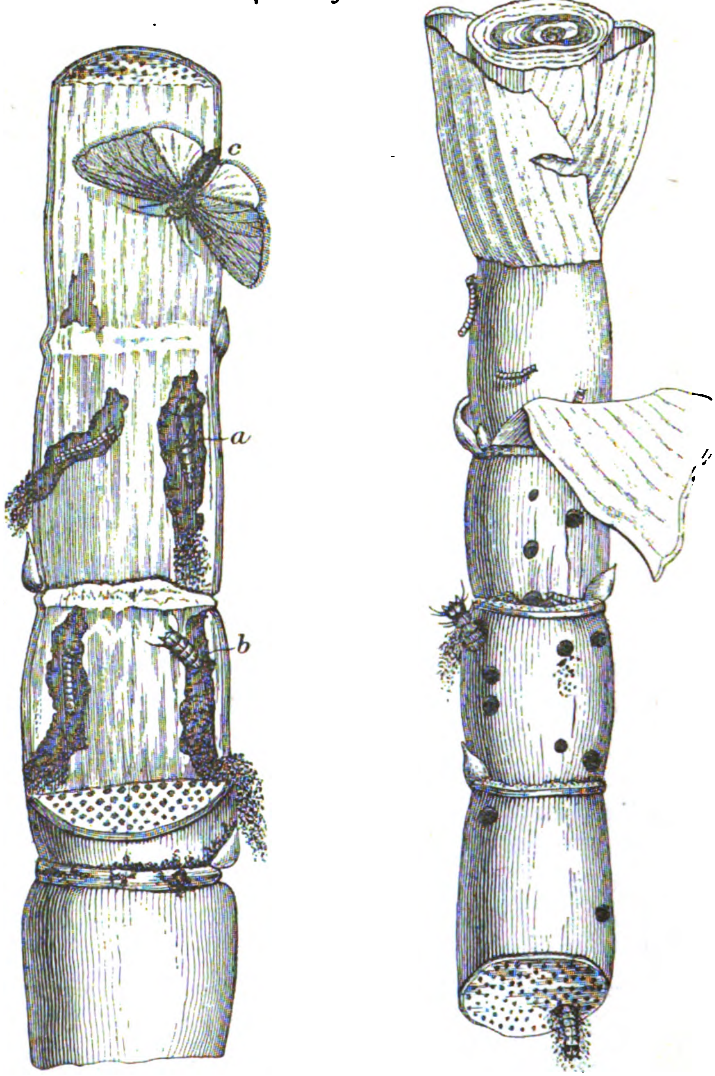
One of the most common species is *Proceras sacchariphagus*, long dreaded in Ceylon, and the cause of great destruction of cane plantations in Mauritius, since its introduction there in

1848. Two kinds common in British Guiana are *Sphenophorus sacchari* and the *tacuma*, a large species of *Rhyncophorus*, very like *R. Zimmermanni*, but not identical with it. Another Guiana species is *Phalæna saccharalis*, which produces six generations in a year. The grub of a beetle (*Tomarus bituberculatus*) also has recently given much trouble in that colony. These are all well-known forms, and the list might be greatly extended; in fact, many species doubtless still remain undescribed and unrecognised.

Further investigations into the number of species, their life histories, and natural parasites, will be very welcome, as indicating measures for their eradication. Meantime it may be stated that the habits of the grubs appear to be pretty nearly identical in all cases. They are provided with powerful mandibles, and their mouths are armed with lance-like instruments, which enable them to pierce the silicious (flinty) outer rind of the cane. Once within the soft juicy mass of the interior of the cane, their voracity leads them to effect its destruction with extreme rapidity. Figs. 14 and 15, reproduced from Nicholas Pike's interesting volume on Mauritius, give a typical illustration of canes attacked by this class of pest. Not only is the plant destroyed, but the juice is rendered useless for manufacturing purposes. The pupal or chrysalis stage is seen at *a*, the larva, maggot, grub, or caterpillar appears at *b*, and the perfect butterfly or imago is represented at *c*.

Among the means to be adopted in checking the ravages of these insects, are to be mentioned the encouragement and cultivation of their natural enemies. Principal among these latter are ants, which attack the insects both in their caterpillar state, whether just issued from the eggs or about to enter the "pupal" condition (commencing to spin their cocoons), and in their perfect or "imago" form, i. e. as moths or beetles. Turkeys and the smaller insectivorous birds devour enormous numbers of the "grubs" (caterpillars). Success has attended cultivating other natural enemies of these noxious insects, to be found in the Ichneumon flies, &c. The plan is to plant a hedge of the Congo or pigeon pea (*Cajanus indicus*)

FIGS. 14 AND 15.



Cane attacked by Borer.

around each field, and to grow the bona-vist bean (*Dolichos Lablab*) and the pigeon pea on all fallow fields, ploughing in this latter growth as a green-soil manure (see Green-soiling, p. 49) afterwards. These plants attract the Ichneumon flies in such numbers, that the whole estate may be completely freed from the destructive vermin.

Many and varied are the other methods attempted for counteracting the ravages of these troublesome caterpillars. When the estate is quite overrun with them, it may be necessary to burn every atom of vegetable matter about the plantation, such as the begass, cane-tops, leaves, and other matters likely to harbour them. But this is an extreme measure, and should be avoided if possible, as it entails the destruction of the best manure the land can have (see p. 47). The abundant application of lime to the soil will generally be found very beneficial in destroying the insects, besides its manurial value (see p. 35).

A widely-adopted plan is to cut off and burn the first shoots that spring from the planted cane-cuttings. These are allowed to grow for about three months, by which time the grubs will have congregated on them. The shoots are then cut close to the ground, piled in heaps, and burned. The second crop of shoots soon appears, and the skins of these latter are said to be much tougher, and better able to resist the attacks of the grubs which may have escaped the burning. This plan is often supplemented by sending labourers to destroy all the caterpillars they can find on the second growth of canes.

These modes of checking the progress of the insects when once they are found upon an estate are all worthy of the greatest attention; but it is equally important not to overlook preventive measures. It is beyond doubt that not only borers but many other injurious insects are propagated on the canes year after year. Hidden in the cane-tops are the chrysalides of the insects, which in due course are transformed into moths and butterflies, whose eggs supply a new swarm of caterpillars and grubs, and thus the evil is constantly maintained.

Obviously, therefore, great good may be gained by ridding the cane-tops of all vermin, whether in a perfect or imperfect state, before planting. A very simple plan is to soak the cuttings for 24 hours in water which is sufficiently hot to destroy the larvæ which may be infesting it, without being hot enough to injure the germinating powers of the plant. A more effective remedy is the use of antiseptic preparations, as they attack parasitic growths which would be unaffected by mere warm water.

Pike alluded to the use of carbolic acid (called also phenol, phenylic acid, and phenylic alcohol) for this purpose in Mauritius in 1873, but he omitted to give any figures as a guide. Dr. Bancroft, in Queensland, has more recently published exact directions for a treatment which he has adopted with complete success: it is as follows:—(1) Clean the joints of the cuttings entirely from trash (leaves) as carefully as possible; (2) immerse the cuttings for 24 hours in a mixture of 1 lb. of carbolic acid to 50 gallons of water, the water being heated to a degree that the hand can bear; (3) immerse the cuttings for a few minutes in a milk of lime, made by mixing 2 lb. of slaked lime with 1 gallon of water; (4) spread the cuttings out to dry in the sun, and turn them occasionally, for one day before planting.

Rust.—From Queensland, there has lately been a great outcry concerning the mischief caused by a new disease in the cane, and which has been termed "rust." It seems to be the same that has been noticed in the Malay Archipelago, Mauritius, the Society Islands, and Bahia. The disease is characterised by a dark-brown or reddish granular incrustation, which makes its appearance on the leaves and stem. It has been attributed to numerous kinds of insect and fungus; but R. M'Lachlan, F.R.S., has finally determined it to be due to the punctures of a minute *Acarus* (mite), which exists upon the diseased cane in myriads. The exact species has not been made out satisfactorily, but the creature is stated to look very like a *Tyroglyphus*, though its habits do not altogether accord with those of that genus. A black-spored fungus is eventually produced by the red spots on the leaves; this is regarded by M. J. Berkeley as a new species, to which he has given the name *Depazea sacchari*. He does not consider that it plays any part in the disease, but merely occupies the already destroyed tissues. The Bourbon canes suffered much more than any other variety.

Prof. A. Liversedge, of Sydney University, made this disease the subject of prolonged study on the estates where it was actually in existence, and issued an exhaustive report of his investigations. In summing up the results of his observations, he concludes that the so-called "rust" is not to be considered as a disease in itself, but rather as a result of an existing diseased condition of the plants. This diseased condition he ascribes to bad cultivation, want of drainage, and improper manuring, to which must be added in some instances unsuitability of climate, and poverty of soil. His advice to the Australian planters exactly coincides with what has been stated in the foregoing sections of the present chapter of this book. Give the plant an opportunity of thriving, provide it with the food and air which are essential to its development, and it will grow healthy and strong. There is no disease but what is caused directly or indirectly by withholding from the plant those conditions which its nature demands; and though the evil may be temporarily checked by the means thus described, the only real and permanent cure lies in a proper system of agriculture.

Smut.—In Natal, the canes are attacked by a kind of "smut," called *Ustilago sacchari*, which is analogous to the well-known disease that affects the cereals of this country, and is entirely due to faulty cultivation.

Yields of Canes and Sugar.—Though the statistics of the cane and sugar production of any one estate or district cannot be taken as affording an index to the capabilities of any other estate or district, on account of the varying conditions necessarily existing, much information of a comparative nature may still be gained by placing such details in a collective form, and they will be useful for reference in drawing conclusions as to the results of new processes and their superiority or otherwise to older plans. They will be most readily consulted in a tabular form.

BARBADOS.

1 foot of sugar-cane weighs about ¾ lb.
1 clump ,, ,, ,, 54 lb.
1 ,, ,, yields ,, 4 gal. of juice.
4 gal. of juice ,, ,, 4 lb. of muscovado sugar.
1 acre ripe cane (holes 6 ft. × 5 ft.) yields 1452 clumps.
1452 clumps of cane yield about 5808 gal. of juice.
5808 gal. of juice ,, ,, 5808 lb. of sugar.
1 acre, planted 6 ft. × 5 ft., at 50 lb. to the clump, will give 72,600 lb. or 36 tons of ripe cut cane, or 2½ tons of raw sugar.

LOUISIANA.

1 acre yields from 44,000 lb. to 60,000 lb. of cane.
The average cost per 2200 lb. is 2½ to 5 dollars.
The density of the juice varies from 6° to 10° B., and averages 8° to 8½° B.; 8° B. is equal to 14·4 lb. of pure sugar per 100 lb. of juice, or 2·96 lb. of sugar for the 90 lb. of juice, contained in 100 lb. of canes; 8½° B. would mean 15·33 per cent. of pure dry sugar.
1240 gal. of juice at 8½° B. produce 1048 lb. of sugar, and 480 lb. of molasses; with the best modern machinery, more sugar and less molasses are got.
1 gal. of juice at 8½° B. weighs 10·62 lb.
1240 gal. ,, ,, 13,169 ,,
100 lb. of cane contain 90 lb. of juice.
12,345 ,, yield 11,111 ,,
11,111 lb. of juice at 8½° B. should give 1700 lb. of sugar.
The actual yield of combined sugar and water of crystallisation is 14·89 per cent.
11,111 lb. of juice therefore afford 1655 lb. of sugar and molasses.
Of the 1655 lb., 1173 lb. are sugar, and 482 lb. molasses.
Thus 427 lb. of sugar and molasses are lost in the manufacture.
11·8 lb. of cane give 1 lb. of sugar and 0·48 lb. of molasses.
10·5 lb. of cane would have given 1 lb. of sugar and 0·66 lb. of molasses, if no loss had occurred.
7·26 lb. of cane would give 1 lb. of sugar, if there were no loss, and no molasses produced.

1 acre will grow from 13,000 to 45,000 canes.
The length of the canes varies from 3 to 8 ft.
,, weight ,, averages 10 oz. per ft.
Canes 4½ ft. long, weighing 3 lb. each, and growing 350 per row of 100 ft., will give 61,125 lb. of canes per acre.
Planters require 35 to 55 lb. of cane to make 1 lb. of sugar and 0·66 lb. of molasses.
The average for the State is 2·25 lb. of sugar and 1·50 lb. of molasses from 100 lb. of cane.
Thus 100 acres give 6,000,000 lb. of cane, affording 135,000 lb. of sugar and 90,000 lb. of molasses.
But 6,000,000 lb. of cane, if no loss occurs in manufacture, can give 571,428 lb. of sugar, and 380,952 lb. of molasses.
And if made into firsts, seconds, &c., sugars, could yield 750,000 lb. of white sugar, and 140,000 lb. of molasses.
While the same cane would make 867,510 lb. of concrete sugar.

MAURITIUS.

1 barrel of cane-juice weighs 530 to 544 lb.
1 ,, ,, yields about 95 lb. of sugar.
1 acre of cane produces 3500 to 5500 lb. of sugar.

EGYPT.

1 acre of cane affords about 500 lb. of refined sugar.

JUICE FROM 100 LB. OF CANE.

100 lb. of cane giving juice at 10° B. will yield

	4·714	gal.	of juice at	50	per cent.	extraction.
,,	5·185	,,	,,	55	,,	,,
,,	5·657	,,	,,	60	,,	,,
,,	6·128	,,	,,	65	,,	,,
,,	6·600	,,	,,	70	,,	,,
,,	7·071	,,	,,	75	,,	,,
,,	7·543	,,	,,	80	,,	,,
,,	8·015	,,	,,	85	,,	,,
,,	8·486	,,	,,	90	,,	,,
,,	8·958	,,	,,	95	,,	,,
,,	9·430	,,	,,	100	,,	,,

CHAPTER II.

COMPOSITION OF THE JUICE.

BEFORE leading the reader into the volumes of argument concerning the best method of making sugar, and minutely detailing the differences of the many processes and apparatus, it will be necessary to make him thoroughly acquainted with the nature and characters of that cane-juice from which the sugar has to be obtained.

It must be confessed at the outset that our knowledge of the subject is still meagre, chemists being unable as yet to state what sugar actually is or how it is produced; but if every planter and manufacturer only knew and applied the information hitherto gathered on the subject, the cane-sugar industry would hold a very different position from that which it now occupies.

Among the many chemists who have studied this subject, the name of Dr. Icery of Mauritius stands pre-eminent, and it is to him chiefly that our knowledge of the composition and characters of sugar-cane juice is due.

Mention has already been made (p. 15) of the structure of the sugar-cane, and the form of its cells has been shown in Fig. 14 (p. 100). Within these cells is contained a sweet watery juice, a sugar-water holding a variable quantity of organic and mineral matters in solution. This is the juice which is extracted from the canes for the purpose of being made to yield its sugar. The nature of the ingredients composing cane-juice is not, under ordinary conditions, liable to variation; the proportions of these ingredients, on the other hand, fluctuate with the soil and climate, the age of the cane, the portion of the cane affording the juice, and other circumstances. Consequently in giving analyses of average samples the figures can only be taken as approximate.

Dr. Icery states the average composition of the juice of ripe Mauritius canes as:—

Water..	81·00 per cent.
Sugar..	18·36 ,,
Mineral salts	0·29 ,,
Organic substances	0·35 ,,

R. H. Harland has stated the composition of some cane-juices examined by him which were expressed from canes grown in the Mary district, Queensland, to be as follows:—

	Guinghan Cane.	China Cane.	Mixed Canes.
Density at 15½° C. (60° F.) ..	11·5° B.	10·5° B.	11·6° B.
	per cent.	per cent.	per cent.
Crystallisable sugar	19·50	16·40	18·30
Uncrystallisable ,, ...	0·25	0·41	0·45
Ash (soluble salts)	0·70	1·11	0·37
Other organic matters	1·17	2·51	3·14
Total solid matters	21·62	20·43	22·26

The same author gives the composition of a juice from the Taal district of the Philippine Islands:—

Crystallisable sugar	18·30 per cent.
Uncrystallisable ,, ...	0·10 ,,
Ash	0·30 ,,
Other organic matters ..	3·25 ,,
Total solid matters ..	21·95 ,,

He also examined the juice of several samples of unripe cane, whose constituents proved to be:—

	I.	II.	III.
	per cent.	per cent.	per cent.
Crystallisable sugar	8·60	7·76	7·24
Uncrystallisable ,, ...	3·10	2·30	2·50
Ash (mineral matters)	0·21	0·25	0·34
Unknown organic matters ..	1·27	1·74	2·89
Total solid matters	13·18	12·05	12·97

It may be said in general terms that cane-juice consists of about 81 per cent. of water, 18 of sugar, 0·6 of organic matters, and 0·4 of inorganic (mineral) matters; and further that about 0·5 to 0·6 per cent. of the sugar in the juice of ripe canes (it is much greater in unripe ones, as shown above) is uncrystallisable.

These several substances are very intimately combined in the juice of the cane, but Dr. Icery has shown that the juice is not of one constant quality throughout the whole of even the same cane. The fact is indeed recognised by planters, since they cut off and reject the tops of the canes before extracting the juice. Further it is to be noted that the juices contained in the soft central or medullary part of the cane are much more rich in sugar than those of the nodular portion (the "knots"), or of the cortical portion (the rind). Dr. Icery experimented upon canes divided in such a way as to be able to separately express the juice from the soft interior, the outer rind (roughly detached, and carrying some of the inner portion), and the knots, with the following results as to the juice and sugar produced:—

	Interior.	Rind.	Knots.
Density of juice at 25° C. (77° F.)	1·082	1·074	1·069
Sugar, per cent.	18·4	17·9	17·1

Conversely, it is found that the saline and organic matters are in increasing proportion in the harder parts of the cane. These are very important facts. The most saccharine (sugar-yielding) juice resides in the softest portions of the cane, and is therefore most easily extracted; when an extra yield of juice is obtained by the exhaustion of the harder portions, the quantity is at the expense of the quality.* The fact has an

* Wray has a statement (on p. 193, footnote, of his 'Practical Sugar Planter') directly to the contrary of this, but it can only be taken as expressing his *opinion*, and not a proved *fact*, therefore it cannot be allowed to outweigh the results of actual experiment.

obvious bearing upon the question of the relative advantages of those mills which extract only 60 per cent. and those which get out up to 85 per cent. of 90 per cent. of juice usually present in the cane.

It is now necessary to devote some space to a separate consideration of each component part (or group) of the raw juice, viz. the crystallisable and the uncrystallisable sugar, the mineral matters, and the organic matters.

The Crystallisable and Uncrystallisable Sugar.—It is assumed that the reader has already made himself acquainted with the nature and properties of the various kinds of sugar, as described in the Introduction to this volume, and that he is quite familiar with the exact meaning conveyed by the terms "crystallisable" and "uncrystallisable" sugar. That being so, it is hardly necessary to remind him that crystallisable sugar is the one article which it is his object to procure, and that the uncrystallisable product is the thing to be avoided.

The relations between the two kinds of sugar are but little understood, and the artificial conversion of uncrystallisable into crystallisable sugar remains an impossibility, though the latter can be "inverted" into the former readily enough. From some experiments made by Harland, while in the Philippine Islands, it would seem that in the growing or ripening plant a conversion of uncrystallisable into crystallisable sugar does take place, the proportion of the former being markedly decreased in the juice of canes expressed 8 days after the cutting. The occurrence of uncrystallisable sugar in the juice of the cane in a natural unchanged state was long disputed; but Dr. Icery and other modern chemists have conclusively shown that it is present at all stages, being in least quantity (about ½ per cent. of the total sugar) in sound ripe canes, and notably increasing in unripe ones and those which have suffered any degree of fermentation.

The presence of uncrystallisable sugar works a twofold mischief. In the first place, the uncrystallisable sugar is itself a loss: that is to say, it has no value as sugar; and in the second place, the existence of this uncrystallisable sugar in the syrup so affects the remainder as to greatly hinder, if not absolutely prevent, the recovery of an equal quantity of the still unaltered crystallisable sugar in a saleable form. The reason of this lies in the fact that the liquid containing the altered sugar has a treacly consistence, and cannot be conveniently deprived of its water by evaporation to such a degree as will leave the unaltered sugar in a saturated solution capable of clean crystallisation on cooling. Practically, therefore, it may be said in round numbers that every 1 lb. of sugar rendered uncrystallisable in a syrup entails an actual loss of 2 lb. of crystallisable sugar.

The chief cause of the alteration in sugar is the fermentation of the juice, or rather of certain constituents of the juice, viz. the organic matters other than the sugar. The conditions essential to this fermentation taking place are mainly the access of air to the juice, and the prevalence of a moderately high temperature. These are the natural conditions: consequently fermentation may (and does) begin in the still living cane, when injuries (such as the gnawing by rats) admit air into the cells. Artificially, fermentation is set up in the juice the moment the latter is extracted from the cane, and it is maintained by the heat necessary for carrying on the various processes of manufacture, increasing in proportion to the duration of the processes and to the degree of heat applied. Acids also provoke fermentation; they are nearly always present in a free state in the juice, as is shown by the latter giving a red colour to litmus-paper. Hence the importance of rapid treatment at low temperatures, and with the least possible exposure to the air.

It might naturally be supposed that fermentation would commence in the juice while still in the cane, as soon as the latter was cut; but this is not the case, at least with canes which have not been injured by rats, frost, or other causes. Thus in Louisiana it is found that sound canes may be kept for 3 or 4 months after cutting, without affecting the sugar contained in the juice, the only result apparently being the loss of a certain portion of the water of vegetation. The juice of some canes which had been cut 7 months marked a density of 8° B., and the sugar was in a perfect state of preservation. Doubtless the comparatively low temperature prevailing in Louisiana is an important factor to be considered in this instance, and in a warmer climate the same result could not be expected in the same degree. Yet some experiments in this direction made by Harland in the Philippines show that sound cut canes may be kept for a week at least, even in the high temperature of an Eastern tropical summer. Moreover he chose unripe canes for the purpose, thinking it probable that their juice would deteriorate more rapidly, on account of their acidity and their relative poverty in sugar.

Two plants were selected, each having two healthy canes growing from the one stool; the juice from one of these was expressed and analysed immediately, the other was put aside in the laboratory for 8 days, at the expiration of which time the juice was expressed and submitted to analysis. The following are the results:—

FIRST EXPERIMENT.

Weight of cane	1 lb. 10¼ oz.	2 lb. 8¼ oz.
Loss of weight in 8 days	..	4·75 oz.
,, ,, per cent.	..	11·8 per cent.
Density of juice	5½° B.	5¾° B.
Crystallisable sugar	5·99 per cent.	7·33 per cent.
Uncrystallisable ,,	1·70 ,,	1·50 ,,
Ash	0·30 ,,	0·32 ,,
Unknown organic matters	2·27 ,,	1·99 ,,
Total solid matters	10·26	11·14
Reaction	Slightly acid	Slightly acid.

SECOND EXPERIMENT.

Weight of cane	2 lb. 1¼ oz.	..	2 lb. 6¼ oz.
Loss of weight in 8 days	..	..	4·7 oz.
,, ,, per cent.	..	..	12 per cent.
Density of juice	5½° B.	..	5½° B.
Crystallisable sugar	8·17 per cent.	..	6·54 per cent.
Uncrystallisable ,, ...	1·90 ,,	..	0·40 ,,
Ash	0·26 ,,	..	0·24 ,,
Unknown organic matters	0·87 ,,	..	2·34 ,,
Total solid matters..	11·20		10·52
Reaction	Slightly acid.	..	Slightly acid.

These results show that no fermentation of the juice had taken place during the time the canes had been exposed after cutting; in fact, the singular result of the uncrystallisable sugar being less in the exposed samples, would seem to indicate that a ripening action had been going on. These results certainly appear to show that canes could be kept and transported long distances without undergoing loss of crystallisable sugar; but this, of course, only applies to sound canes, and the result might be quite different in cases where the rind of the cane was cracked, or eaten into by rats. Obviously something also depends upon the climate, as in the West Indies and Demerara, it is positively asserted that the juice must be expressed within 48 hours after cutting, to prevent excessive inversion taking place; this is somewhat overcome by the use of antiseptics, and the application of ½ oz. of dry salicylic acid per 500 gallons of juice is said to much reduce the quantity of lime necessary for the subsequent defecation.

Hydrometers.—It is possible to ascertain approximately the quantity of sugar contained in a sample of cane-juice by observing its density. This is done by means of a hydrometer (also called an areometer), of which there are several kinds in use, differing in their standard (basis) and graduation. The one most generally adopted among sugar-makers out of England is that of Baumé (B.); in England, Twaddell's (Tw.)

is most commonly employed. The following rules for the conversion of the scales will be found useful :—

I. To convert B. degrees to sp. gr. (for liquids lighter than water),—

$$\frac{144}{B.^\circ + 134} = \text{sp. gr.}$$

II. To convert sp. gr. to B. degrees (for liquids lighter than water),—

$$\frac{144}{\text{sp. gr.}} = B.^\circ$$

III. To convert B. degrees to sp. gr. (for liquids heavier than water),—

$$\frac{144}{144 - B.^\circ} = \text{sp. gr.}$$

IV. To convert sp. gr. to B. degrees (for liquids heavier than water),—

$$144 - \frac{144}{\text{sp. gr.}} = B$$

V. To convert Tw.° to sp. gr., = (Tw.° × 5) + 1000, placing the decimal point after the first figure, thus (80° Tw. × 5) = 400 + 1000 = 1·400 sp. gr.

VI. To convert sp. gr. to Tw.°, — $\frac{\text{sp. gr.} - 1\cdot000}{5} = \text{Tw.}^\circ$

The indications of the hydrometer refer to the proportion of solid matters contained in a certain quantity of water, all these matters augmenting the density of the liquid, without reference to their character. Hence the figures marked by the hydrometer express the quantity of sugar present, plus the other solid matters. The varying nature and proportion of these other solid matters introduce an element of uncertainty into the result, which can only be estimated approximately from the experience of a number of analyses of such juices. Upon such analyses, Dr. Icery founded the table which is reproduced below (see next page), the French measures employed by him being reduced to percentages.

The Mineral Matters.—From numerous analyses, the quantity of mineral salts contained in the juice of canes best fitted for sugar manufacture is estimated at 4·29 per cent. of the liquid. Saline matters, like organic substances, are found in a greater proportion in the head than in other parts of the cane. The analyses of young canes have not always confirmed the often-expressed opinion that the salts in the juice of the cane are greater in quantity in proportion as the plant is farthest from the period of its development. On the contrary, the nature of the soil appears to have a much more strongly-marked influence, and it is to this that the variations in the figures representing the saline substances must be referred.

TABLE of the Quantities of Sugar in a definite Volume or Weight of Juice corresponding to the principal Degrees of Baumé, and obtained directly by a series of Experiments at 25° C. (77° F.).

Baumé Degrees.	Weight of Sugar per cent. of the Juice (indicated).	Weight of Sugar per cent. of the Juice (actual).	Differences resulting from the Influence of other Substances besides Sugar (principally Uncrystallisable Sugar).
4	2·8	2·6	4·9
5	4·9	4·8	4·7
6	7·8	7·4	4·0
6¼	8·5	7·9	
6½	9·1	8·6	
6¾	9·8	9·2	
7	10·5	9·9	3·6
7¼	11·1	10·5	
7½	11·8	11·1	
7¾	12·4	11·7	
8	13·1	12·3	3·2
8¼	13·7	12·9	
8½	14·4	13·5	
8¾	15·2	14·2	
9	15·9	14·9	2·6
9¼	16·5	15·5	
9½	17·2	16·1	
9¾	18·0	16·7	
10	18·8	17·4	2·1
10¼	19·6	18·0	
10½	20·4	18·7	
10¾	21·1	19·4	
11	21·7	20·0	1·5
11¼	22·6	20·6	
11½	23·0	21·1	
11¾	23·7	21·6	
12	24·4	22·7	1·3

The fixed mineral matters contained in cane-juice are principally composed of potash, soda, lime, and iron, in the state of oxides, carbonates, chlorides, sulphates, biphosphates, and silicates, with which are found blended salts of alumina and magnesia. The annexed analysis of the average ash of a great number of juices, extracted from canes of different species, and cultivated in soils of different natures, may be considered as showing the proportions in which the most important substances are found :—

Potash and soda	18·83 per cent.
Lime	8·34 ,,
Oxide of iron	1·99 ,,
Silica	11·48 ,,
Alumina, magnesia, and acids in combination with the bases	59·36 ,,

The Organic Matters.—The vegetable (organic) matters contained in cane-juice have been divided into three groups; the first embraces the substances which are termed "granular matter"; the second, the albuminous material, capable of coagulation by heat; the third, nitrogenous substances which can only be coagulated by alcohol and metallic solutions. This of course excludes the sugar itself, which is also an organic (vegetable) matter. Neglecting the sugar, the relative percentage proportions of the other vegetable matters of the juice will be as follows :—

Granular matter	28·7 per cent.
Albuminous ,, ...	7·6 ,,
Other vegetable matter..	63·7 ,,

And their percentage proportions of the juice will be :—

Granular matter	0·100 per cent.
Albuminous ,, ...	0·027 ,,
Other vegetable matter	0·223 ,,
	0·350 ,,

The "Granular Matter."—The "granular matter" is supposed to be formed by corpuscles or granules suspended throughout the liquid, and consisting of globular, transparent bodies containing semi-fluid matter in a thin covering. They communicate a milkiness to the liquid, and are with difficulty precipitated from its upper layers on standing; but they may be easily and almost (though never quite) completely separated by filtration.

It is remarkable that juice thus filtered may be kept for 6 to 24 hours in conditions of temperature most favourable to fermentation, without showing the slightest indication of such an action; but after this period, varying with the climate, it becomes dim, corpuscles are developed, fermentation then sets in and continues slowly, and, at a temperature of 25° C. (77° F.), well-formed bubbles appear in the liquid.

On the contrary, when the juice has been simply cleared from the coarse fragments of vegetable matter, which it always carries down with it, fermentation is rapidly produced after extraction from the cane, and the liquid becomes viscid in a few hours.

At the boiling-point, cane-juice is freed from part of the albuminous substance which it contains, and this substance, coagulating under the influence of heat, seizes on the granular matter, and draws it into the flakes which form on the surface of the liquid. This albumen of the cane-juice has also great importance as a cause of fermentation. Juice which, after boiling, has been completely freed from its albumen and its globules by means of filtration, may be kept perfectly fresh for many hours, at a temperature of 30° C. (86° F.).

It thus appears that it is sufficient to rapidly raise the newly-extracted cane-juice to the boiling-point, and to filter it immediately, in order to have a perfectly limpid liquid, which can be kept for a considerable time without any alteration.

Further, these globular and albuminous substances essentially contribute to develop acidity in the juice, and are one of the principal causes of the formation of uncrystallisable sugar. When they are eliminated, acidity is less strongly increased by the action of heat, and always remains very inferior to what it would have been in the contrary case.

The Albuminous Matter.—The albumen found in cane-juice coagulates at about 80° C. (176° F.), and is precipitated by powerful acids, without being re-dissolved in any sensible manner by an excess of the reacting substance.

The Nitrogenous Matter.—After the albumen is partially separated by heat there remains in the juice a complex organic

TABLE showing the Percentage Weights of CRYSTALLISABLE and INVERTED SUGAR, and of SALINE MATTERS, contained in SYRUP at 25° C. (77° F.) and 41° B., the quality of the Sugar made being nearly uniform.

	Names of Establishments.	Reaction of the Syrup.	Percentage of Uncrystallisable Sugar contained in the Juice producing the Syrup analysed.	Total Sugar.	Crystallisable Sugar.	Uncrystallisable Sugar.	Proportions of Crystallisable and Uncrystallisable Sugar per cent. of the Total Sugar.		Saline Matters per cent.
							Crystallisable Sugar.	Uncrystallisable Sugar.	
First syrup	La Gaiété	almost neutral ..	0·3	83·0	75·2	7·8	91	9	2·7
	Labourdonnais ..	acid	0·4	81·3	59·7	21·6	73	27	4·0
	Bel-Etang	almost neutral ..	1·2	71·8	54·4	17·4	76	24	..
	Sébastopol ..	neutral	0·9	74·1	59·2	14·9	80	20	..
	Moko	almost neutral ..	0·8	69·9	52·5	17·4	75	25	..
Second syrup	La Gaiété	,, ,,	..	69·2	57·6	11·6	83	17	4·6
	Labourdonnais ..	acid	..	74·1	49·9	24·2	67	33	5·0
	Bel-Etang	,, ...	..	50·6	29·6	21·0	58	42	..
Third syrup	La Gaiété	neutral	..	62·9	48·3	14·0	77	23	6·0

DETERMINATION of the Relative Quantities of UNCRYSTALLISABLE SUGAR and SALINE and ALBUMINOID MATTERS found in the JUICE, and the Different Syrups produced from it, reduced to the Temperature of 25° C. (77° F.) and a Density of 1·071 sp. gr.

Canes of full growth and ripeness; juice manufactured with a neutral reaction after the separation of the scum.	Reaction.	Percentage of Total Sugar.	Crystallisable Sugar.	Uncrystallisable Sugar.	Proportion of Crystallisable and Uncrystallisable Sugar per cent. of the Total Sugar.		Percentage of Ash.	Percentage of Albuminoid Substances.
					Crystallisable Sugar.	Uncrystallisable Sugar.		
Juice of the canes	acid ..	16·7	16·4	0·3	98	2·	0·32	0·39
Syrup from the same examined at the moment of boiling, sent from the battery to the vacuum-pan at 22° B.	neutral ..	16·5	15·8	0·7	95	5	0·25	0·32
1st syrup, the produce of the above after the extraction of the sugar of the first boiling	,, ..	14·7	12·2	1·5	83	17	0·83	0·63
2nd syrup, the produce of the above after the extraction of the sugar of the second boiling	,, ..	12·5	9·8	2·7	78	22	1·08	1·09
3rd syrup, the produce of the above after the extraction of the sugar of the third boiling	,, ..	11·4	8·3	3·1	73	27	1·64	2·13
Canes of full growth but not yet ripe; juice less rich, and manufactured with an almost neutral reaction.								
Juice of the canes	acid ..	14·4	12·9	1·5	87	13	0·22	0·47
Syrup from the same, examined at the moment of boiling, sent from the battery to the vacuum-pan at 22° B.	almost neutral	..	..	..	..	..	..	..
1st syrup, the produce of the above after the extraction of the sugar of the first boiling	,,	12·5	9·6	2·9	76	24	0·87	0·71
2nd syrup, the produce of the above after the extraction of the sugar of the second boiling	neutral ..	9·9	5·7	4·2	57	43	1·10	1·32
3rd syrup, the produce of the above after the extraction of the sugar of the third boiling	,, ..	..	..	..	..	..	..	..

matter which can be precipitated by alcohol and by neutral acetate of lead, and which is very soluble in alkalies and acids, even in tannic acid. Separated and purified by several precipitations in alcohol, this substance is without smell or taste, white, amorphous without influence on polarised light, giving out ammonia when heated with lime or potash, and deliquescent, though only partially re-dissolving after its separation. Left in water, it forms a disturbed and viscid solution; mixed with sweetened water, it causes it to become equally viscid, and it appears to be the real cause of that viscid consistence which cane-juice and syrup assume under fermentation. This substance, escaping the action of the agents used to defecate the juice, accumulates in considerable quantity in the syrups. It must, therefore, be considered as one of the chief causes which hinder the extraction of sugar at the second boiling, as it is a powerful obstacle to the regular crystallisation of this substance, and excites rapid fermentation when sufficient water is present.

Effects of the manufacturing Processes.—In order to estimate the amount of inverted (rendered uncrystallisable) sugar contained in the unmanufactured juice, and produced by the effects of the manufacturing processes, Dr. Icery made numerous analyses, the average results of which are given in two annexed tables. From them, it will be seen that while, in the case of fully grown and ripened canes, the *third* syrup contains only 27 per cent. of uncrystallisable sugar; yet in the case of fully grown and *un*ripe canes, the *second* syrup contains 43 per cent. of uncrystallisable sugar. It is generally conceded that when the uncrystallisable sugar in a syrup exceeds 37 per cent. of the total sugar, the syrup cannot be profitably re-boiled to yield a further quantity of sugar.

The annexed tables (pp. 120–123) exhibit the results of 78 analyses by Dr. Icery, recording the date of the analysis, the name of the estate, the kind of cane, the age of the cane, the reaction of the juice, its temperature, its density by hydro-

No.	Dates.	Estates.	Kinds of Cane.	Age.	Reaction.*	Temp. Centigrade.	Degree by Baumé.
				months.		deg.	
1	April 1864	La Gaiété	Bellouguet, plant canes	12	s.a.	25	9·1
2	"	"	Ditto, plant canes	..	"	..	5·0
3	July 1864	Queen Victoria	Diard "	18	"	..	9·0
4	Aug. 1863	La Gaiété	Bamboo "	15	a.	..	9·8
5	"	"	" "	..	"	..	9·7
6	"	"	Otaheite "	..	"	..	9·8
7	"	"	Bamboo and Otaheite, plant canes	..	"	..	9·7
8	"	Argy	Bamboo, 2nd ratoons	..	v.a.	..	9·5
9	"	Deep River	Bellouguet, plants	18	"	..	8·8
10	"	"	Bamboo "	..	"	..	9·1
11	"	Bell Etang	Bellouguet "	..	"	..	8·0
12	"	La Gaiété	Bamboo "	15	"	..	10·0
13	"	"	Penang, 3rd ratoons	12	s.a.	..	9·4
14	"	"	Bellouguet, plants	15	v.a.	..	9·1
15	Aug. 1864	Queen Victoria	Bamboo "	18	s.a.	..	9·5
16	"	La Gaiété	" "	17	"	..	8·9
17	"	"	" "	16	"	..	9·7
18	"	"	" "	3	"	..	6·7
19	"	"	" "	3	"	..	6·5
20	"	"	" "	6	"	..	5·8
21	"	"	Mixed	14	"	..	9·7
22	Sept. 1863	"	Bellouguet and Bamboo, plants	15	"	..	9·8
23	"	"	Ditto, 2nd ratoons	12	"	..	10·2
24	"	"	Bellouguet "	..	v.a.	..	9·5
25	"	Beau Rivage	Bamboo, 1st ratoons	..	s.a.	..	10·5
26	Sept. 1861	La Gaiété	" plants ..	15	"	..	9·4
27	"	Bel Etang	Mixed	17	a.	..	8·4
28	Oct. 1863	La Gaiété	Bamboo, plants ..	15	s.a.	22	10·4
29	"	"	" "	..	"	..	10·6
30	"	"	" "	..	a.	..	10·8
31	"	"	Guinghan "	..	"	..	10·2
32	"	"	Bellouguet "	..	"	..	11·2
33	"	"	Bamboo, ratoons	..	"	25	11·2
34	"	"	Guinghan "	..	"	..	12·0
35	"	"	Bellouguet, plants	..	s.a.	..	10·0
36	"	"	Penang, 1st ratoons	..	"	23	10·2
37	"	"	Penang and Bamboo, 1st ratoons	..	"	..	10·1
38	"	"	Bellouguet, plants	15	v.a.	..	10·5

* a. signifies acid; s.a., slightly acid; v.a., very acid.

Specific Gravity.	Percentage of Albuminous Matters.	Weight of Ash.	Indications of the Polarising Saccharometer.		Indications by Chemical Analysis.			Observations.
			Direct Notation.	Equivalent Percentage of Sugar in the Juice.	Percentage of Total Sugar.	Crystallisable Sugar.	Uncrystallisable Sugar.	
1·068	0·54	..	85·8	14·000	13·0	..	..	Body of the cane.
1·036	0·66	..	31·9	6·200	7·0	5·00	2·00	Head of ditto.
1·067	0·42	..	99·3	16·200	16·0			
..	..	..	109·0	17·800	17·0			
..	..	..	108·3	16·800	16·0			
..	..	..	110·5	18·000	18·0			
..	..	..	108·9	17·800	17·0			
..	..	..	107·0	17·500	17·0			
..	..	..	96·8	15·800	15·5			
..	..	..	97·9	16·000	15·0			
..	..	..	80·0	13·000	13·5			
..	..	..	113·6	18·600	18·0			
..	..	..	101·7	16·600	16·0			
..	..	..	96·8	15·800	15·7			
1·072	0·56	..	108·1	17·600	16·5			
1·066	0·45	..	97·9	16·000	16·0			
1·073	0·46	..	107·2	17·500	16·5			
1·050	0·31	..	53·9	8·800	10·0	7·00	3·00	Short gross shoots.
1·049	0·38	..	59·9	9·800	11·0	7·00	4·00	
1·043	0·55	0·30	50·6	8·200	10·5	8·00	2·50	
1·072	0·48	0·36	105·5	17·249	17·0	16·70	0·30	
..	..	..	109·0	17·800	17·0			
..	..	..	117·5	19·100	18·0			
..	..	..	102·6	16·700	16·5			
..	..	..	126·0	20·600	19·0			
1·070	0·37	0·32	107·8	17·625	17·0	16·76	0·24	
1·063	0·29	0·18	84·7	13·800	14·0	12·40	1·60	
..	..	..	117·0	19·100	18·0			
..	..	..	124·8	20·400	19·0			
..	..	..	127·6	20·900	19·0	..	..	Taken in the same state.
..	..	..	123·5	20·300	19·0	..	..	
..	..	..	135·8	22·000	20·0	..	..	
..	..	..	134·7	22·000	20·0	..	..	Attacked by disease.
..	..	..	141·9	23·200	20·0			
..	..	..	112·2	18·300	17·0			
..	..	..	117·7	19·100	17·5			
..	..	..	117·7	19·100	17·5			
..	..	..	124·5	20·300	19·0			

No.	Dates.	Estates.	Kinds of Cane.	Age.	Reaction.*	Temp. Centigrade.	Degree by Baumé.
				months.		deg.	
39	Oct. 1864	La Gaiété	Bamboo, ratoons	13	s.a.	25	4·2
40	,,	,,	,, ,,	..	v.a.	..	9·8
41	,,	,,	,, ,,	3	s.a.	..	5·5
42	,,	Beau Rivage	Bamboo, plants ..	15	,,	..	9·9
43	,,	Queen Victoria	Mixed	18	,,	25	10·0
44	,,	Bel Etang	,, ...	..	,,	..	8·3
45	,,	La Gaiété	Bamboo	2	,,	..	2·2
46	,,	,,	Diard, plants ..	15	,,	..	10·9
47	,,	,,	,, ,, ..	..	,,	..	10·6
48	,,	,,	Penang ,, ..	..	,,	..	11·0
49	,,	,,	,, ,, ..	..	,,	..	10·4
50	Nov. 1863	,,	Bamboo ,, ..	13	v.a.	..	10·8
51	,,	,,	Penang and Bamboo, plants ..	15	a.	..	10·3
52	,,	,,	Penang, ratoons ..	..	,,	..	11·0
53	,,	,,	Bellouguet, ratoons	..	,,	..	10·7
54	,,	,,	Guinghan ,,	..	,,	..	11·0
55	,,	,,	Bamboo ,,	..	,,	..	11·9
56	,,	,,	Bellouguet ,,	..	v a.	..	11·9
57	,,	,,	,, ,,	..	,,	..	11·2
58	,,	Queen Victoria	,, ,,	..	a.	26	10·6
59	,,	Constance	Bamboo and Guinghan, 2nd ratoons	..	,,	..	11·2
60	Nov. 1864	La Gaiété	Otaheite, ratoons	14	s.a.	25	11·4
61	,,	,,	Bellouguet, plants	15	,,	..	11·0
62	,,	,,	Mixed, ratoons ..	13	,,	..	10·2
63	,,	,,	,, ,, ..	2	,,	..	..
64	,,	,,	Guinghan ,, ..	13	,,	..	5·2
65	,,	,,	,, ,, ..	..	,,	..	6·6
66	,,	Labourdonnais	Bellouguet, 2nd ratoons	..	v.a	..	11·6
67	,,	,,	Diard, 1st ratoons	..	s.a.	..	11·2
68	,,	,,	Guinghan, ,,	..	,,	..	11·6
69	,,	La Gaiété	Mixed	2	,,	..	4·0
70	,,	,,	Bellouguet, ratoons	13	,,	..	4·0
71	Dec. 1863	,,	Penang and Bamboo, ratoons ..	..	a.	28	11·3
72	,,	,,	Guinghan, plants	..	,,	27	10·9
73	,,	Belle Etoile	Bellouguet, 2nd ratoons	..	v.a.	28	8·8
74	Dec. 1864	Moka	Bellouguet	15	s.a.	25	4·7
75	,,	La Gaiété	Bamboo, plants ..	14	,,	..	8·4
76	Jan. 1864	Belle Etoile	Bellouguet, 2nd ratoons	..	v.a.	27	10·7
77	,,	,,	Guinghan, plants	..	s.a.	28	10·8
78	Jan. 1865	Bel Etang	Bellouguet, ratoons	14	,,	25	8·5

*a. signifies acid; s.a., slightly acid; v.a., very acid.

Specific Gravity.	Percentage of Albuminous Matters.	Weight of Ash.	Indications of the Polarising Saccharometer. Direct Notation.	Indications of the Polarising Saccharometer. Equivalent Percentage of Sugar in the Juice.	Indications by Chemical Analysis. Percentage of Total Sugar.	Indications by Chemical Analysis. Crystallisable Sugar.	Indications by Chemical Analysis. Uncrystallisable Sugar.	Observations.
1·031	0·71	0·48	17·6	2·800	4·7	3·40	1·30	Head of the cane. } From the same plantation.
1·071	0·37	0·44	114·9	18·800	17·5	17·30	0·20	Body of the cane. }
1·040	0·43	0·24	34·4	5·600	7·5	5·10	2·40	Short gross shoots. }
1·075	0·46	0·31	113·6	18·500	17·0	16·7	0·3	
1·075	0·33	..	114·9	18·800	17·0	16·5	0·5	
1·062	..	..	89·6	14·600	14·0	12·8	1·2	
1·016	0·66	0·54	4·6	7·000	2·7	1·6	1·1	
1·083	0·19	0·21	130·9	21·400	19·7	..	..	{Obtained from the same canes. } 1st pressing.
1·079	0·27	0·23	125·4	20·450	18·9			2nd ,,
1·083	0·15	0·13	130·4	21·300	19·6	..	..	Ditto, ditto. } 1st pressing.
1·079	0·20	0·23	123·2	20·100	18·5			2nd ,,
..	..	..	129·8	21·200	19·5			
..	..	..	123·2	20·100	19·0			
1·083	..	..	132·0	21·600	19·5			
1·080	..	..	124·3	20·200	19·0			
1·083	..	..	131·4	21·400	19·5			
1·090	..	..	144·0	23·500	21·0			
1·090	..	..	143·5	23·500	21·0			
1·083	..	..	136·7	22·400	20·0			
1·080	..	..	125·4	20·400	19·0			
1·083	..	..	134·5	22·000	20·0			
1·086	0·23	0·31	139·7	22·840	21·0			
1·083	0·45	0·23	130·9	21·400	19·7			
1·073	0·38	..	120·4	19·600	18·2	17·9	0·3	Fine and ripe. } Same canes.
..	..	..	11·0	1·800	3·8	2·5	1·3	New shoots. }
1·037	0·68	..	40·0	6·340	6·4	5·2	1·2	Juice from the head.
..	..	..	58·0	9·480	10·8	9·4	1·4	Ditto.
1·087	0·52	0·32	135·3	22·120	21·5	21·0	0·5	
1·084	0·53	0·41	133·1	21·760	20·0			
1·087	0·43	0·33	138·6	22·660	20·9			
..	..	..	18·1	2·950	6·8	4·2	2·6	Young rapidly-grown shoots.
..	..	..	8·2	13·50	5·4	4·3	1·1	Heads.
1·086	..	..	135·3	22·000	20·0			
1·080	..	..	131·0	21·400	19·5			
..	..	..	93·0	15·200	14·0	..	..	Fermented canes.
1·034	0·75	0·52	34·4	5·670	8·3	6·6	1·7	
1·063	..	..	91·6	15·000	14·5	14·0	0·5	After heavy rain.
..	..	..	126·0	20·600	19·0			
..	..	..	129·9	21·200	19·0			
1·064	..	..	91·3	14·870	15·0	13·7	1·3	After heavy rain.

meter, its specific gravity, the amount of albuminous matters in it, the weight of the ash, the proportion of sugar indicated, the proportion found by actual analysis, the relative proportions of crystallisable and uncrystallisable sugar, and remarks concerning special conditions; they form a unique record of observations covering a great space, both with regard to locality and time.

Synopsis of the Operations entailed in preparing Sugar from Cane-juice.—A brief synopsis of the various operations gone through in preparing sugar from cane-juice, and the several ways in which those operations are or may be performed, will fitly conclude this chapter.

1. The Extraction of the Juice and all its Inherent Constituents from the Cane:—

a. By crushing the cane:
  Roller mills.
b. By disintegrating the cane.
c. By macerating the cane.
d. By "diffusion."

2. The Separation from the Juice of all the Matters except the Sugar and Water (termed Defecation and Clarification):—

a. By heat.
b. By chemicals.
c. By filtration.

3. The Removal of the Water from the Sugar (termed Concentration and Granulation):—

A. By heat:
  a. Pans heated by fire.
  b. ,, ,, steam.
  c. Film evaporators.
  d. Vacuum-pans.
  e. Bath evaporators.
  f. Fryer's concretor.
B. By cold.

4. The Cleansing of the Sugar-crystals by Washing and Draining (termed Curing):—

a. Simple draining.
b. Claying.
c. Spirit washing.
d. Vacuum chest.
e. Centrifugals.

CHAPTER III.

EXTRACTION OF THE JUICE.

AN explanation has already (p. 106) been given of the manner in which the juice of the cane exists in the plant, enclosed in little cells, which are surrounded and protected by lignose or woody matter, the latter forming about $\frac{1}{10}$th of the total weight of the cane. The liberation of the imprisoned juice may be effected either by (1) rupturing these cells so that their contents flow out, or (2) combining a soaking in water with the rupturing process, or (3) utilising the membrane of the cells themselves as a means of allowing the escape of the sugar and other "salts" in solution, by the process known as "diffusion." Each of these methods will receive separate description.

By Crushing the Cane: Roller Mills.—It will be both interesting and instructive to briefly survey the development of mechanical appliances for crushing the sugar-cane, as it frequently occurs in remote districts that the simple means employed by our forefathers are much more applicable to the planter's needs than the most recent perfection of engineering skill.

The earliest forms were of the rudest kind. Among the ancestors of the present Hindoo ryots, and among the modern Carib Indians of British Guiana, the apparatus consisted of a tree-stump carved to represent the head of a deity, into whose mouth was thrust the end of a long pole, together with the piece of cane to be crushed.

This ineffective method gave place to one by which the juice was crushed out in a mortar. The primitive mill still used in Dinajpur (India) is an adaptation of this plan, and is constructed as follows. A sound tamarind tree being selected, it is cut down at about 2 feet from the ground, where it may be 1½ feet or more in diameter; the stump is then hollowed out in the form of a mortar, and from the bottom of the hollow, a hole is bored a little way perpendicularly. The exterior of the stump is next pierced by a hole which meets the previous hole at an angle, and thus affords an outlet for the juice, which runs into a strainer, fixed over an earthen pot sunk into the ground amongst the roots of the tree. The pestle does not pound the pieces of cane, but crushes or squeezes them. It consists of the trunk of a tree some 18 or 20 feet in length, and about 1 foot in diameter, rounded off at the larger end, which is placed in the hollow of the mortar in an inclined position. A pair of oxen are yoked to a horizontal pole, which is supported at the outer end by a bamboo hanging by a notch made in the root end from the upper and smaller end of the long pestle, while the other end is attached by a loop to a bamboo hoop which encircles the stump, and thus acts as a runner. The pestle, therefore, forms a double-armed lever, the fulcrum of which is situated at the edge of the mortar, the cane being crushed between the sides of the pestle and mortar respectively. The force with which the pestle acts is increased by the driver sitting upon the outer extremity of the horizontal pole, and sometimes by weights being added. Such a machine, however, is ineffectual for crushing the cane until the latter has been first cut into small pieces. To this end, a bamboo stake is driven firmly into the ground, and a deep notch is made in the end projecting upwards. The attendant passes the canes through this notch, which slits them longitudinally, while he cuts off the slit canes, in lengths of about 1 foot each, with a rude chopper.

The sugar-mill of Chinapatam (India) is a slight improvement. Instead of the standing stump of a tree being used, which could only be done when a suitable tree grew on the desired spot, the mortar is carefully fashioned out of the trunk of a tree some 10 feet long, 8 feet of which is firmly embedded in the ground. The hollow, for two-thirds of the depth, is in the shape of an inverted truncated cone, the remaining third being cylindrical, with a hemispherical projection at the bottom, like the lower part of a common beer-bottle. A forked branch of a tree is worked down to a beam or plank 4 to 6 inches thick, and varying from near 18 inches in breadth at the single end to less than 1 foot at the forked ends. This beam is placed horizontally with the hollow against the mortar, and the bullock-driver sits on the undivided end to which the cattle are attached, while the beam turns round the mortar. The pestle is a piece of hard wood of the usual form, which is pressed down by a beam, one end of which is attached above the undivided end of the lower beam. There is a hollow on the under side of this upper beam immediately over the mortar, in which rests the top of the pestle, the other extremity being pulled downwards by cords attached to the forked ends. By tightening or slackening these cords, the upper beam acts as a regulating lever to give the pestle more or less force. The whole arrangement, when at rest, has very much the appearance of a huge lime-squeezer.

The transition from the apparatus last described to the vertical wooden roller mill now in use at Chica Ballapura, and in other parts of India, was but natural. This mill has the same idea of a lever pressing upon the top of a pestle applied to another purpose, in the beam which is fixed to the top of the longer of the two rollers which projects above the framework in which they are placed. The other roller, which is only the height of the frame, is turned by the four spiral grooves and ridges at the upper end being jammed against corresponding grooves and ridges on the long roller,—a precursor of the transmission of motion by means of cog-wheels.

Two such cylinders of hard wood placed in a frame, horizontally instead of vertically, so that they could be turned by two men, one at each end, and could be easily moved from place to place, formed a mill that met the requirements of those who had little cane to squeeze. Its cheapness, however (it can be made for 2 rupees, or 4*s*.), was probably the greatest inducement to its adoption. Such mills are in common use near Calcutta. They are almost universally employed by the Chinese, amongst whom they are conveyed from place to place, along the rivers and canals in the sugar-districts, by migratory sugar-boilers.

The use of edge-runner mills, in which a large heavy wheel, generally of stone, was made to revolve vertically upon its edge in a small circular area some 8 to 10 feet in diameter, was scarcely a step in advance, and these mills are now obsolete for cane-crushing.

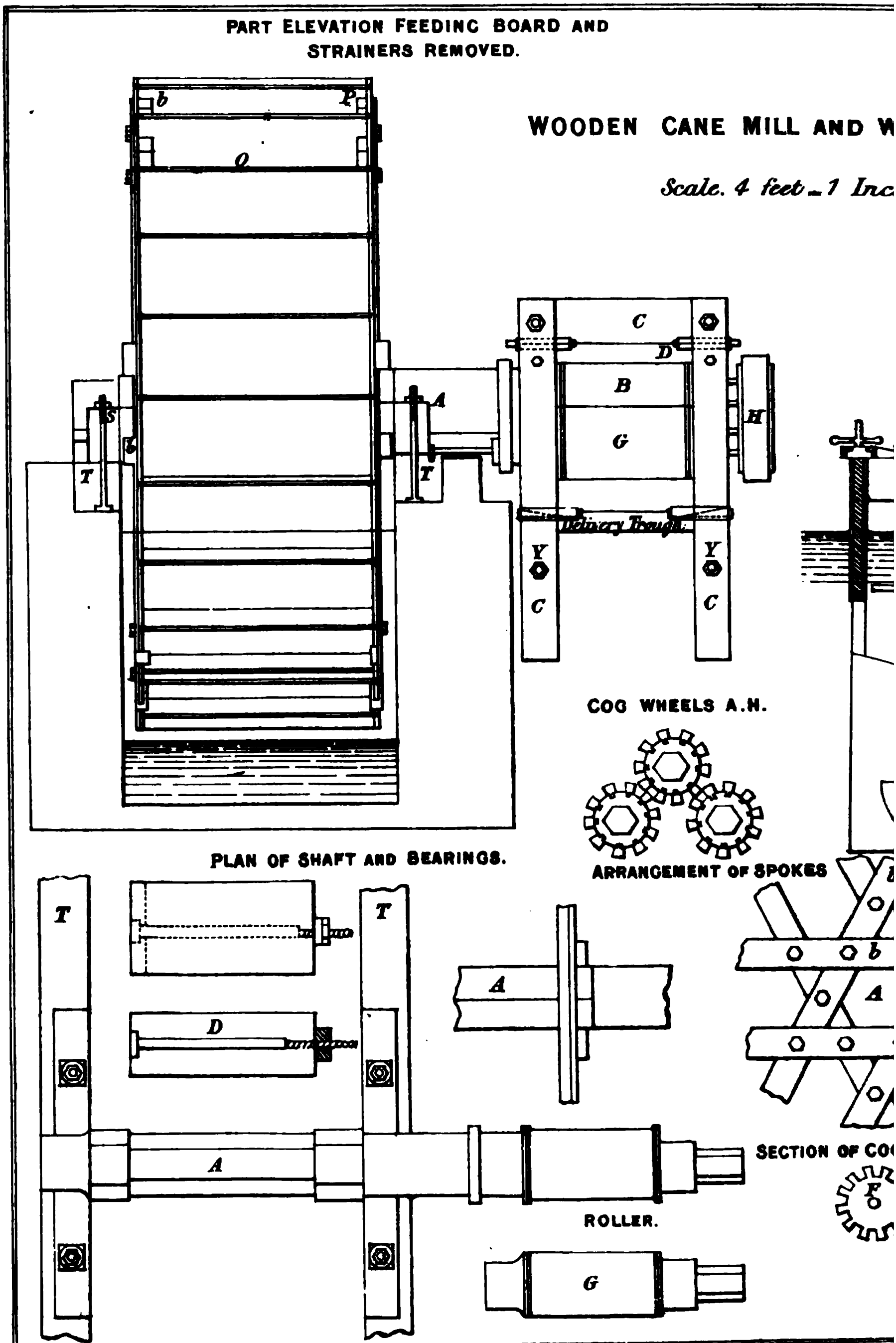
Vertical wooden rollers were employed in Europe in the 13th century, and in the 15th century their use extended to Madeira and Brazil. The old vertical wooden mill is probably still to be found in many places in the West Indies and elsewhere.

Wooden rollers were succeeded by those of stone, and then of iron. Examples of stone-roller vertical mills are still in existence, while vertical mills with iron rollers are comparatively common.

Horizontal mills with iron rollers are now certainly by far the most generally used, and the most advantageous in many respects. Consequently, their various forms will be the principal subject of the following descriptions.

On the other hand, there are many instances where the planter would gladly avail himself of the productions of the country, rather than import expensive European machinery, and to men thus situated, instructions for making a wooden sugar-cane mill could not fail to be acceptable.

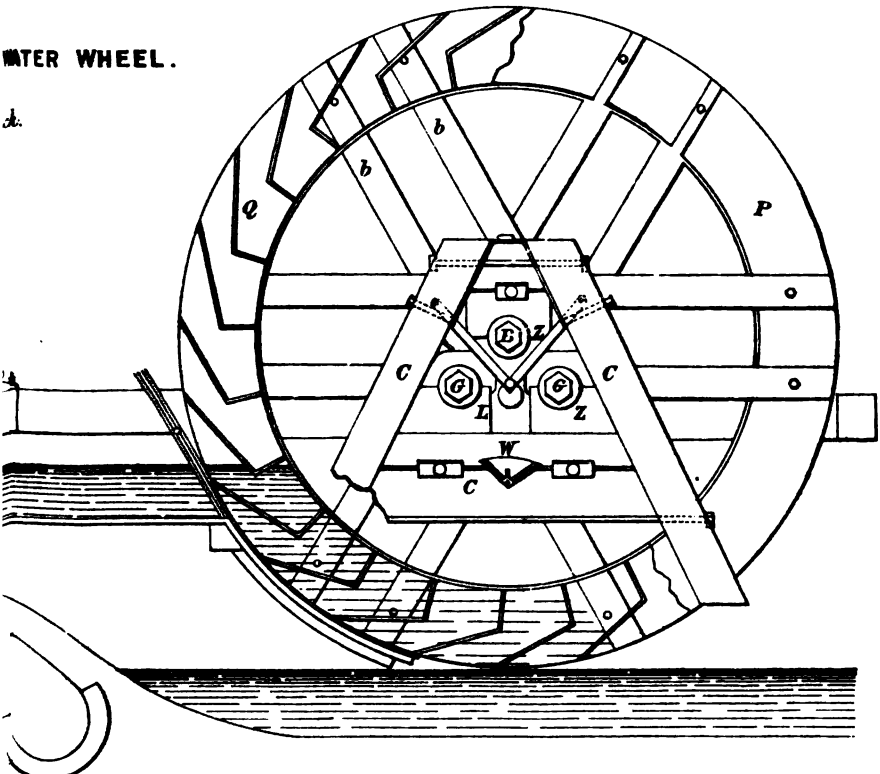
Wooden Cane-mill and Water-wheel.—Lieut. J. Clibborn, of the Bengal Civil Service, while engaged as Assistant Engineer on the Northern Division of the Ganges Canal, noticed


PART ELEVATION FEEDING BOARD AND
STRAINERS REMOVED.
WOODEN CANE MILL AND W
Scale. 4 feet = 1 Inc
Delivery Trough
COG WHEELS A.H.
ARRANGEMENT OF SPOKES
PLAN OF SHAFT AND BEARINGS.
SECTION OF CO
ROLLER.

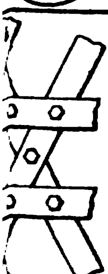
E & F. N

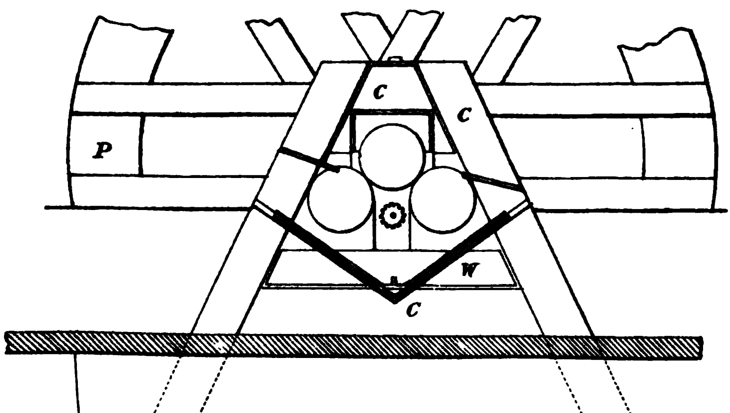
ELEVATION AND SECTION

MATER WHEEL.



SECTION THROUGH ROLLERS WEDGES REMOVED.





WHEELS.

…ton. London & New York

the difficulty experienced by the native cultivators in providing bullock-power to work their *kolos* or mills, and determined to initiate the utilisation of the force represented by the numerous small falls in the canal distributories near sugar plantations. With this object, he designed and constructed a water wheel and cane-mill at the Bhaisani Falls, on the right main rajbaha of the northern division of the Ganges Canal.

The construction is designed to be of the simplest and cheapest kind possible, being almost entirely of wood. It is built by a country *mistri*, and can be kept in order by the ordinary village carpenter, whom the cultivator employs to look after his *kolo* during the season. It must be remembered, also, that with a few simple additions, other uses may be found for the water-wheel.

The simplicity of the arrangement (which is shown in Plate I.) consists mainly in the fact that the shaft A of the water-wheel is prolonged to form the upper roll B of the cane-mill, which does away with the necessity for complicated methods of communicating power. The framing C is also simple, being made triangular, and the adjustments being effected by wedges D.

The Indian cane is probably not so stiff in structure as that grown in the West Indies, and the ordinary method of causing the cane, after passing through the first pair of rollers, to turn up and go through the second pair, would not answer. A fluted roll made of sissú wood is therefore substituted. It is caused to revolve by means of the kikar cogs, driven into the main shaft at F, and answers perfectly.

Motion in the required direction is communicated to the two lower rollers G from the upper shaft by the cog-wheels H, which are made of wood instead of cast-iron, since if a cog-wheel breaks, it can be quickly replaced, and the motion is smoother; moreover, cast-iron spur-gear of that size would cost half the total price of the whole mill.

The cane is laid on the board touching the rollers, which will draw it between them. It then passes forward and through the second pair, the dry begass passing over a board and falling on the ground. The expressed juice runs between the rollers, and through a sheet of perforated zinc underneath (which catches all the broken bits of cane, &c.), on to the sheet-iron tray L, and then into the trough W, from which it can flow into the boiling-pans at once, or it can be filtered if desired. The grooves, ½ inch deep, which are shown at the edges of the rolls, are to prevent the juice flowing out at the bearings.

As the mill is not always working, it is necessary to make arrangements for passing off the water.

The main shaft is made of sissú wood 18 inches in diameter, hexagonal where it forms the water-wheel shaft.

This hexagonal portion is slightly tapered at one end, and reduced in thickness at the middle, in order to allow it to pass into the spokes of the wheel, where it is wedged up, and small angle-pieces are bolted on to retain it in place. The spokes *b* are of sál scantling 8 inches × 3, and are quite stiff enough without any cross-bracing.

The shrouding P, which is 18 inches deep, is made of 1½-inch deodar planking, and is fastened on the spokes *b*. It is fixed underneath the first pair, let into the second, and over the third, in such a manner as to remain in the same plane.

The buckets Q, of 1-inch deodar planks, are let into ½-inch deep grooves in the shrouding P, and the whole wheel is kept together by 12 ½-inch bolts, passing through the ends of the spokes. The sole-boards, also 1-inch deodar, are nailed on the shrouding and buckets, in such a manner as to leave a ½-inch slit at the top of each bucket for ventilation.

The main shaft is supported on kikar bearing-pieces S, which are bolted down to a framing T, made of sissú, and firmly fixed in the masonry of the falls.

The framing C of the mill is made of sál wood, securely mortised, and held together by 1½-inch bolts Y. The lower portion is embedded in masonry to prevent movement. The bearing-blocks of the lower roll G are supported on a bar, beneath which are two wedges; by means of these and the wedge above the upper roll, adjustment can be effected. The wedges have bolts through them, which, when screwed up, prevent any chance of slipping.

The bearing-blocks Z of the forward lower roll are carried over as well as below the bearings, in order to prevent the roll rising. All these bearing-blocks are tongued into the frame, to prevent lateral movement; and either of the two lower rolls can be removed from the frame, by easing down the wedges.

The cog-wheels are made of a block of sissú, with kikar teeth dove-tailed in, and then two iron rings are shrunk on at each end. They have slightly-tapered hexagonal holes cut in the bosses, which fit on to the end of the rollers. It is better not to drive these quite home in the first instance, so as to allow of their being tightened up occasionally.

The sheets of iron to catch and carry the expressed juice to the delivery-trough are supported on small angle-irons screwed to the frame, so as to allow of their being drawn out to be cleaned. For the sake of portability, they are made of light sheet-iron on a wooden frame. On the top of them are laid the sheets of perforated zinc, which are kept from touching by a small ledge 1 inch high. A little black-lead (graphite) applied occasionally is all that is required for lubrication. The bearing should be kept dry, and the surface-speed of the rollers ought not to be more than 20 feet per minute, or all the juice will not be expressed from the cane. It would be a great improvement to shrink iron collars, 6 inches wide and ½ inch thick, on the water-wheel bearings, which would prevent any wear. It would also be advantageous to cover the rolls with ⅛-inch or $\frac{1}{16}$-inch sheet-iron. A better plan is to cover the rollers with kikar wood on end, 3 inches thick, dove-tailed into the rollers; this appears to work very well. These improvements would add very little to the cost of the mill, certainly not 50 rupees (5*l.*).

If any difficulty should be found in procuring sissú wood of sufficient scantling to make the main shaft, it could be built up of a core of sál wood 1 foot in diameter, and thickened at the required places by the addition of strips of kikar or sissú. Built-up shafts like this are in common use in many parts of the world, and withstand the effects of climate better than solid work. This, of course, would necessitate the iron sheeting. With a supply of 14 cubic feet of water per second, and a fall of 4·25 feet from surface to surface, this mill will crush 1 maund (say 80 lb.) of cane in 4 minutes, the nominal horse-power used being about 6·2. The outturn, however, depends entirely on the fall available, as the wheel and mill are quite strong enough to crush twice that amount, with a sufficiently high head of water.

The following is a list of the woods used in the construction of the mill:—

For the mill-framing, wheel-spokes, sluice-gates, and framing to support,—sál or saul (*Shorea robusta*).

For the wheel,—any wood not likely to be affected by dry-rot.

For the shaft, rolls, and cog-wheel bosses,—sissú, sissoo, or sheeshum (*Dalbergia Sissoo*).

For the cogs, bearing blocks, and wedges,—kikar (*Acacia leucophlæa*).

For the shrouding, sole-board, and buckets,—deodar (*Cedrus* [*Abies*] *Deodara*).

If the mill crushed 1 maund of cane in 4 minutes, thus affording 1 maund of juice in 8 minutes, and assuming 200 maunds (say 16,000 lb.) of juice to the beegah (here equal to ⅝ acre) as a fair average return, it would appear that the mill is capable of working off 1 beegah in 26 hours (say 30 hours including stoppages), or 72 beegahs (say 45 acres) in a working season of 3 months.

The expenditure incurred in crushing 1 beegah of sugar-cane by the native kolo, according to 4 separate authorities, stated in Indian currency, is as follows :—

	1.			2.			3.			4.		
	R.	A.	P.	R.	A.	P.	R.	A.	P.	R.	A.	P.
Cutting cane into short pieces	0	4	0	0	14	0	0	10	6			
Pedia and Muthia who put cane into press	1	11	0	2	2	0	2	1	0			
Miscellaneous repairs	1	0	0	0	12	6	1	4	0			
Price of lath	3	0	0	3	0	0	0	15	0			
Hire of bullocks	6	0	0	6	0	0	6	0	0	11	4	0
Hire of kolo and pans	0	11	0	0	11	0	1	2	0	1	14	6
	12	10	0	13	7	6	12	0	0	13	2	6

Average, R. 12 11 0, or say 24*s.* 8*d.* in English currency.

The earnings of the mill at the rate of kolo cost would be 913 rupees (say 90*l.*) in one season.

A point to be borne in mind is that the cost of construction would not be increased if a greater fall of water were available, while the outturn would be more. In fact, the rollers and framing, for the sake of simplicity, are made quite strong enough for water giving twice the power now exerted at Bhaisani.

The specification of the materials required is as follows :—

Description.	No.	Length.	Breadth.	Depth.	Contents.	Total.
Deodar wood—						
Shrouding	2	50·0	..	0·16	16·0	
Backing	1	27·0	5·5	0·1	14·8	
Buckets	24	2·0	5·25	0·1	25·2	
Total deodar wood ..	..	..	..	..	..	65·6 cubic feet
Sál wood—						
Spokes	12	12·0	0·66	0·25	23·76	
Frame	4	8·0	1·00	0·75	24·00	
"	2	6·0	1·00	0·75	9·00	
"	2	5·0	0·75	0·75	5·62	
"	1	5·0	1·00	1·00	5·00	
Total sál wood ..	..	..	..	..	..	67·38 cubic feet

Description.	No.	Length.	Breadth.	Depth.	Contents.	Total.
Sissú wood—						
Shaft	1	14·0	1·8	..	25·2	
Rollers	2	5·0	1·8	..	18·0	
Fluted rollers	1	6·0	0·5	..	3·0	
Cog wheels	3	1·0	1·8	..	5·4	
Framing under kikar bearings	2	12·0	1·0	1·0	24·0	
Total sissú wood ..	..	..	..	..	..	75·6 cubic feet
Kikar wood—						
Bearings	2	6·0	0·75	1·0	9·0	
,, ...	4	3·0	0·75	1·0	9·0	
,, ...	2	2·0	0·75	1·0	3·0	
,, ...	5	..	..	..	5·0	
Total kikar wood ..	..	..	..	..	..	26·0 cubic feet
Iron work—						
Bolts, &c.	½″	72	2 ft.	..	47 lb.	
,, ...	¾″	24	,,	..	36 ,,	
,, ...	1¼″	16	,,	..	64 ,,	
,, ...	1½″	22	,,	..	136 ,,	3·5 maunds
Trough, &c.	..	..	..	..	..	1·0 ,,
	..	..	..	..	..	4·5 maunds

Items.	Quantity.	R.	A.	P.	Per	Contents.	Total.
Deodar wood, cubic feet ..	70	1	0	0	Cub. ft.	70	
Sál wood ,, ..	70	2	0	0	,,	140	
Sissú wood ,, ..	76	1	8	0	,,	144	
Kikar wood ,, ..	25	1	8	0	,,	38	
Iron work, maunds	4·5	15	0	0	maund	67	
Labour ,, ...	..		..		..	250	
Grand total cost	..		..		..	..	679 rupees

Or say 68*l.*

Iron Cane-mills.—It may truly be said of cane-mills that their name is legion, and a comprehensive account of all the forms introduced or proposed would fill a large volume. For all practical purposes, it will suffice to describe a few of the typical arrangements adopted by the chief engineering firms. It may be premised that no subject seems to be in a less satisfactory state, scarcely any two opinions coinciding as to what is the best form of mill.

The following is an account of the constructive details of an ordinary 3-roller cane-mill. The combined mill and its engine are shown in elevation and in plan in Plate II. The mill consists of a bed-plate A of cast iron, weighing not less than 2 tons 5 cwt., and of the section shown in Plate III. It is formed with a concave bottom to receive the cane-juice, and has a delivery B cast on the side, for discharging the juice into the tank B^1, whence it is raised to the clarifiers by the pump B^2, which is worked from a crank on the shaft of the upper roll of the mill. Fitting strips are cast on each side, and faced to receive the side frames E.

The bed-plate is bolted down to the foundations with four 3½-inch bolts C passing through the side frames, and held by plates and keys, and also with four 1½-inch holding-down bolts D 6 feet 9 inches long. The side frames E are of cast iron, and weigh not less than 36 cwt. each; they are cored through to receive the bolts C, and are cast with bosses for adjusting screws F, 2¼ inches diameter, by which the space between the rolls is regulated. The upper roll is distant from the two lower ones about ⅓ to ¼ inch. The frames are accurately faced at bottom, and fitted to the bed-plate. They are held down by the bolts C, which also hold down the centre caps G of the upper roll. Spaces are left in the frames to attach a "trash-turner" H, which is placed between the two lower rolls, and under the top one, to guide the cane between the upper and second lower roll. Openings are left to place the rolls; and cast-iron filling-up pieces are provided, accurately fitted and held in place by diagonal bolts, 2¼ inches in diameter. A wrought-iron feeding-table H^1, and wrought-iron begass-delivery H^2, are provided. The three cast-iron rolls J are each 2 feet 2 inches in diameter, and of the section shown in Plate III. Each roll should weigh not less than 35 cwt., and be rough turned. The two lower rolls are cast with flanges on the outer sides, to prevent the cane-juice spreading beyond the rolls. Each roll is cored

8 inches square through the centre, and is hung with 8 keys to the shafts K; wrought-iron rings are shrunk on to the shafts outside the rolls, to prevent the keys starting. The shafts K are of the best wrought iron, 8 inches square, with 7-inch journals, and have square ends for hanging pinions to connect the rolls. A clutch-box M is cast on the pinion, for connecting to the intermediate shaft L. The bearings N are of the best gun-metal, accurately bored and fitted in the side frames with a flange on each side. Steel plates are fitted at the back of the bearings, to receive the thrust of the adjusting-screws F, which are passed through spaces in the side frames.

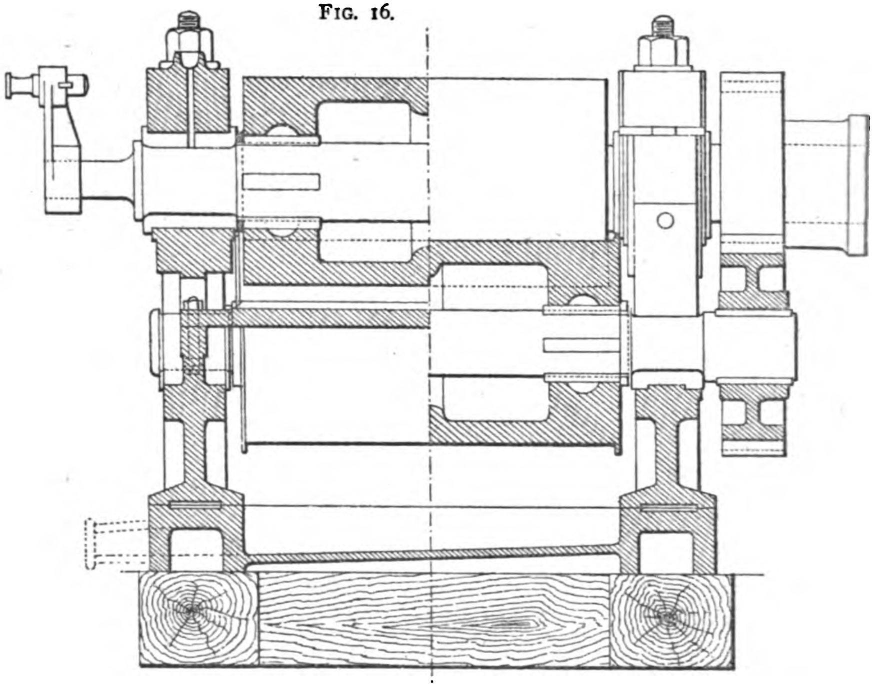
Three spur-pinions P, each 2 feet 2 inches in diameter, 3·14 pitch, and 8 inches broad, are hung, each with 8 keys, to the ends of the roller-shafts, to connect the rolls for work. The intermediate shaft L is of cast iron, 8½ inches square, 9½ inches square at each end, and connected to the shaft of the upper roll by the square clutch-box M, and to the intermediate gearing by the square clutch-box W. The intermediate gearing consists of a spur pinion (see plan) P^1, 1 foot 9 inches in diameter, 3·14 pitch, 9 inches broad, bored out and fitted to the engine-shaft; it makes 40 revolutions per minute, and works into the spur-wheel Q, which is 7 feet in diameter and 9 inches broad, and is hung to the shaft R with 8 keys. The shaft R is of cast iron, 8½ inches in diameter, and the journals are 7 inches in diameter by 9 inches long, with collars left on each side. The distance between the inside of bearings should not be less than 4 feet 4 inches. This shaft makes 10 revolutions per minute, and runs in the plummer-blocks S, which are fitted with gun-metal bearings, and are provided with wall-plates and holding-down bolts, 1½ inches in diameter, to fasten them down to the brickwork. The pinion T is 1 foot 9 inches in diameter, 3·14 pitch, 9 inches broad, hung to shaft R with 4 keys, and works into the spur-wheel U, which is 7 feet in diameter, 9 inches broad, and 3·14 pitch, has 6 arms, and is hung to the shaft V with 8 keys. This shaft is of cast iron, 9 inches in diameter; one end is formed 9½ inches square for connection to the mill. The shaft V runs in two plummer-blocks X, which are fitted with turned gun-metal bearings, and are provided with wall-plates and holding-down bolts. The shaft V makes 2½ revolutions per minute, that being the speed at which the rolls are required to revolve. Motion is obtained from a high-pressure engine, of 16 nominal horse-power, having a fly-wheel 14 feet in diameter, weighing 3 tons, and making 40 revolutions per minute. Steam is supplied from a Cornish boiler, 20 feet long, 6 feet in diameter, and 3 feet tube, and having the usual fittings.

The enlarged details of the mill are shown in elevation, horizontal section taken through AA and BB in the elevation, transverse sectional elevation taken through centre of mill on the line C C in the half plan, and in half plan in Plate III., and in longitudinal sectional elevation taken through the lines D D and E E of the half plan in Fig. 16. Fig. 17 shows two views of a spur-pinion.

The method of using the mill is as follows. The canes are introduced into the mill from the feeding-table H^1, and are crushed between the top and first bottom rollers. Guided by the "trash-turner" H, they pass between the top and second bottom rollers, by which the remaining juice is expressed, and the exhausted cane, now called "begass" (also spelled "megass," "bagasse," &c.), is carried away by the delivery-table H^2. Care is taken that the exhausted spongy cane does not again come into contact with the liberated juice, so as to reabsorb it.

Figs. 18 and 19 show an end view and front view of the 3-roller cane-mill made by Manlove, Alliott, Fryer, and Co. of Nottingham and Rouen. The bed and cheeks are entirely of cast iron, but the metal is carefully proportioned to its work. Strong wrought-iron tie-bolts take the main tensional strains in the mill. The side roll caps, while well established when the mill is working, are readily removable, and the rolls can be slid out without any lifting.

FIG. 16.



Scale ½ in = 1 ft.

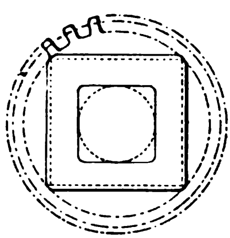
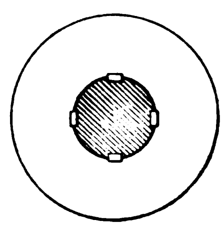


FIG. 17.



Ordinary 3-roller Mill, and Spur-pinions.

Rousselot's 3-roller mill, as made by Fawcett, Preston, & Co., is shown in Figs. 20, 21, and 22. The bed-plate D is seated on a strong timber framework, through which the large bolts I (Fig. 18) pass, allowing the top roll to lift a little when any extraordinary strain occurs. The canes pass by the carrier H (Fig. 19) down the slide E, through the rolls, and the

FIG. 18.

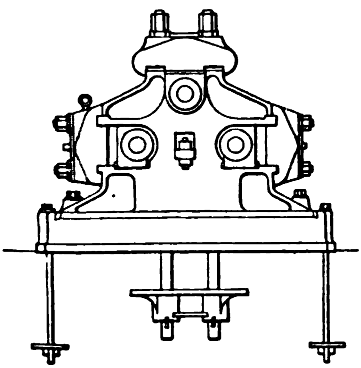
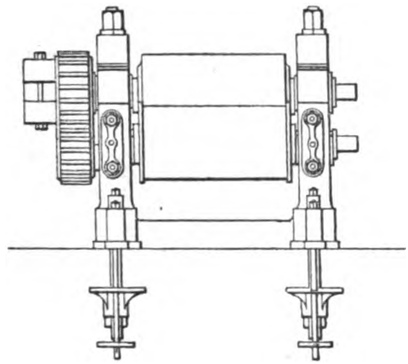


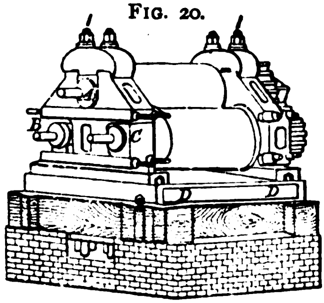
FIG. 19.



Manlove & Co.'s 3-roller Mill.

begass emerging at D is taken away by a carrier worked by the drum I. The ordinary frame of cast iron is not exposed to tension. The resistance of the canes between the rolls A B C is taken from the top roll A through the cap and bolts, and compresses the frame, while the tendency to separate the bottom rolls is controlled by the horizontal tie-bolts; it is claimed that for practical purposes, the frame might be made of oak instead of iron, as the working strains are thrown upon the wrought iron, instead of being borne by cast iron, as in other mills. The 3 cast-iron rollers are keyed on to the wrought-iron shafts. The "returner-bar," or "knife," or "trash-turner," as it is variously denominated, is a flat or curved plate, placed at a distance of 2¼ to 3 inches below the bottom of the top roll, made to touch the

FIG. 20.

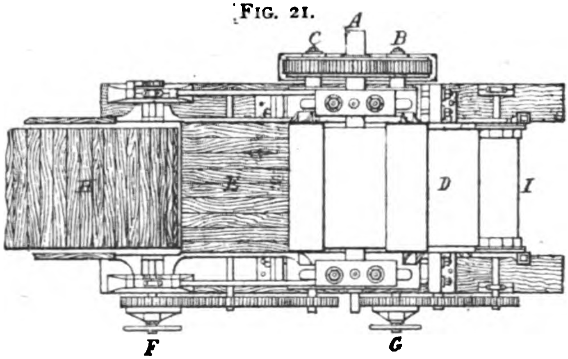


Rousselot Mill.

circumference of the front roll, and to stand off about $\frac{1}{8}$ inch from the lower back roll, so as to allow the juice to run down.

The mill shown in Fig. 20 is composed of 2 cast-iron frames *d*, secured to the bed-plate *e* by bolts at the corners.

FIG. 21.



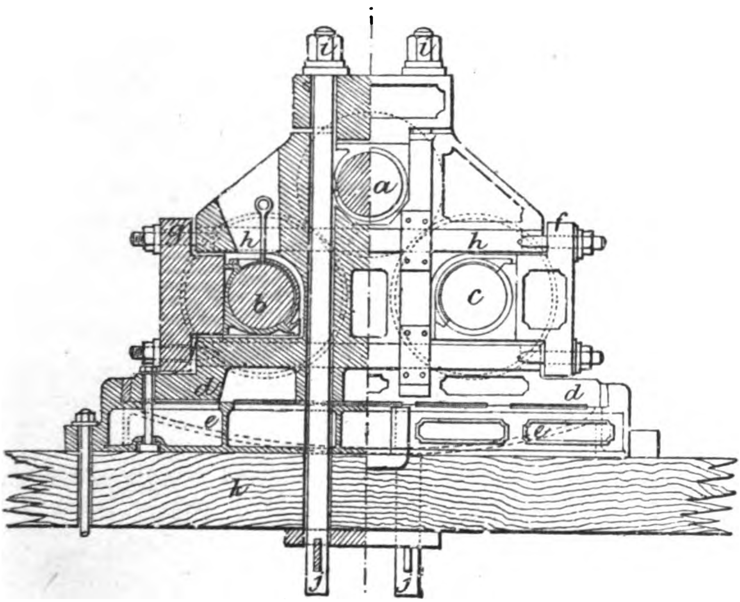
Rousselot Mill.

Seats are prepared on the frames *d* for carrying the brasses for the shafts of the rolls *a b c*. The bolts *i j* pass through the frames and bed-plate and through the timber *k*, and take the strain of the top roll; and the bolts *h*, of which there are 4 for each frame, take the strain on the caps *g f*. In this manner, the strain is borne by the wrought-iron bolts instead of being thrown on the cast-iron frames, enabling more juice to be extracted with safety than can be done with the ordinary cast-iron frame. The yield of sugar from the cane crushed in this mill at the central factory in St. Lucia, during the season ending in May 1881, is stated at 8 per cent. of the weight of the cane; the cane there seldom gives juice of 10° B., yet by the careful use of a Rousselot mill, defecators, triple-effect, clarifiers, strike-pan, and centrifugals, with a very limited consumption of animal black, 10,000 tons of cane give 800 tons of sugar of superior quality, averaging in London 25*l.* a ton.

It was formerly the custom to make the returner-bars much lighter than those ordered and supplied at present.

When canes are passed through a mill without choking, everything works smoothly; but from the moment that a cane doubles up, trouble begins. The rolling friction of the mill is a slight matter; but the sliding friction in the confined space between the top roll, the front roll, the returner-bar, and the

FIG. 22.



Rousselot Mill.

back roll, is very great. If the returner-bars are weak, they bend by the pressure, and the jam is relieved: the bar is taken out and straightened, and work is resumed. A pressure of 50 lb. a square inch drives the mill when there is no jamming; but 80 lb. is required when it is "braked" by accumulation of begass between the rolls and the returner-plate; this begass becomes hot and hard with friction, the resistance has to be overcome, and returner-bars are made to resist the force of a 60-H.P. engine, geared 20 to 1, and making 40 revolutions per minute.

Many engineers contend that those who are trying to increase the yield in juice by very slow movement, are in error, and they recommend experiment in the direction of lighter and repeated crushings, combined with maceration. By using two mills of moderate proportions, more effective work is said to be obtained, because there is less sliding friction; and it is questioned whether the extra quantity of juice obtained by the extra force of a large mill is not at the expense of the quality.

The mill erected at Aba-el-Wakf, Upper Egypt, for the Khedive, in 1872, was, however, a direct departure from this dictum.

It is shown in front elevation, plan, and side elevation respectively, with the detail of the bearing, in Plate IV.

The three rolls employed in this mill are each 48 inches in diameter by 5 feet 6 inches long, staked by means of 8 keys at each end, on to 18-inch wrought-iron shafts, the keys being arranged so as to "hit and miss" on opposite ends, in order that they may be readily driven in or out without removing the rolls. They are not in any way secured against working out. Staked by 4 keys on the ends of the roll-shafts outside the mill-frames, are spur-wheels, each nearly twice the diameter of the rolls. The spur-wheels of the two lower rolls being on the same side, and passing each other, are actuated by a double-shrouded pinion, keyed on to a second-motion shaft, which passes under the bed-plate of the mill, and carries, at its opposite end, an internal-geared wheel 11 feet 9 inches in diameter. The top roll spur-wheel is on the opposite side of the mill to the wheels of the bottom rolls, and is actuated by a shrouded pinion keyed on a short second-motion shaft, one end of which has a journal in a bracket bolted to the mill frame, and the other revolves in a pedestal fixed to a massive A-frame, and carries, overhung, a spur-wheel of the same diameter and pitch as the internal wheel on the lower second-motion shaft. The outer end of the crank-shaft of the steam-engine is carried in a pedestal resting on the bottom of the

A-frame, and by means of separate pinions keyed on it, engages into the upper spur and the lower annular wheel.

The effects of this are (1st) that the power of the engine is divided over two pinions, having, together, 18 inches of face, a greater width than could usefully be given to one pinion gearing into one wheel; (2nd) the second-motion shafts distribute the power through three pinions, having, together, 38 inches of face, and, owing to the large diameter of the roll spur-wheel, travelling nearly twice as fast as the peripheries of the rolls, and, on that account, having to endure only half the pressure on the teeth and journals that would have arisen under the old system of gear; and (3rd) the large diameter of the roll-wheels allows three teeth to be in gear at one time instead of only one. In order to permit of a variation in the distance apart of the rolls, without affecting the accuracy of the gearing, the brasses which carry the two lower roll-shafts are arranged to slide upon their seats in a direction nearly at right angles to the lines of centres of their spur-wheels and the pinions they engage into; and these brasses, instead of being kept up to their work by the points of large set-screws in the usual fashion, are supported over their entire width by quoins or inclined planes, drawn up by pairs of bolts passing through the top distance-pieces closing up the gaps in the side frames, the angles at which these gaps lie offering also the contingent, but not inconsiderable, advantage of enabling the bottom rolls to be taken out without interfering with the top roll.

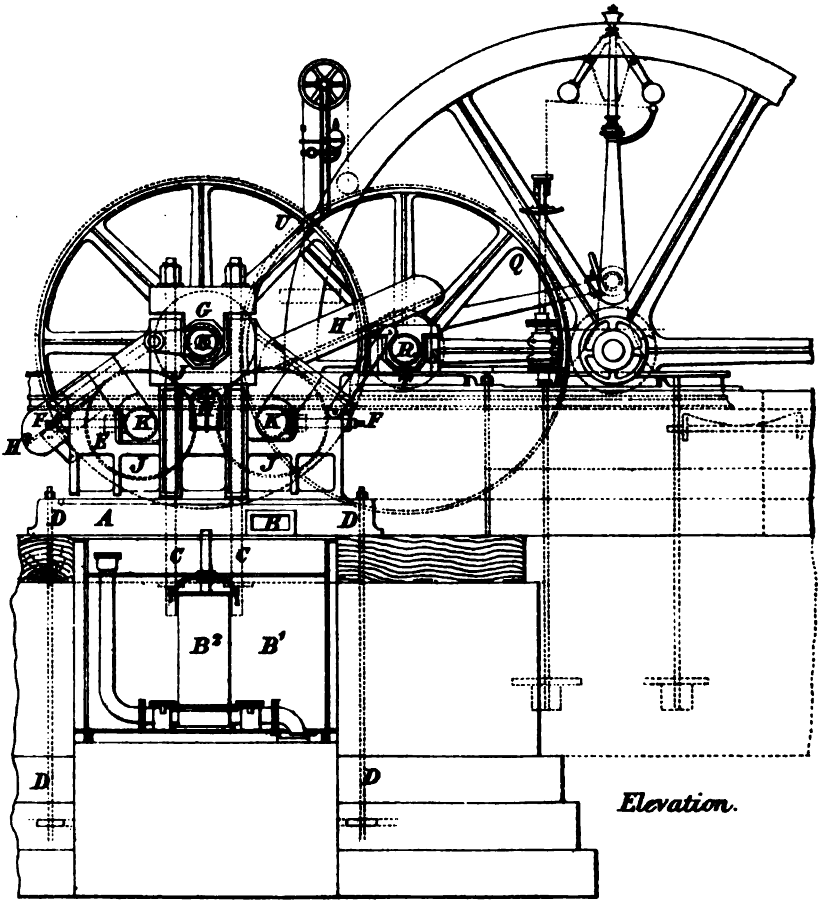
The caps of the top rolls are held by 6-inch bolts passing completely through the side frames and base-plate, under which they are cottered without the intervention of the usual layer of timber or other elastic material, so that there is no possibility of yielding, however severe the strain. At Bene Mazar, the same strength of gear was applied to rolls 48 inches in diameter and 6 feet 6 inches long, and both sizes worked without the smallest difficulty or accident.

It will be noticed that the spur-wheel driving the first lower roll is considerably overhung, but this is not objectionable, because the power required in the first squeeze of the canes is very much less than that expended in the final pressing, which circumstance compensates for the overhang, the shafts being of equal diameters.

To illustrate more clearly the differences between the ordinary and novel systems of gearing, the pressures on the various moving parts are given in the annexed table.

The large wheels and rolls are all staked on with 4 or 8 keys, and not bored and turned in the usual manner; it is believed that more trustworthy work can be done in the former way with heavy gearing, and it offers facilities in erection and repairs. The arrangements for lubrication are necessarily very efficient. It is difficult to estimate the pressure exerted by the top roll, but as its journals occasionally become slightly warm, it is probable that the limit of 1200 lb. per square inch is reached; in that case, the area on the diameter of the two journals being 576 square inches, the pressure would be at least 300 tons. The 4 main cap bolts, 5 inches in diameter under the thread, are competent to carry a working load of 390 tons. The cane-carriers are driven by spur-gear through clutches from the front bottom rolls, and the begass-carriers by belts from the top second-motion shafts.

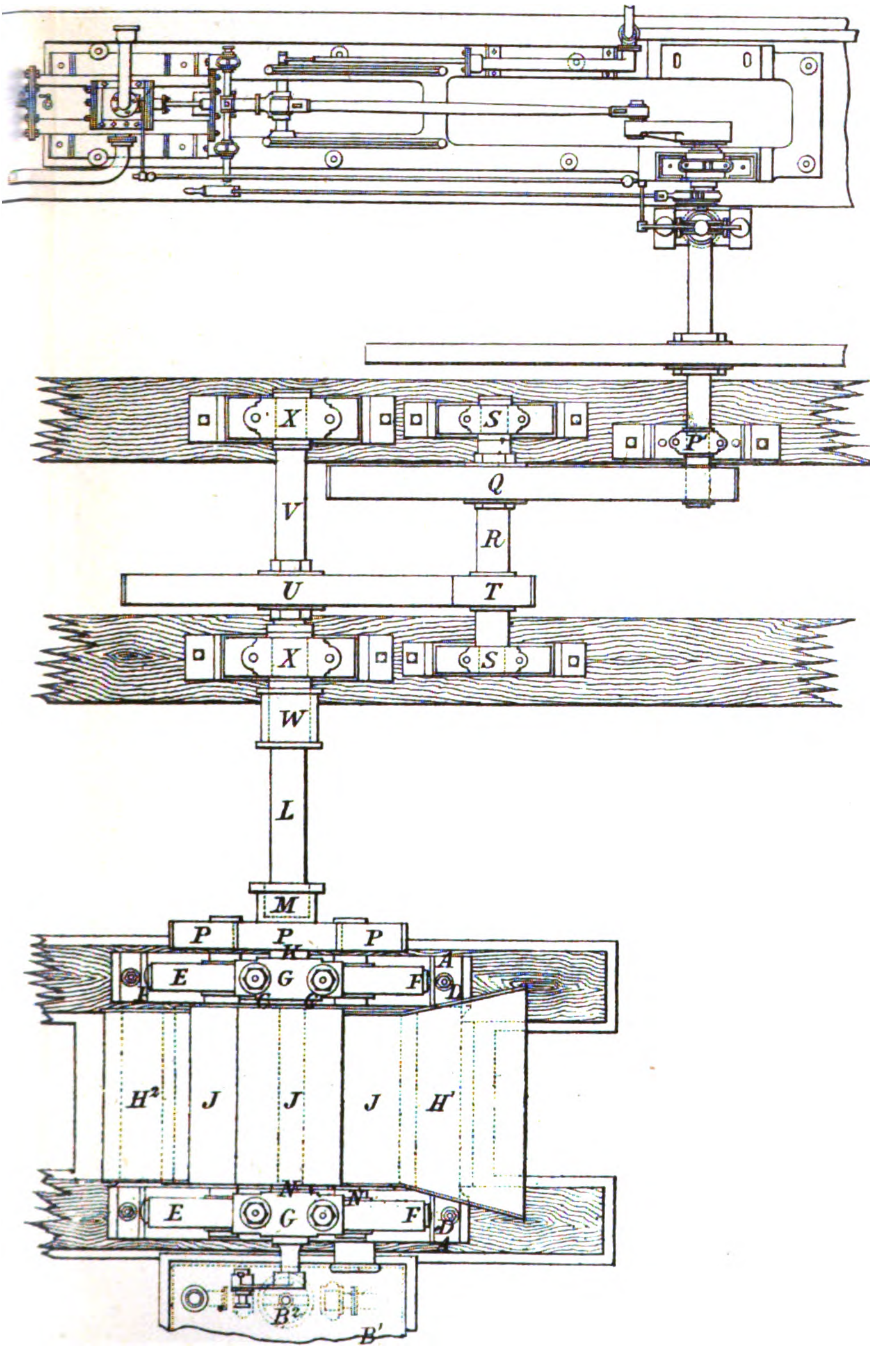
The very diverse opinions concerning the merits of this system may be briefly summarised. It is conceded that large rolls possess an advantage in the spent cane having less opportunity of reabsorbing the juice, by reason of the greater difference between the feed and delivery sides of the mill; but it is argued that the rolls need only be of sufficient diameter to ensure rigidity (say 28 or 30 inches for rolls 5 feet 6 inches long), and that the extra size of roll requires extra power to produce the extra pressure, and crush the extra quantity of cane, necessitating extra expenditure in first cost of plant.



COMBINED 3 ROLLER

CANE MILL AND ENGINE.

E & F N. Spon,


X
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B'

Table showing the PRESSURES on TEETH and JOURNALS of CANE-MILLS with Rolls 4 Feet in Diameter, worked by an Engine indicating 100 H.P., at 30 Revolutions, to give 18·3 Feet speed of Roll Surface per Minute.

Ordinary System.					System at Aba-el-Wakf.				
	Number of Revolutions per Minute.	Speed of Pitch Line in Feet per Minute.	Load on each Tooth in contact per Inch of Face in lbs.	Pressure on nearest Journal in lbs.		Number of Revolutions per Minute.	Speed of Pitch Line in Feet per Minute.	Load on each Tooth in contact per Inch of Face in lbs.	Pressure on nearest Journal in lbs.
Crank shaft pinion	30·00	210·0	557	15,000	For top roll gear ..	30·00	188	414	} 9,000
					For lower ditto ..	30·00	188	414	
Spur wheel in gear with ditto	6·64	210·0	557	1,500	For top roll gear ..	5·08	188	414	20,000
					For lower ditto ..	5·08	188	414	7,000
Second motion pinion	6·64	72·0	1,223	21,000	For top roll gear ..	5·08	36	1,309	29,000
					Double pinion for lower roll ditto	5·08	36	764	27,000
Spur wheel in gear with ditto	1·46	72·0	1,223	12,000	For top roll gear ..	1·46	36	1,309	13,000
					For cane ditto ditto	1·46	36	764	35,000
					For begass ditto ditto	1·46	36	764	15,000
Mill pinions on top roll	1·46	18·3	1,906	50,000 sideways	Mill pinions. Not represented in System at Aba-el-Wakf.				
Ditto on cane ditto	1·46	18·3	1,906	51,000					
Ditto on begass ditto	1·46	18·3	1,906	25,000					

On the other hand, it is contended that it is an advantage for the cane to be a long time under pressure. This time is twice as great in mills with 4-feet rolls, as in those with 2-feet rolls at the same surface speed. The usual rate adopted in the West Indies is 18 feet per minute as the surface speed of the rolls. The Aba-el-Wakf mill runs at 27, 30, and even 36 feet, with equally good extraction, the feed being generally 15 to 18 inches deep. The gearing has advantages in that each pair of wheels is always in true gear with two or three teeth in contact, the load per inch of the width of face is never excessive, and though there are 10 wheels instead of the usual 7, they are smaller and more convenient for manufacture and transit, while weighing in the aggregate 2 tons less.

Repeated experiments have all tended to prove that while only 46 per cent. of the juice is extracted by a speed of 8 revolutions per minute, as much as 70 per cent. is obtained by the same mill when the speed is reduced to 2½ revolutions per minute.

A comparative account may here be given of the working results obtained with a small rapid mill and a large slow mill upon the estate of Don Miguel Arribas, in Porto Rico, referring, not to a small experiment, but to the working-off of a whole year's crop. The cane was all weighed into the mills, and the boiler-power and concentrating apparatus were identical in both cases.

The rapid mill had rollers 22 inches in diameter by 48 inches long, and an average speed of 24 feet per minute, driven by a horizontal engine with a cylinder 12 inches in diameter and 30-inch stroke, the piston making 300 feet per minute, with an average pressure in the boiler of 60 lb.

The slow mill had rollers 36 inches in diameter by 66 inches long, and an average speed of 9 feet per minute, driven by a horizontal engine with a cylinder 22 inches in diameter and 48-inch stroke, the piston making 200 feet per minute, with an average pressure in the boiler of 60 lb., steam being cut off after the piston has travelled ⅝ of the stroke.

Table No. 1 shows the results obtained from one grinding by the rapid mill, with cane in good season, yielding juice of 10° B., and leaving 10 per cent. of woody fibre. No. 2 shows the results obtained from one grinding by the slow mill, with average good canes, a little over ripe and dry, yielding juice of 11° B., and 13 per cent. of woody fibre.

TABLE No. 1.

Quantities.	Canes in lb.	Juice in gallons.	Juice in lb.	Sugar in lb.	Molasses in lb.	Total Green Sugar.
387 loads	1,170,332	65,442	702,092	72,081	37,464	109,545
1 load	3,024	169·1	1,814·44	186·25	96·80	283·05
100 lb. ..	100	5·59	59·9	6·16	3·20	9·36
1 gallon	nearly 18	1·00	10·73	1·10	0·572	1·672

TABLE No. 2.

629 loads	1,369,275	98,350	1,063,163	138,750	64,944	203,694
1 load	2,177	156·36	1,690·25	220·6	131·67	352·27
100 lb. ..	100	7·18	77·61	10·13	4·74	14·87
1 gallon	13·07	1·00	10·81	1·41	0·66	2·07

The differences of weight (shown by the tables) of the average cart-load during the two grindings require some explanation. During the first grinding, the canes, being cut in good season, weighed somewhat more, volume for volume, than the drier canes cut during the second grinding. The reason, however, consists principally in the irregular cutting of the fields of cane during the second grinding, there being some parts of different fields that, from their very dry state, and being more exposed to wind and dust, required immediate grinding, while the remainder could hold out a few days without serious injury; so that it frequently occurred that, on finishing the cutting of these dry parts, the canes on the ground were not sufficient to fill the carts, hence the lower average weight per load.

From Table No. 1, it will be seen that the rapid mill gave 59·9 lb. of juice per 100 lb. of cane ground; the yield of the slow mill, as shown by Table No. 2, being 77·61 lb. of juice for the same quantity of cane, being an increase of 17·71 lb. per 100 lb. of cane ground, which is equal to an increase on the crop, as made by the rapid mill, of 29·61 per cent. This would be correct if the canes ground in both instances had been the same in quality; this not being the case, a true conclusion can only be arrived at by finding out the saccharine matter obtained and lost in each case. The total amount of saccharine matter obtained by the rapid mill was 9·36 per cent., but there is a loss of 0·268 lb. of saccharine matter per gallon of juice obtained, resulting from the skimmings and washings not being used up, there being no still on the estate.

The gallons of juice per 100 lb. of cane were 5·59; this multiplied by 0·268 = 1·49 lost for each 100 lb. of cane ground, leaving out fractions of little value, so that 9·36+1·49 = 10·85 per cent. of saccharine matter was obtained by the rapid mill from canes yielding juice of 10° B. Canes yielding 90 per cent. of juice of 10° B. contain 18·38 per cent. total saccharine matter, so that 18·38 – 10·85 = 7·53 lb. saccharine matter lost in the begass of each 100 lb. of cane ground in the rapid mill.

Table No. 2 shows that the slow mill has given 14·87 lb. of total sugars per 100 lb. canes ground, with a loss of 0·26 lb. of saccharine matter per gallon of juice obtained, for the reason above mentioned. The gallons of juice per 100 lb. canes, 7·18, × 0·26 = 1·86; that gives 14·87 + 1·86 = 16·73 lb. saccharine matter per 100 lb. of cane ground.

Canes giving 86 per cent. of juice of 11° B. contain 19·20 per cent. total saccharine matter, therefore 19·20 – 16·73 = 2·47 lb. of saccharine matter lost in the begass of each 100 lb. of cane ground.

Lost in begass of rapid mill	7·53 per cent.
Lost in begass of slow mill	2·47 ,,
Difference in favour of s'ow mill ..	5·06 per cent.

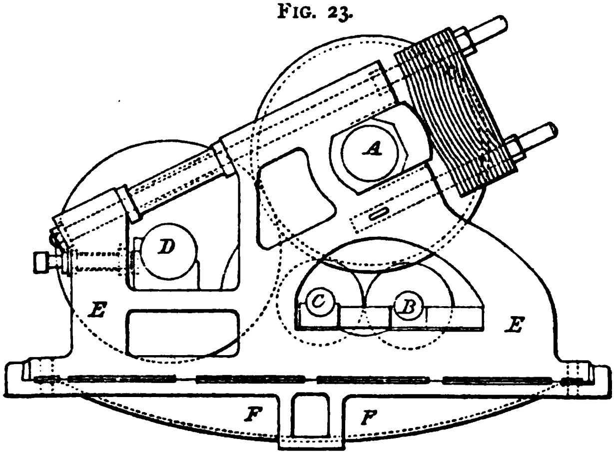
Which represents a net increase on the crop of 46·6 per cent.

10·85 : 5·06 : : 100 : 46·6 per cent.

The only fuel used in both cases was the begass produced on the estate.

Various advantages are claimed for the De Mornay mill, shown in section in Fig. 23, and it will probably be more

FIG. 23.

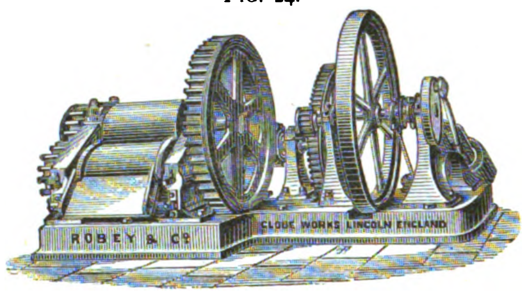


De Mornay Mill.

widely adopted when better known. In Cuba and Demerara it is unknown; but it has been manufactured for South America by Fawcett, Preston, & Co., and worked there with great success. The canes enter between the rolls A B, and are carried onwards by the roll C, inclining upwards until they are grasped by A D. There is no returner-bar to cause abnormal friction and resistance, and no sliding or rubbing of the top roll on a mass of crushed cane. It is stated that this mill, when properly constructed and proportioned, will grind cane with 50 lb. steam pressure, when the ordinary 3-roller mill fitted with a returner-bar requires 65 lb., or the difference between a 15- and a 20-H.P. engine.

Robey & Co., Lincoln, pay much attention to the manufacture of first-class machinery for the extraction of sugar from the cane, and mills made by them have earned high praise from sugar cultivators. The mill illustrated in Fig. 24 is specially designed for small plantations, and will

FIG. 24.



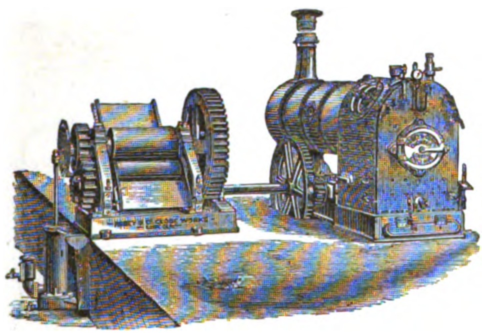
Robey's Mill.

produce from 2 to 3 tons of sugar per day from cane and juice of average quality. The rollers are 20 inches in diameter by 30 inches long, and are driven by a train of strong gearing actuated by an engine of 8 horse-power nominal, but capable of working up to 16 horse-power. The whole is fixed on a strong cast-iron foundation-plate, by which means its erection is much facilitated. The foundation-plate is made in two parts, for the sake of greater ease in transit. These mills, similar to the one illustrated, with gearing and engine complete, are made of the following sizes:—With roller 16 inches diameter by 24 inches long; ditto, 18 ditto by 27 ditto; ditto, 20 ditto by 30 ditto; ditto, 22 ditto by 39 ditto; ditto, 25 ditto by 48 ditto.

If required, boilers are supplied, suitable for fixing on the copper flue; they have large heating surface, and are adapted for megass and other inferior fuel. They are supplied with all boiler fittings, viz. 2 safety valves, gauge cocks and water gauge, steam pressure gauge, whistle and blow-off cock; also with set of furnace fittings, consisting of furnace front, with fire and ash pit doors planed to fit air-tight; one chimney damper and one furnace damper, with their respective frames and balance weights, are supplied; the furnace damper is lined on both sides with fire logs.

The following are the dimensions of the boilers usually made:—4 feet diameter by 10 feet long, with 36 tubes; 4 feet 3 inches diameter by 10 feet long, with 48 tubes; 5 feet diameter by 10 feet long, with 72 tubes; 5 feet 6 inches diameter by 10 feet long, with 82 tubes; 6 feet diameter by 10 feet long, with 100 tubes.

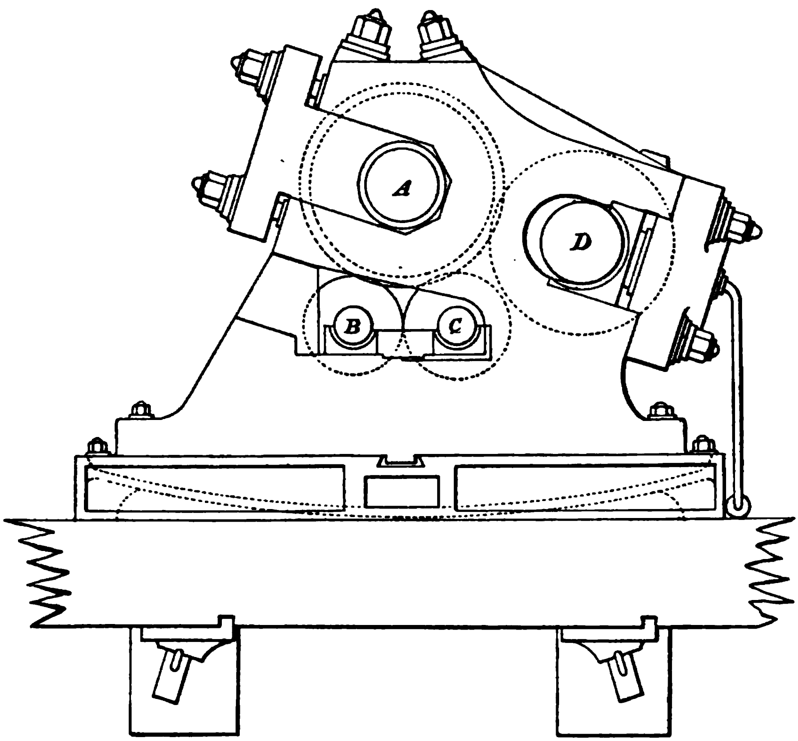
FIG. 25.



Robey's Sugar-mill Engine and Boiler.

Fig. 25 shows Robey & Co.'s sugar cane mill driven by an improved Robey fixed engine and locomotive boiler combined, an arrangement which possesses many important advantages, especially in connection with mills of small size. Both mill and engine are erected complete upon their own base plate, which enables their re-erection abroad to be done in a very simple and easy manner. The engine is of special make, the boiler having enlarged fire-box, suitable for megass or other inferior fuel, and all the working parts are simple in construction and easy of access, so that they can be erected and managed with great facility. All parts being properly fitted and tested before being sent from the factory are sure to fit into place and work properly when re-erected abroad. These mills are made of various sizes, with rollers and engines, as given below:—5 horse-power single cylinder "Robey" engine and sugar mill, with rollers 16 inches diameter by 24 inches long, with gearing; 6 horse-power ditto, 18 ditto by 28 ditto; 8 horse-power ditto, 20 ditto by 30 ditto; 10 horse-power ditto, 22 ditto by 39 ditto; 12 horse-power ditto, 25 ditto by 48, ditto.

FIG. 26.



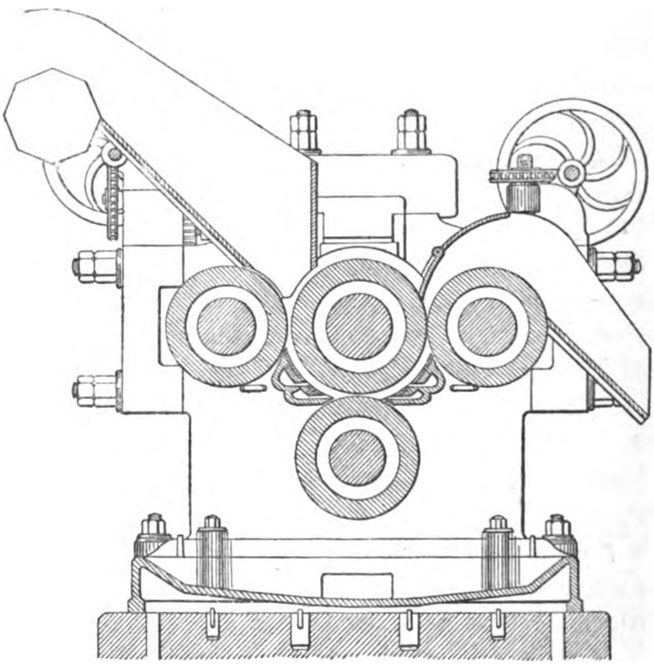
Improved De Mornay Mill.

Fig. 26 shows the improved De Mornay mill, and is taken from a drawing of a mill lately constructed for a large estate in Demerara. The improvements in the De Mornay mill, recently patented by Messrs. Fawcett, Preston, & Co., Limited, of Liverpool, consist of (1) the application of hydraulic cylinders instead of steel springs, a constant pressure being maintained on the rams of the cylinders by means of an accumulator; (2) the adoption of thoroughfare bolts through all the caps, by which all strains are taken up by the wrought-iron bolts, and not by the cast-iron headstocks; and (3) the peculiar construction of the scraper for removing the megass from the main roll. This scraper is brought up over the top of the roll, but without touching it, and is then bent downwards till it touches the roll; thus it removes the megass from contact with the roll as soon as possible after crushing, and therefore prevents re-absorption of juice by the megass. This absorption of juice by the crushed megass presents a very serious loss, the extent of which is now fully appreciated.

Cane-mills have been constructed with 4 and even 9 rolls. In the 4-roll mill, where 2 rolls are placed above and 2 below, the driving power is said to be not much greater than that required for an ordinary 3-roll mill, while more juice is obtained. In the 5-roll mill, 3 rolls are placed below and 2 above; 10 per cent. more juice is said to be extracted by this plan, but much greater power is needed, and the begass is generally more broken up.

In the ordinary 3-roller mill, two pressures are supposed to be exerted in crushing; but in many cases the cane roller is little more than a feeder for the canes, thus leaving the entire grinding or crushing to be virtually done by the begass or back roller at one pressure. In Fletcher and Leblanc's 4-roller mill, as illustrated in Fig. 27, the cane roller fulfils the corresponding duty of a "défibreur," that is, it breaks the canes open and reduces them to an even layer, and, following this, there are two distinct and heavy pressures to which the canes are subjected, of sufficient power to extract the highest percentage of juice possible. From this it will be seen that the canes are subjected to three distinct pressures. Further advantages may be obtained by the use of hollow trash turners, by which the begass can be moistened by steam or water, or both, thus introducing the maceration process. In the 4-roller mill the three outer rollers are made adjustable by means of wedge blocks, which are set up by bolts. The wedge blocks can also be made adjustable by

FIG. 27.



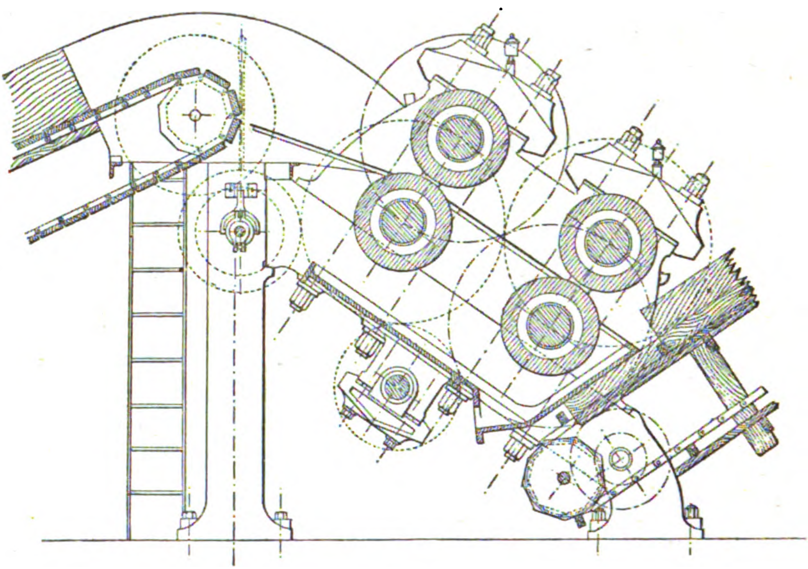
Fletcher and Leblanc's 4-roller Mill.

worm-gearing and hand-wheels, so that when the mill is working a "choke" can be avoided. Each roller can be removed without disturbing the others, or taking down the standards; and this mill has also the advantage of having all the principal strains resisted by wrought-iron bolts, consequently it is almost impossible for the standards to break. Should an accident occur to any one roller, and the roller become disabled, the mill could still be used as a 3-roller mill, thus avoiding any delay in grinding. Existing 3-roller mills can be altered to this system by having new standards and an additional roller and shaft, the old bed-plate and rollers being retained; and if the engine and gearing is of modern construction and sufficiently powerful, these may be used, and thus the advantages of double crushing and maceration may be obtained without the heavy expense of an entirely new plant.

A characteristic feature of this mill is that the begass, on its delivery from the mill, forms, from one side to the other of the begass roller, a perfectly homogeneous layer, composed of small pieces some 3 inches, more or less, in length, *so dry* that it may be conveyed at once direct, by the usual appliances, through the hoppers to the furnaces; thus, a fuel of first-class character is promptly provided. Another advantage is that the main roller and the begass roller do not become foul or covered with particles of begass. In fact, the surfaces of the rollers remain clean and almost dry. This arises from the circumstance that the juice proceeding from the third crushing falls, in the form of rain, and is not re-absorbed by the begass, which passes regularly from below. The rollers almost touch, their separation being less than $\frac{1}{16}$ inch. Among the begass are rarely found pieces of cane half ground, or more or less whole, as invariably happens in mills in common use, particularly towards the extremities of the rollers next the flanges. This mill is made by G. Fletcher & Co., King Street, Poplar, London, E., and Masson and Atlas Works, Derby.

Another four roller mill is shown in Fig. 28. The chief features are that the main bolts take the strains in a direct line, the trash-turner is dispensed with, and the rollers are connected and driven by gearing wheels of large diameter.

FIG. 28.

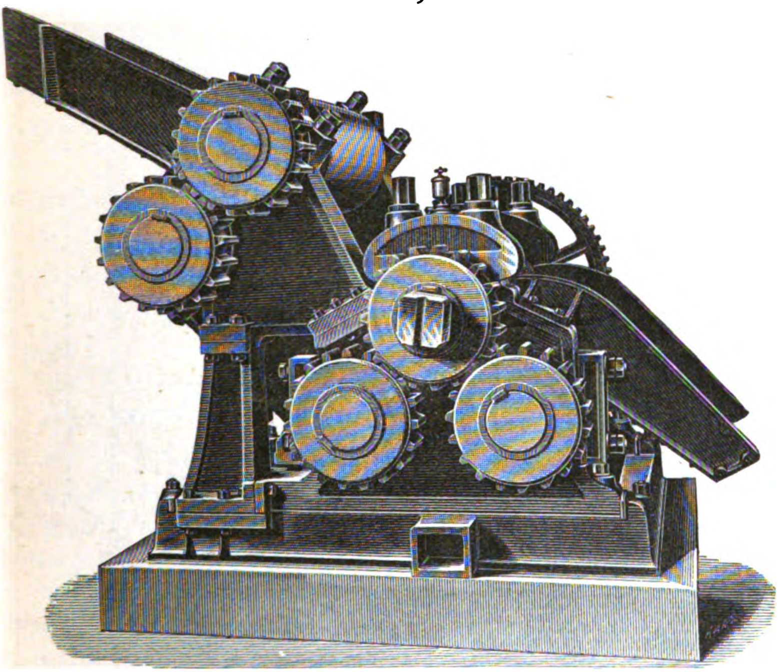


Mirrlees' 4-Roller Mill.

Thomson and Black's patent 5-roller cane mill (Fig. 29), as manufactured by Messrs. M'Onie, Harvey, & Co., Glasgow, has obtained a very high repute amongst planters and engineers, not only in Brazil, where this type of mill was first adopted, but also in Demerara and Peru, where very large mills of this class are now at work. The arrangement is simply that of an ordinary 3-roller mill, with two auxiliary rolls mounted in front. These auxiliary rolls have their surfaces specially grooved, so that the canes in their passage from the carrier to the mill proper are thoroughly split up, and the feed is reduced to some degree of uniformity. In regular practice, these mills give an expression of 74 and 78 per cent.

of juice, results which go far to make good their claim to superiority.

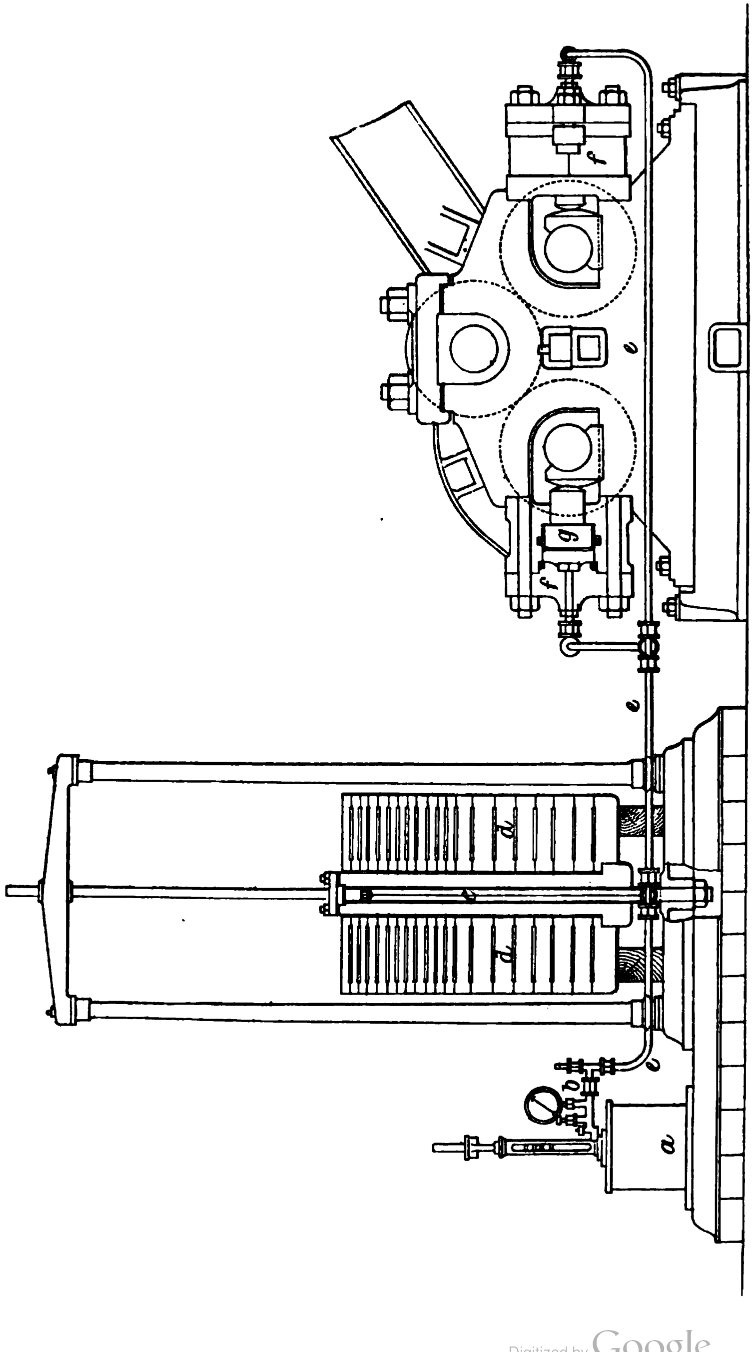
FIG. 29.



Thomson and Black's 5-Roller Mill.

A recent important addition to cane mills is the application of hydraulic pressure to the rolls, so that the mill can adjust itself to the inequalities of feeding that are unavoidable. The arrangement adopted by Duncan Stewart & Co. is shown in Fig. 30. The letters indicate the following parts: *a*, small hand pump for charging accumulator; *b*, valves for charging and discharging; *c*, hydraulic accumulator, ram, and cylinder; *d*, weights on cylinder, which is loaded to pressure required on rolls; *e*, steel piping connecting accumulator with cylinders on mill; *f*, steel cylinders with rams *g*, which traverse to and fro as canes are fed between the rollers; *g*, cast-iron rams, sheathed with brass to prevent corrosion; *h*, steel tops to limit

FIG. 30.



Stewart's Hydraulic Attachment to Cane Mills.

pressure on top roller, so as to prevent abrasion when mills are running empty.

In applying this attachment, the four screws or wedges, side or top caps, now used in cane mills are replaced by steel hydraulic cylinders supplied with a fluid (water or oil) under a known pressure, which pressure has been decided upon by experience; once this has been found, the same good results can always be confidently counted upon, and will not be dependent upon the acknowledged great attention which is requisite with ordinary mills, and thus a higher and constant percentage of juice is maintained.

Among the advantages may be pointed out the following:—

1st. A higher percentage of juice.

2nd. The power of maintaining the percentage constant.

3rd. Freedom from breakdowns.

4th. Less attention required to regular feeding.

5th. The power by such equal crushing to regulate the boiler furnaces for burning wet begass.

With regard to the above, it may be remarked that the percentage of juice, by the application of the hydraulic attachment to a mill giving an average of 60–62 per cent. is increased to 66–68 per cent. The increase of juice with mills doing 70 per cent. crushing and upwards is, of course, not so marked; at the same time there always is an increase. Another very important fact in favour of the hydraulic attachment is that the liability to breakage arising from overfeeding, or the introduction of any foreign substance, either accidentally or maliciously, is reduced to a minimum. Less attention is also required to regular feeding, as the rollers open more at one end than the other, should the feed of cane be thin at one side, and thus accommodate themselves to the irregular feed—in other words, this mill adapts itself to the feed, whilst under the ordinary system the feed has to be adapted to the mill. By means of the improved and uniform crushing, the begass can be burned direct from the mill in the boilers and furnaces as fuel.

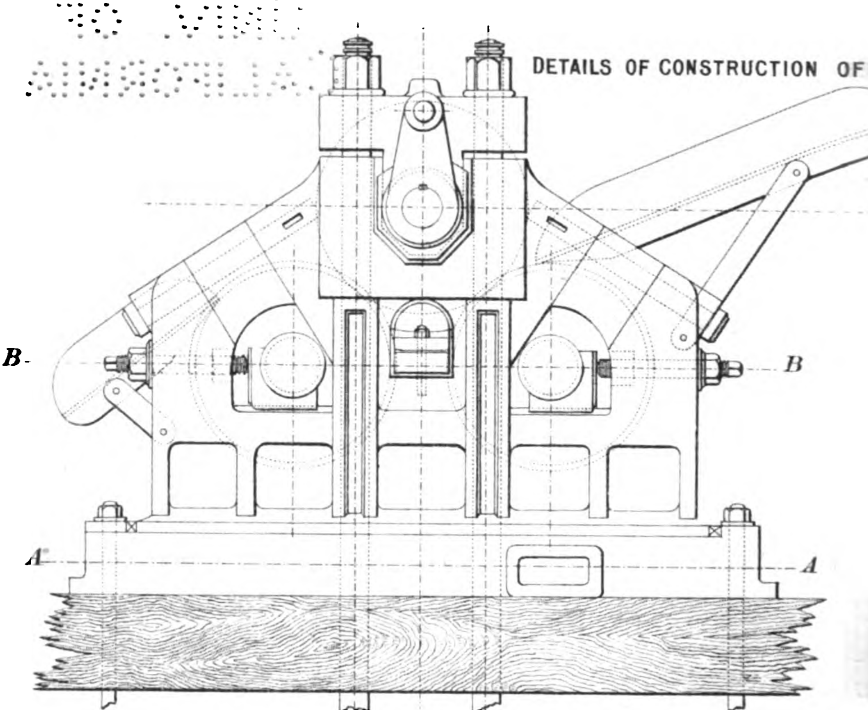
With reference to mills generally, it may be mentioned here, that it is now an acknowledged fact, that the sugar cane, in consequence of the difference in composition between the juices of the vascular and of the cellular tissues, does not contain so much sugar as most writers on the subject have credited it with. Until within the last two or three years, it has been almost the universal custom of chemists to calculate the amount of sugar in the whole cane from the amount present in the juice extracted, by assuming that that left in the begass possessed the same composition. This method must now be given up, as it shows more sugar in the cane than there actually is, because, as has been shown by Francis, Alexander, and Harrison,* the juice left in the begass does not contain the same percentage of sugar as is present in the quantity of juice usually expressed by a mill. This fact is of great importance and interest to advocates of the mill, as it proves that more sugar is extracted from the cane by its use than was hitherto supposed. It ought to give much satisfaction to many to learn that with a thoroughly well proportioned and strongly geared mill fitted with the hydraulic attachment, it is now quite a simple matter to maintain an expression of 74-78 per cent. of juice, and further, that this amount of juice contains from 90 to 94 per cent. of the sugar in the cane—a result which quite equals anything that has yet been done in a diffusion battery.

The hydraulic attachment for mills, as made by Manlove, Alliott, Fryer, & Co., Nottingham, is illustrated in Fig. 31.

At the Glasgow International Exhibition was shown a new gear which accomplishes the same result as the hydraulic attachment in a simpler and ruder fashion, by means of springs acting on "toggle" levers; and whilst it is applicable to almost any sugar mill, it is specially suited to those of such

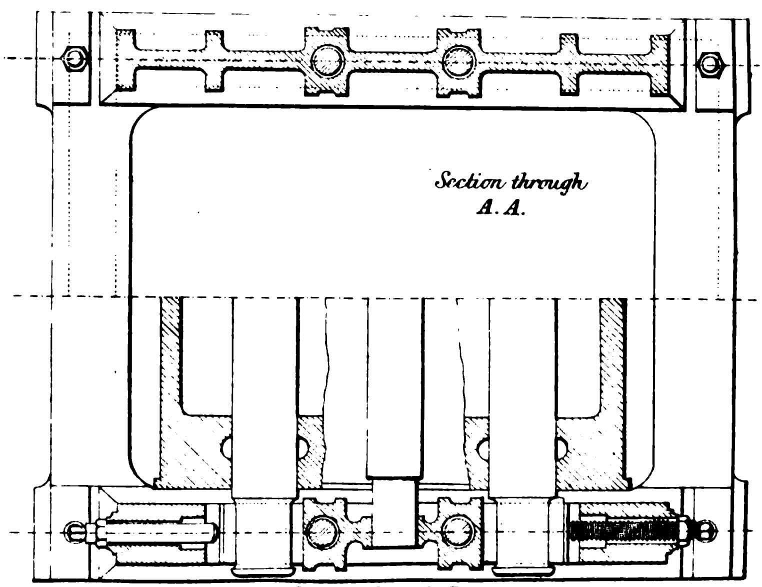
* 'Sugar Cane,' July and October, 1886.

DETAILS OF CONSTRUCTION OF



Elevation.

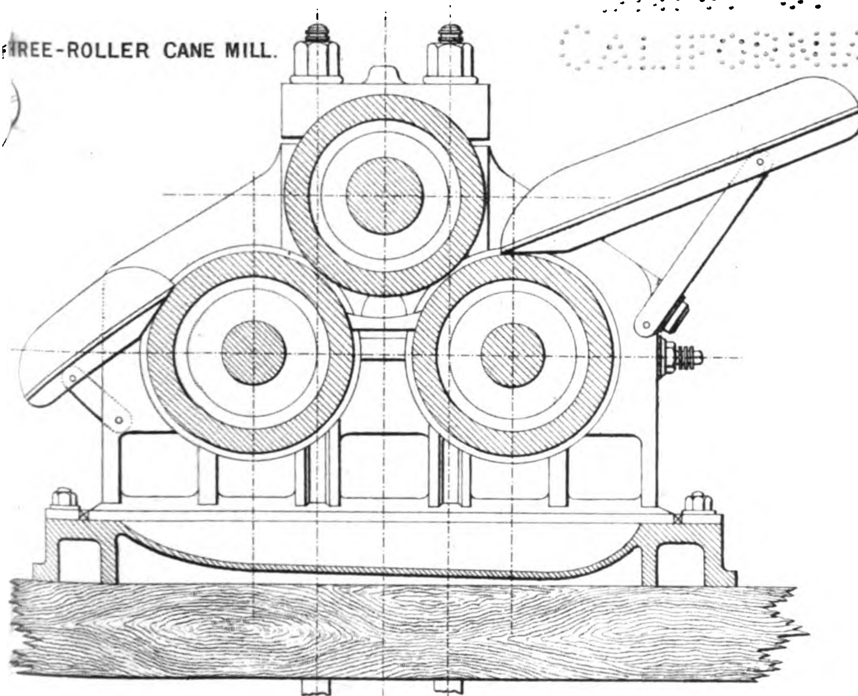
Scale.



Section through B.B.

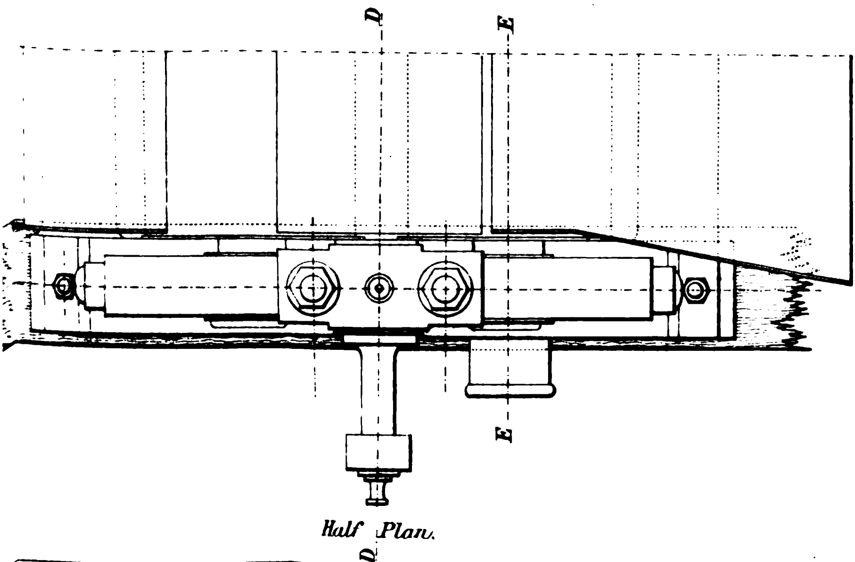
E & F. N Spon.

THREE-ROLLER CANE MILL.



Inch-1 Foot.

Section through C.C.

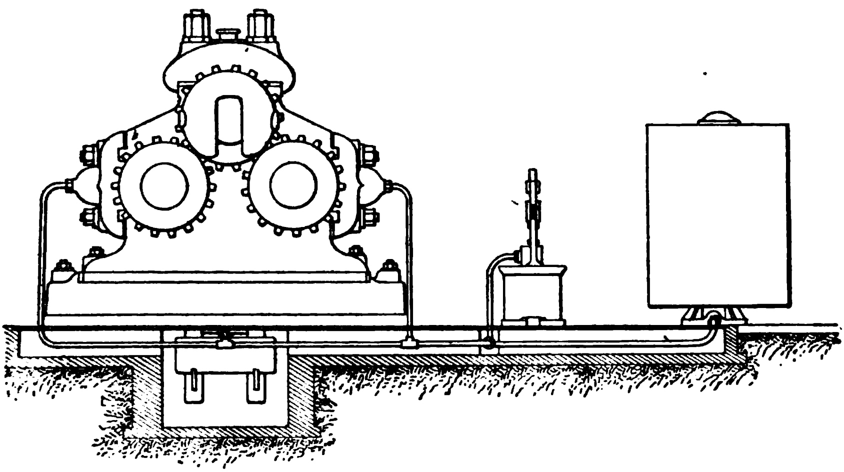


Half Plan.

London & New York

moderate size as not to justify the cost of the more expensive hydraulic apparatus, or where the necessary skilled attention is not available; and the makers claim for it every advantage

FIG. 31.



Manlove's Hydraulic Attachment.

offered by the hydraulic gear, together with others which the latter system does not afford. The principal points may be summarised as follows:—

1. The first cost is much less than that of the hydraulic apparatus, and the expense for erection and upkeep is only nominal.

2. Owing to its simple construction, it does not need and skilled attention.

3. No additional space is needed, and no pipe connections. The apparatus is compact and self-contained, and as soon as placed on the mill it is ready for work.

4. The degree of pressure on the roller is readily adjustable, by turning the nuts compressing the springs.

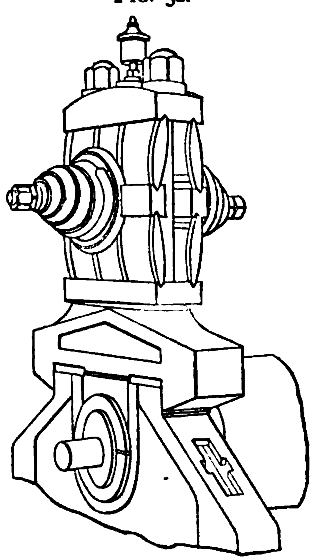
5. The pressure on the gearing end of the roller may be

varied to the extent necessary to compensate for the thrust of the pinions.

6. The volute springs adopted are similar to those largely used for the buffers of locomotives and other rolling stock, where the work is far more severe than in the present application. It may therefore be reasonably expected that the springs will retain their full efficiency for a long time; but, as their cost is small, the makers advise spare springs being sent with each apparatus, enabling an injured spring to be replaced in a few minutes.

7. Particular attention is directed to the compensating action of the "toggle" levers, which is the special feature of this invention, and enables springs to be used without the disadvantages which have hitherto prevented their application. It will be observed that the action of the parts is such that the springs when least compressed, and therefore exerting their minimum thrust, are acting at the greatest leverage, and *vice versâ*. It results from this peculiar action that by the selection of a suitable spring the load on the journal may, if desired, be made uniform for the whole distance through which the roller lifts, in this case exactly reproducing the effect of an hydraulic cylinder; but the makers prefer to take advantage of the facilities afforded to proportion the springs so as to give a pressure increasing slowly as the roller rises, this being considered advantageous.

FIG. 32.



Toggle Gear.

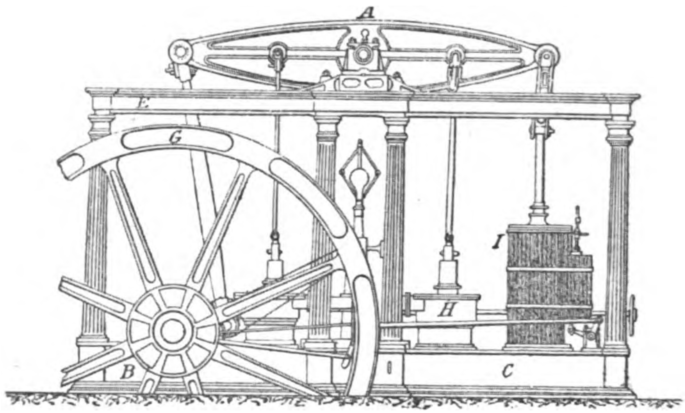
The apparatus (Fig. 32) is readily applicable to any mill of the ordinary construction.

Motors, Fuels, and Furnaces.—Though not perhaps strictly in chronological sequence, this seems a convenient point at which to introduce the questions of the relative advantages of the various kinds of motive power, and the various kinds of fuel, as well as to describe furnaces constructed specially for the purpose of burning the begass.

With regard to the suitability of the several kinds of power for driving cane-mills, it has been ascertained, by comparing the results of 44 mills in Guadeloupe, that:—with windmills of inferior construction, the cane-mills extracted only 50 per cent. of juice; with ordinary windmills, 56·4 per cent.; with animal power, 58·5 per cent.; with water power, 59·3 per cent.; with steam power, 61·8 per cent. The reasons for these differences probably lie in the following facts:—Wind power is least efficient because most subject to variation, while the others increase in capacity apparently in direct ratio to the working force they possess in excess of what is constantly demanded of them, thus preventing those repeated stoppages or slackenings of speed which are sure to occur when the power is not sufficiently in excess to overcome the checks arising from unequal feeding. Wind-engines might be made more available in many places by the intervention of modern electrical engineering, so as to equalise the power. Cattle-mills and water-wheels are in wide use; where a good head of water is obtainable, and the mill is properly constructed, water-power will probably be found to fall very little short of steam-power, while possessing the great advantage of very much reduced cost, particularly where fuel is scarce or dear.

Figs. 33 and 34 show in elevation and plan an economical combination of a vertical beam-engine arranged so as to work two large air-pumps, and with power enough to drive the cane-mill at the same time. This style of engine is applicable when the sugar-factory is organised so as to run day and night, as all should to work profitably. It is evident that by using one large engine instead of three (one each for the cane-mill, the triple-effect, and the strike-pans), much loss by friction and expense of attendance are saved. In the figure, E represents an entablature carrying the beam A, mounted by 8 columns on the bed-plate C; H are two large air pumps in connection with the triple-effect and vacuum-pan; a massive fly-wheel G is necessary to secure regularity of motion.

FIG. 33.



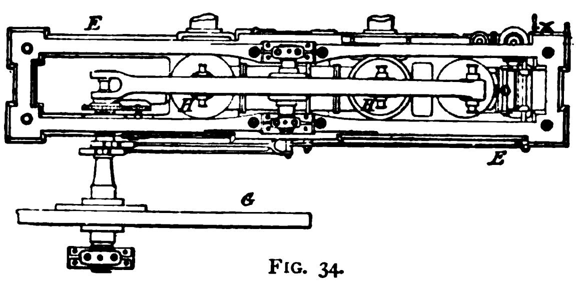


FIG. 34.

Cane Mill Engine.

The use of coal and wood as fuel needs no remark. Arguments for and against the burning of the begass as a source of heat have been already put forward (see pp. 47–48). As begass continues to be very largely consumed as fuel, it will be interesting to give here some figures concerning its evaporating power.

Supposing the cane-mills to express 68 per cent. of juice, which is probably a low figure for the majority of modern mills, 6000 gallons per hour would produce 30,325 lb. of wet begass. From experiments made on a large scale in Egypt, it appears that dry begass, fit for burning in the furnaces ordinarily using it, weighs 53 per cent. of the wet; and 29,578 lb. of dry begass will evaporate as much as 16,000 lb. of ordinary English north-country coal, so that it requires 1·85 lb. of begass to do the same work as 1 lb. of coal. The canes yielding 6000 gallons of juice produce 16,072 lb. of dry begass, which quantity is consumed in the evaporation of 809·5 cubic feet of water, or at the rate of nearly 20 lb. of begass to the cubic foot. According to Black, 14·8 lb. should suffice; but an imperfect experiment, made with a small Cornish boiler at Magaga, gave only 3·06 lb. of water per lb. of begass, or 20·7 lb. to the cubic foot. As an approximation, 1 lb. of coal is about equal to 2 lb. of begass, or 16 lb. of begass to the cubic foot of water; so that there seems to be margin enough to warrant the statement that the refuse of the canes should give fuel sufficient to make the sugar, especially where the climate is favourable to drying the begass.

But this statement appears to hold good only when the canes are far from being exhausted of their juice, and thus it happens that many estates burning their begass require coal or other fuel in addition. The annexed table of the assumed composition of the dry begass under the several degrees of exhaustion has been drawn up by Anderson :—

Percentage of juice extracted	60·0	70·0	80·0
,, ,, water dried out	21·1	13·6	5·7
,, ,, water left in	1·9	1·6	1·5
,, ,, sugar ,,	6·0	3·8	1·8
,, ,, ligneous matter	11·0	11·0	11·0
	100·0	100·0	100·0
,, ,, sugar and ligneous matter, on 100 parts of juice	28·3	21·1	17·3

The last line of figures shows how rapidly the fuel available decreases with the increased juice-yield of the cane-mills, and it must be remembered that the lesser quantity of fuel has the greater quantity of juice to evaporate.

At Cairo, in March 1874, the consumption of begass by a 10-H.P. portable engine was found to be 17·77 lb. per H.P. per hour, which, taking the average consumption of coal by this engine at 6 lb. per H.P. per hour, gives the proportionate consumption of coal and begass as 1 to 2·96. When the begass was dried in the sun, it made an excellent fire, and required no larger air-space between the grate-bars than was necessary for burning wood. Sir F. Bramwell and Dr. Letheby, reporting on the Khedive's sugar-factories, stated 377 lb. of dry begass (the produce of 1 ton of canes) to be equivalent to 180 lb. of Welsh coal.

Begass, whether wet or dry, can only be satisfactorily burned in furnaces of peculiar construction. If the reader will refer to the analysis of canes given on p. 33, he will find that 26 to 54 per cent. of the total ash of the cane consists of silica. This silica forms a deposit upon the bars of furnaces burning straw, begass, and such substances. It does not collect in hard masses on the bars, so as to prevent the ingress of air, until the boiler has been for some time at work; and experiment shows that if an apparatus can be made to act before the silica becomes agglomerated, the space between the bars can be kept as free and open as when burning coal or wood.

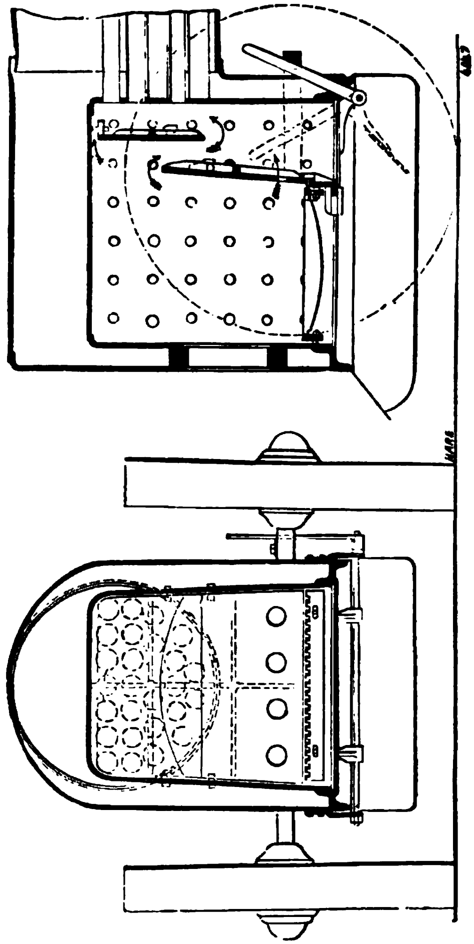
With this object a simple apparatus was used at Aba-el Wakf, consisting of a rake with 5 or 6 teeth, according to the width of the fire-box, the top of these teeth projecting about 2 inches above the fire-bars. One end of this pricker is attached to a handle, which extends outside the ash-pan, and can be worked by the stoker, and the whole apparatus slides backwards and forwards upon 2 wrought-iron guides underneath the fire-bars. When the apparatus is used, it is drawn from the back to the front of the fire-box, along one side of the fire-bars. It is then shifted to the other side of the 4-inch space, and travels from the front to the back of the fire-box along the other side, and thus cuts away all the deposit of silica, which falls into the ash-pan. There is also liable to be a slight deposit of silica and slag in some of the tubes of the boiler, especially in the 2 lower rows, thus impeding the generation of steam. To obviate this and the necessity for stopping the engine and cleaning the tubes, a steam jet consisting of a wrought-iron pipe with a brass rose at one end, may be attached, with an indiarubber pipe, to a tap in front of the boiler. When the tubes are furred, this rose-jet is inserted through the flaps in front of the boiler, and the whole of the silicious deposit is blown through the tubes into the smoke-box.

Fig. 35 illustrates a portable steam engine and boiler for burning begass, as made by Ransomes, Sims, & Jefferies, Ipswich. It is constructed on the basis of Head and Schemioth's patent boiler for burning straw, with some recent improvements in the direction of economising fuel and protecting the fire-box. This latter is provided with two baffle plates, forming a combustion chamber through which the smoke passes on its way to the tubes; the flame from the burning straw passes through the large holes in the lower plate and ignites the smoke and gases, causing the most perfect combustion; no cold air can come in contact with the tube plate, as it is first warmed by passing over the baffle plates. The few ashes remaining are deposited on to a trap door between the lower bridge and tube plate, and can be readily discharged into the ash-pan by moving the handle at the side of the fire-box.

Not only begass, but reeds, cotton and maize stalks, indigo refuse, furze, or brushwood, can be burned in this boiler. Coal or wood can be substituted when the baffle plates and feeding apparatus are removed. The feeding apparatus is self-acting, and is driven from the engine shaft by means of a strap. One man can efficiently supply begass to the feeder.

There has recently been introduced a furnace for burning undried begass in such a condition as it presents on leaving

FIG. 35.



Ransomes' Begass Burner.

the cane-mill. It is the invention of J. L. Marie, of Saint Pierre, Martinique, and is made in this country by Manlove, Alliott, Fryer, & Co., of Nottingham. Figs. 36 and 37 represent a longitudinal vertical section and horizontal section respectively of the begass furnace, while Fig. 38 illustrates the application of the begass furnace to the fire-box of a locomotive boiler.

FIG. 36.

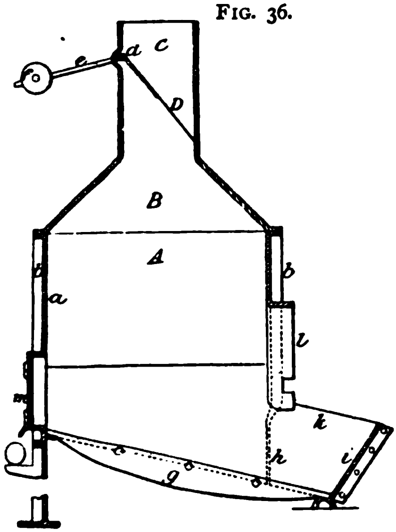
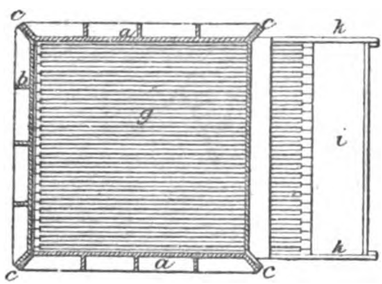


FIG. 37.

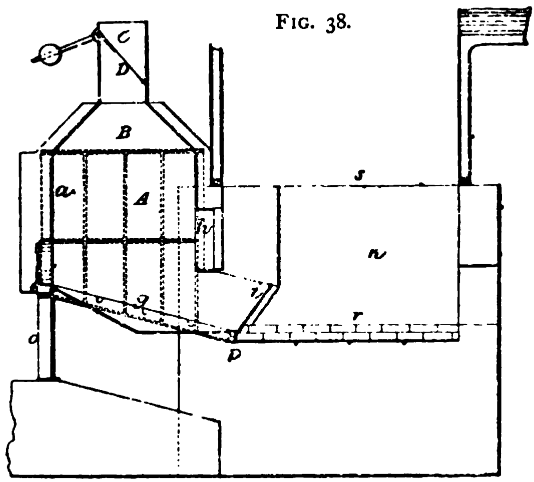


Marie's Wet Begass Burner.

The furnace chamber A is constructed preferably of cast-iron plates *a* stiffened by ribs *b*, bolted together by flanges *c*, and encased in brickwork. The pyramidal crown B of the furnace chamber is also constructed of cast-iron plates, bolted upon chamber A, and surmounted by the hopper C, in which the begass is dried, and through which it is fed to the furnace. A self-acting balance-door or valve D is placed within the hopper in the inclined position shown; it works on pivots at *d*, supported in the sides of the hopper, one of them having a lever arm *e* fixed to it outside the hopper, upon which is placed a counterweight *f*, adjustable along the arm *e*, to regulate the quantity of begass admitted each time the door opens. The fire-bars *g* at the lower part of the furnace are inclined as shown, and their lower ends extend through an opening *h*, and are supported by an inclined bridge *i*, bolted to extensions *k* of the side walls of the furnace. The upper part of the opening is surrounded by a flange *l*, which may fit in the doorway or beneath the fire-box of the boiler, the form and dimensions of the said flanged opening or throat being varied as circumstances may require. The doors *m* just above the fire-bars give access to the furnace.

As shown in Fig. 38, the chamber A and crown B would be encased externally in brickwork, and the sides *a*, or their

FIG. 38.



Marie's Wet Begass Burner.

most exposed parts, would be lined internally with fire-brick or fire-clay; the walls *n* which support the boiler may also be faced with fire-brick. The begass furnace is here shown supported at front on feet, and at back upon a wrought-iron girder *p*, whose ends are built into the walls that support the fire-box *s* of the boiler. The lower part of the boiler fire-box is completely closed by brickwork *r*, supported on girders built into the same side walls; and the interval between the begass furnace and the fire-box being also built up, the whole of the air to support combustion must come in through the fire-bars *g*.

Although exterior to the boiler, this begass furnace has greater heating power than an internal furnace, as begass coming wet from the mill requires to be dried to render it fit for fuel, and receives its preliminary drying in this external furnace. A coal fire having been first lighted in the furnace A, its walls become highly heated; the wet begass is then fed in through the hopper C, whose balance-door D opens to give passage to and spread the begass uniformly upon the grate *g*, the door D closing again immediately to re-establish the natural draft through the grate. The flame of the fire immediately envelopes the fresh fuel, and owing to the high temperature in the furnace, the gases at once begin to be liberated. As the surfaces of internal boiler furnaces do not exceed the relatively low temperature of the surrounding water, a great part of the gases is carried off unconsumed, and becomes partly condensed on the cooler surfaces, and partly passes away in the form of dense smoke; whereas in this furnace, the heat which in the former case would go to heat the water is stored up in the walls of the furnace, which quickly become hot enough to almost instantly dry the begass, and render it eminently fit for burning. As all the gases are compelled to pass through the mouth or aperture leading to the boiler furnace *s*, perfect combustion is ensured, and there is little or none of the usual deposit in the boiler tubes.

The advantages of a furnace which will burn wet begass are not confined to the mere saving of the time and outlay required for drying, but extend to the equally important gain represented by the avoidance of that risk of fire, which is so constantly to be feared when begass is stored in large quantity, and by the utilisation of the combustible qualities of the saccharine matter left in the canes, before it is destroyed by fermentation. The furnace is simple to construct and manage, and little likely to get out of repair. It is independent of the fireplace to which it is desired to attach it, and has been very successfully applied not only to the boiler furnaces for the cane-mills, but also to the "copper walls" for making muscovado sugar.

Norbert Rillieux, of Paris, has also devised a plan for effecting the drying of the begass on its way to the furnace. The apparatus is shown in elevation and plan in Figs. 39 and 40. The begass in its wet state is delivered by the elevators *a* into the hopper *b*, leading at bottom into a chamber communicating with the furnace *c* of the steam-boiler *h* employed. In this hopper, is a hinged horizontal flap *d*, on to which the begass falls, and which is held in place by a balance-weight till the load accumulated upon it over-balances the weight, when the begass is discharged down into the chamber and passes into the furnace to be burnt, the flap being closed again by the balance-weight. While the begass is retained in the hopper, and descends through the chamber, it is subjected to currents of hot gases from the furnace, so as to become dry before passing into the fire. The hot currents may be accelerated by connecting the hopper by a pipe *e* with the chimney *f* of the boiler, the draught being regulated by a throttle-valve; and if required, a blowing-fan *g* may be provided in the pipe, and regulated so as to produce the required degree of desiccation in the begass.

FIG. 39.

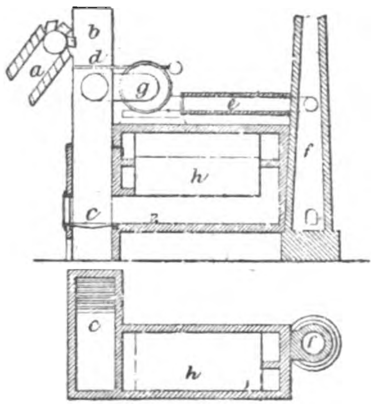


FIG. 40.

Rillieux's Begass Drier.

The following remarks on the thermotic value of damp megass are taken from a paper on the subject by Alfred Fryer, published in the 'Sugar Cane,' July 1873.

Megass, like other classes of fuel, is never absolutely dry, and even a carefully prepared sun-dried sample will contain 9 or 10 per cent. of water.

The following table shows the proportions of woody fibre and moisture found in megass :—

Quality.	Megass.	Parts by Weight of		Per cent. of Moisture.
		Fibre.	Moisture.	
1	Absolutely dry	10	0	0
2	Good sun dried	10	1	9
3	Average dry megass	10	2	17
4	Fresh from most powerful mills obtaining 75 per cent.	10	10	50
5	Fresh from good steam mills expressing 66 per cent.	10	16	62
6	Ordinary steam mills extracting 62 per cent. ..	10	19	66
7	Average windmills yielding 55 per cent.	10	25	72

In the above table it is assumed, that taking the average of plant canes and ratoons, juicy and dry, the woody fibre constitutes 13 per cent. of the weight of the canes.

Let it be supposed for the present, that megass of each of the seven foregoing types can be completely burnt. It is desired to ascertain the number of available units of heat from the combustion of one pound of woody fibre, and also what is the maximum temperature of the products of combustion. Thus, in example No. 1, one pound of megass alone will be taken ; in example No. 4, two pounds will be taken, which will be composed of one pound of fibre and one pound of moisture.

It is assumed that the products of combustion enter the chimney at a tempeiature of 600° F. Also that each pound of dry megass requires in practice 9·7 lb., or 130 cubic feet of air, for its combustion. That if the megass be burnt directly from the mill, the sugar present in the moisture will act as fuel ; but as the total residual moisture is less rich in sugar than is cane juice, and as decomposition sets in from the very moment that the cell which contains the juice is ruptured, it is assumed that ten per cent. of the moisture is

TABLE SHOWING THE AMOUNT OF HEAT GENERATED BY ONE POUND OF MEGASS FIBRE, both anhydrous and associated with varying proportions of Moisture; the maximum Temperature of the products of Combustion, and the number of Feet of Gases and Vapour passing up the Chimney at 600° Fahr.

No. of Experiment.	Quality of Megass.	Moisture.	Heat from one Pound Dry Combustible.	Heat from Sugar in Associated Juice.	Total Heat.	Loss by Conversion of Moisture into vapour.	Lost in Chimney.	Heat available.	Maximum Temperature of Products of Combustion.	Volume of Gases and Vapour at 600° in Chimney.	Volume of Gases and Vapours at 600°, after combustion of sufficient fuel to liberate 4503 available units.	Ditto, ditto, 4342 available units.
		per cnt.	units.	units.	units.	units.	units.	units.	units.	cub. ft.	cub. ft.	cub. ft.
1	Anhydrous	0	6,100	0	6,100	0	1,597	4,503	1,910	288	288	278
2	Good sun dried	9	6,100	50	6,150	101	1,627	4,422	1,840	293	298	288
3	Average dry	17	6,100	100	6,200	202	1,656	4,342	1,786	299	310	299
4	From mill extracting 73 per cent.	05	6,100	500	6,600	1,010	1,894	3,696	1,380	343	417	403
5	,, ,, 66 ,,	62	6,100	800	6,900	1,616	2,072	3,212	1,160	376	528	509
6	,, ,, 62 ,,	66	6,100	950	7,050	1,919	2,161	2,970	1,068	323	597	574
7	,, ,, 55 ,,	72	6,100	1,250	7,350	2,524	2,339	2,487	910	426	770	743
8	Wigan Cannel	..	14,000	..	14,000	..	3,159	10,841	2,320	655	272	262
9	Average Steam Coal	..	13,000	..	13,000	..	3,159	9,841	2,150	651	298	288

sugar with a heat equivalent of 5000 units. That the temperature of the air and fuel are 80° F. That the specific heat of products of combustion by weight is ·27. That the specific heat or vapour of water by weight is ·85.

In the foregoing table the loss of heat caused by the conversion into steam of the water formed by the combustion of the hydrogen has been deducted, and column 4 gives the units of heat diminished to this extent. This mode of computation is necessary, as the waste heat is discharged into the chimney at a temperature so high as to preclude the condensation of any vapour of water.

The maximum temperature given for the products of combustion of coal is lower than that given in some treatises. This arises from the heat being diffused not only among the air *chemically* necessary to furnish the oxygen from the complete combustion of the megass, but also the surplus which is actually required in practice. The figures here presented may be accepted as nearly correct, and are strictly comparable with those relating to megass.

Defibrators.—The imperfect liberation of the cane-juice by the crushing process of the ordinary mill has led to experiments in other directions. One result has been the invention of machines for effecting a more thorough mechanical disintegration of the cane tissue.

The defibrator (*défibreur*) invented by Mignon et Rouart is arranged on the principle of their machine for crushing straw into pulp for the manufacture of paper. The cane is reduced to a pulp, and, by subsequent pressure, 77 per cent of juice is said to be separated.

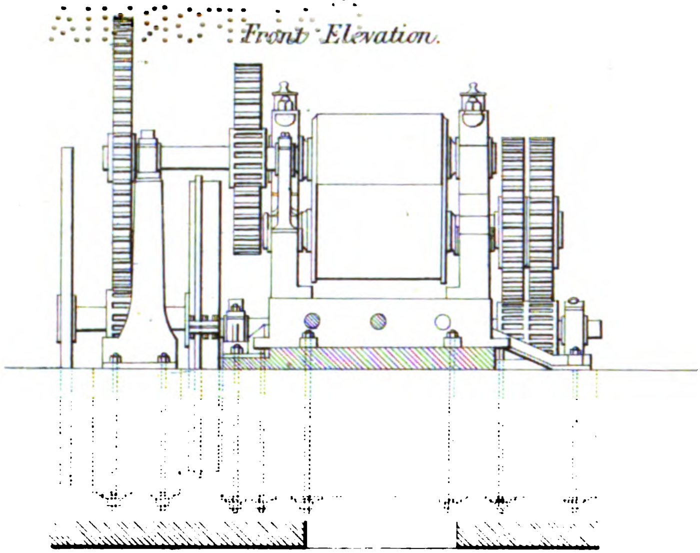
In the crushing machine, the cane is fed into a cast-iron cylinder 17 inches in diameter, where it is cut up by a series of double-pointed or triple-pointed cutters, arranged helically, and fixed on a horizontal revolving shaft. These co-operate, in the manner of shears, with three series of blades fixed to the interior surface of the cylinder, and by the combined action of the opposing series of blades, the cane is completely broken up, and is at the same time passed through the cylinder by the screw-like action of the revolving cutters. The pulp is discharged from the other end of the cylinder into a hydraulic press, where it is subjected to a pressure of 80 atmospheres, for the separation of the juice.

The press is constructed with a differential piston or plunger, of two diameters, 39⅝ inches and 16 inches. The pressure is applied, first, to the smaller piston, the force of which is sufficient for expressing the greater portion of the juice. When the piston arrives within an inch or two of the end of its traverse, the pressure is applied to the annular area of the larger piston, in addition, when the "hard pinch," as it may be called, is applied to express the juice which remains in the pulp. The filter consists of three cylindrical receptacles, 20 inches in diameter, which are filled with pulp, and are presented in rotation to the ram, which is formed as a prolongation of the plunger. The receptacles are formed by a series of rectangular bars placed circularly and nearly in contact with each other. Through the very small crevices between the bars, the juice is forced, whilst the begass or cake is dropped out below.

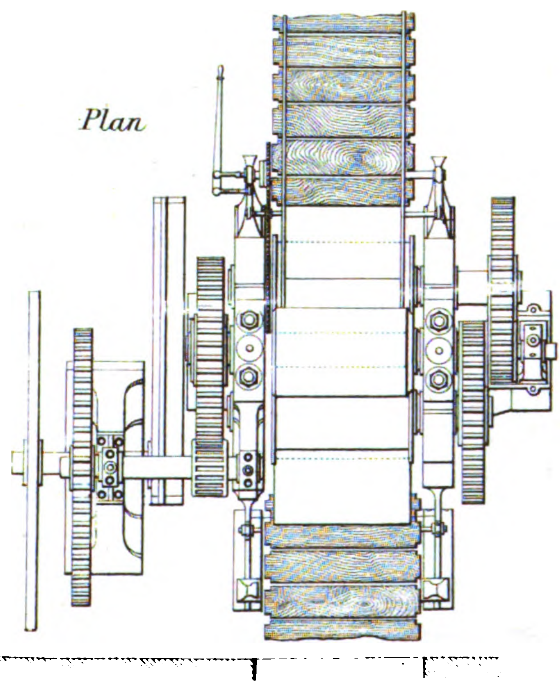
With these machines, when the crusher makes 30 to 40 revolutions a minute, 30 to 60 tons of sugar-cane may be treated in a day of 24 hours. The machinery is in operation in Guadeloupe, and the following figures have been given concerning it :—

Work done by the Crusher.				Work done by the Press.			
Weight of Cane crushed.	Time of Operation.	Work in 24 hours.	Number of Revolutions of Crusher.	Weight of Cane pressed.	Time of Operation.	Weight of Juice.	Density of Juice.
lb.	minutes	tons		lb.	minutes	lbs.	° B.
220	5	28·6	30	220	6	154	10·00
220	4	35·8	30	220	6	160	10·00
440	7	40·7	30	661	12 to 15	500	7·50
2645	30	57·3	40	693	,,	528	8·75
881	11	52·0	35	168	,,	253	10·00
1322	14½	58·5	40	440	,,	338	8·00

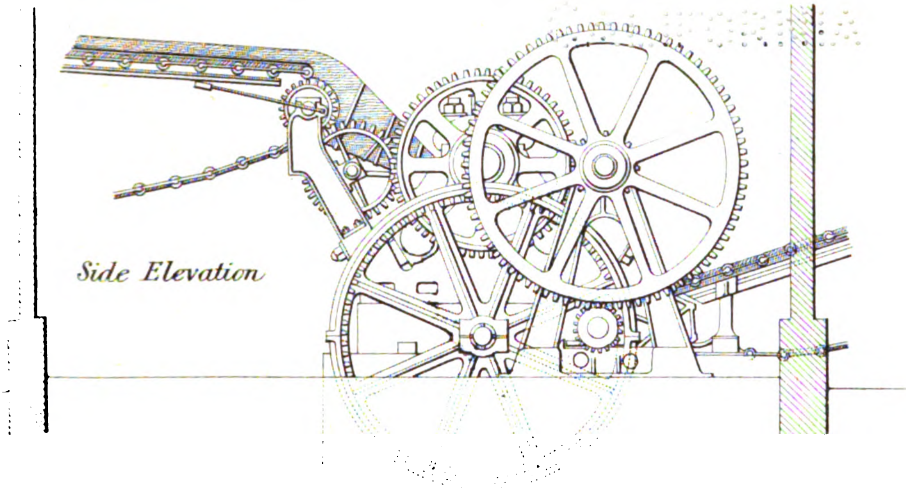
Front Elevation.



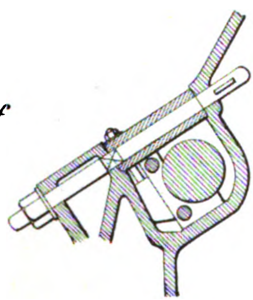
Plan



E & F N. Spon, London



Detail of Bearing



ABA-EL WAKF SUGAR FACTORY

THREE ROLLER CANE MILL.

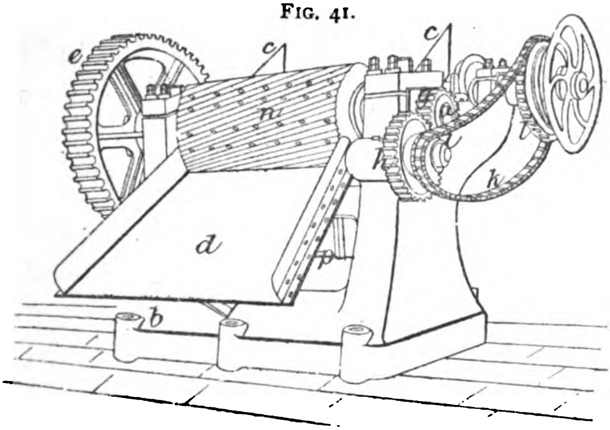
Scale: ¼ Inch = 1 Foot.

& New York

The machinery sent to Guadeloupe can crush 59 tons of cane per diem. Simply crushed and submitted to one pressing, the cane is said to have afforded 77 per cent. by weight of very rich juice, the begass when crushed further yielding 25 per cent. of its weight.

The defibrator invented by P. Faure, of Paris, and made by Manlove, Alliott, Fryer, & Co., of Nottingham and Rouen, is shown in perspective view in Fig. 41, and in horizontal

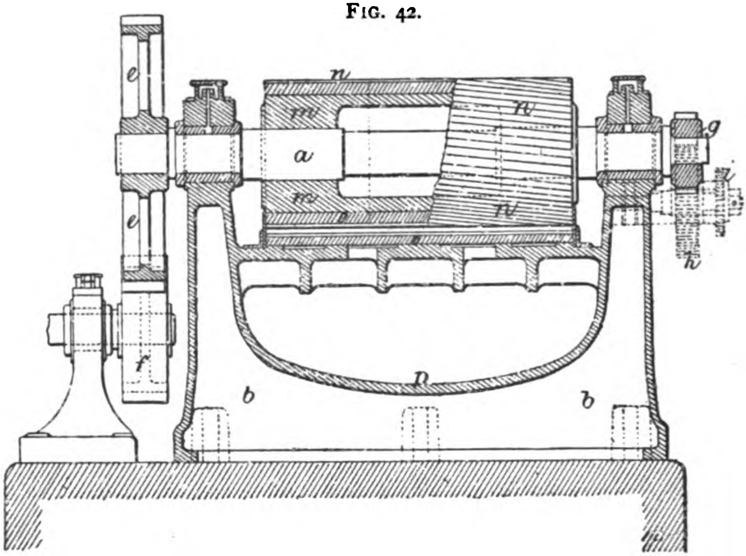
FIG. 41.



Faure's Defibrator.

section in Fig. 42. The description of the figures is as follows :—*a* is a shaft carrying a drum or cylinder, whose surface is provided with teeth, running preferably in a helical direction, and which may be cast on, attached, or cut out of the solid; *b*, a strong frame; an articulated cane-carrier (not visible in the figures) receives its motion from the defibrator itself, and is capable of being put in and out of gear at will; *c*, inclined plane bringing the canes in front of the drum of the defibrator; *d*, inclined plane for withdrawal of the defibrated canes, conducting these canes on to the cane-carrier which carries them to the ordinary cane-mill; *e*, strong spur-wheel fixed to one end of the shaft *a*, and receiving motion from the motor by a pinion *f*; *g*, pinion fitted to the other end of the shaft *a*, and communicating movement to another spur-wheel *h*, in front of or behind which is placed another

FIG. 42.



Faure's Defibrator.

toothed wheel *i* for a pitch-chain *k*; *l*, another toothed wheel for pitch-chain fixed to the axis of the cane-carrier; *m*, drum of polygonal form keyed on to the shaft *a*, and to which are attached the toothed plates *n*, which serve to defibrate the cane. The teeth of these plates may be straight, and form eccentric cams, but they are made preferably to run in a helical direction, and to the toothed surface a perfectly cylindrical form is given. *o* is a double lower counter-plate, formed of two distinct parts, eccentric to the axis of the drum; the front counter-plate is on the feed side, where the opening is wider, and its teeth project in the same direction as those of the drum, although inclined inversely; the object of these helical teeth is to rectify the position of those canes which are presented too much in an endwise direction; the back counter-plate or working counter-plate at the outlet side has teeth which project in a direction opposed to those of the front plate. It is this working counter-plate which effects the defibration of the canes, which it arrests and rolls upon, crushing them under the pressure of the teeth of the drum.

The small quantity of juice which results from the defibration passes through small interstices or holes in the counter-plates, into the channel *p* provided underneath these plates, whence it is conducted by suitable orifices and pipes to the juice expressed by the cane-mill.

The canes in their natural state are fed by hand or by the carrier broadside-on upon the inclined plane *c*, which conveys them in front of the defibrator. The canes fall into the opening of the defibrator, which is always equally set. Carried away by the teeth *n* of the drum *m*, they are soon pressed against the helical teeth, which are inclined in a direction contrary to those of the first counter-plate, and rectify the position of any canes which might be presented to these teeth in a too endwise direction. The canes are carried on to the back counter-plate, with teeth in an opposite direction, where they are crushed, defibrated, and finally delivered on to the inclined plane *d* in the form of a long fibrous broom. By making the bearings of the shaft *a* to slide, or simply by arranging screws or wedges under the counter-plates, the space in which the cane is crushed may be increased or reduced at will.

The object of this machine is not to supersede the ordinary cane-mill, but merely to prepare the cane for it, by breaking up the fibres and knots lengthwise. It is stated that by its use, the yield of juice from the canes has been increased from 70 or 71 per cent. to between 78 and 82 per cent.

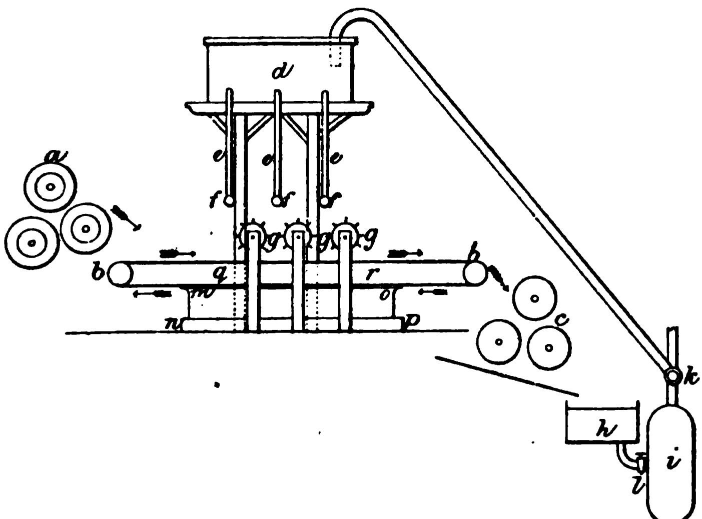
Maceration.—It has been sought to facilitate the extraction of the juice from the cane by submitting the cane to the action of water or steam, either before the crushing operation in the roller mill, or at an intermediate stage between two such crushings. It seems to be an undecided point whether the saturation or the extra crushing should be credited with the increased yield of juice. Probably both assist; but it has been proved that the return of juice is raised from 60 per cent. to 75 per cent. by previously slicing the canes longitudinally, without any application of water or steam.

In this connection, it may be mentioned on the authority of the late Col. T. P. May, a well-known American author, who was at one time a large sugar-planter in Louisiana, that auxiliary mills (double crushing) have given highly satisfactory results in Louisiana. These mills have been erected by Leeds & Co., for many years the largest makers of sugar machinery in that state. Five rolls are the number adopted by this firm, and, on the Poydras plantation, one of these mills yielded the unusual result of 126 lb. of sugar from 1 ton (2000 lb.) of canes. This quantity probably refers only to first sugars, and does not include seconds,—thirds are rarely made in Louisiana,—and in any case omits the sugar contained in the molasses. This last item is important, as Louisiana molasses is so highly esteemed in the United States for table use, and brings such a good price, that there is no inducement to reduce its sugar to a minimum.

Several methods have been devised for carrying out the saturating process on a practical scale, among which the most important are (1) Duchassaing's, and (2) the combined invention of W. Russell and G. W. Risien, of Demerara. They are generically known as "maceration" or "imbibition" processes.

The apparatus employed in Duchassaing's process is shown in Fig. 43. The mill *a* receives the canes and crushes them, giving 68 per cent. of juice. The begass falls upon an endless cloth *b*, which conducts it to a second mill *c*; *d* is a tank containing boiling water; *e* are tubes terminating in pipes *f* parallel to the endless cloth, which sprinkle water from the tank *d* upon the begass passing from the first to the second mill; *g* are beaters which turn the begass and thus equalise the imbibition; *h* is a tank which receives the juice from the mill *c*; *i* is a *monte-jus* which sends this juice, if its density is not sufficiently great, into the tank *d*, to serve for a second

FIG. 43.



Duchassaing's Macerator.

maceration of new begass, or, if it is dense enough, by the joint *k* to the defecation. The endless cloth *b* dips so that the portion between *q r* immerses the begass in boiling water contained in the vessel *m n o p*, thus increasing the maceration. Since the apparatus has come into extensive use, it has been simplified by dispensing with the beaters *g* and the vessel *m n o p*. This system raises the yield of sugar from 9·40 per cent. on the cane to 11·04 per cent.; it received an award of 4000*l.* from the General Council of Guadeloupe in 1876.

In Russell and Risien's process, 2 mills are used, and they are connected by an intermediate chamber, in which runs an endless band or other suitable contrivance for carrying the partially exhausted canes from the first to the second mill for further treatment.

The mills may be placed at a distance of 30 feet (more or less) apart; and the chamber, extending from mill to mill, is in the form of a shoot or covered trough. Inside the chamber, and near the top, is placed a system of perforated piping, by which cold or hot water or cane-juice may be thrown, in a spray, upon the partially-exhausted canes; and between the endless band is placed a second series of perforated pipes, used to drive steam through the endless band, and, mixing with the water or cane-juice, saturate the partially-exhausted canes. The juice from the first mill, after passing through a sulphurous gas churn, is forced through a set of combined juice-heaters and water-traps, and the condensed water and steam from the water-traps is conducted to the piping before described at the top of the chamber for saturating purposes. The begass, being conducted from the first mill to the second by the endless band, is thoroughly saturated by this condensed water, and is further treated by steam from the lower pipes passing up through the band, which steam also serves to cleanse the band. When the begass reaches the second mill, the water that it has absorbed by saturation is expressed from it, and carries with it the soluble matters contained in the cells of the cane. The begass is carried away from the second mill for fuel or manure.

The juice obtained by this second treatment is carried through a separate set of juice-heaters, heated by the exhaust steam from the engine driving the second mill. This juice, after passing through the heater, may be mixed with the juice from the first mill, or it may be conducted into the piping in the chamber and used for saturating the begass as it circulates, thus absorbing a larger proportion of saccharine matter; it is eventually conducted, when of sufficient strength, to augment the supply from the first mill.

In some cases, the juice from the second mill is sent direct into a second set of clarifiers, mixed with scums and other washings of sugar works, treated with an excess of lime, and afterwards by carbonic acid gas. The juice and washings at this stage must not exceed 5° B. in richness.

The juice, after "carbonation," is decanted and mixed with the juice from the first mill, and made direct into "first" sugar, or mixed with the molasses from the first boiling to make a superior "second" sugar, as, in the present method of making "second" sugar, a large quantity of water has to be used in diluting the molasses before boiling. The residue, after decanting, may be forced through filter-presses, so as to deprive it of all juice.

It is claimed for this system that, by an addition of water equal to 50 per cent. of the original cane-juice, a gain of at least 25 per cent. on the sugar now extracted from the cane by the most improved mills is obtained; that is to say, if the original cane-juice is 100 gallons, and there are added 50 gallons of water by saturating the begass in its transit from the first to the second mill, the result will be 50 to 60 gallons of additional juice, which in richness is equal to at least 25 gallons of the original juice.

The apparatus is illustrated in Figs. 44, 45, and 46.

Fig. 44 shows a side elevation of the first cane-mill, saturator, first juice heater, second cane-mill, first heater for second juice, and second heater for second juice; Fig. 45 is a plan of Fig. 44; Fig. 46 shows the details of the saturator box. The first mill *a* and second mill *b* are about 45 feet apart from centre to centre; *c* is the chamber connecting the mills, and provided with man-holes; *d* is an endless band to carry the canes from the first to the second mill; *e* is the first system of perforated piping by which water or cane-juice may be thrown upon the canes; *f* is the second series of perforated pipes placed under the endless band *d*; *g* is the first cane-juice heater; *h*, sulphur box; *i*, first heater for second juice from the mill *b*; *k*, second heater for second juice; *l*, elevator for finished begass; *m*, gutter from first mill to sulphur box; *n*, first juice liquor pump; *o*, second juice liquor pump; *p*, first pump valve box; *q*, second pump valve box; *r*, pipe carrying

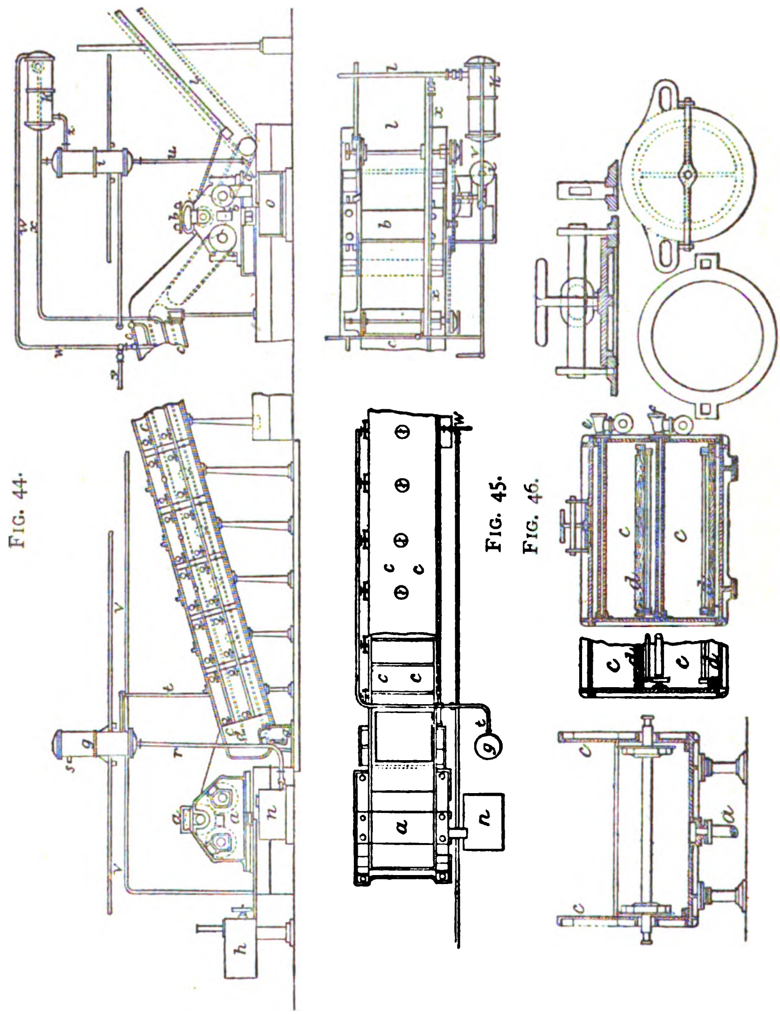


FIG. 44. FIG. 45. FIG. 46.

Russell and Risien's Maceration Plant.

first juice to heater *g*; *s*, pipe leading to clarifier; *t*, supply pipe for hot water to upper saturator supply pipes; *u*, pipe carrying second juice to heater *h*; *v*, connecting pipe between heaters *h i*; *v'*, pipe for delivering second juice into gutter of sulphur box; *w*, pipe, with cock attached, to deliver second juice into the upper range of saturator supply pipes; *x*, pipe for supplying the lower range of saturator supply pipes with steam or water; *y*, pipe conveying condensed steam and water to heater *h*; *z*, exhaust steam pipe from engine; *a'*, pipe for carrying away the water or water and juice that may collect in the chamber *c* during the saturation of the begass; cocks regulate the distribution of water or steam from the pipes *e f*; the endless band *d* consists of chains, lateral bars, and wire meshwork.

The method of operation is as follows:—The partially-exhausted canes, upon being delivered from the first mill *a*, are carried by the endless band *d* for further treatment by the second mill *b*. During their passage through the chamber *c*, they are subjected to a spray of hot water from the pipes *e* (cane-juice may be used), and to a jet of steam or water from the pipes *f*. The juice obtained by the treatment in the first mill *a* passes through the sulphur box *h*, and is afterwards forced through the juice-heater *g*, and then to the clarifier. The condensed water from the heater *g* passes through the pipes *t e*, and is used for saturating the canes in their passage through the chamber *c*, the canes being further treated by jets of steam or water from the pipes *f*. This saturation dissolves the crystalline matter resident in the cells of the canes. The canes then pass through the second mill *b*, which expresses the juice caused by the saturation. This second juice falls into the second liquor pump *o*, and is forced through the heaters *i k*. The second juice thus obtained may be passed through the pipe *v'* to join the first juice, and thence to the clarifiers; or it may pass through the pipe *w* into the upper pipes *e* to saturate the canes; or it might be sent direct to a second set of clarifiers from the heater *k*.

An account of the working of this process will now be given, premising that the figures must be taken for what they are worth, as no means exist for checking them.

The machinery described was worked for 32 days; the output in that time was 400 hhds. of sugar and 200 puncheons of rum, the quantity of mixed juices dealt with having been 859,600 gallons. The first juice polarised from 88° to 96°; the average of the mixed juices was 80°. On this basis, the yield of sugar should have been 1,124,356 lb. The actual yield was—

400 hhds. sugar × 1860 lb. each	=	744,000 lb.
200 puns. rum × 17 lb. a gallon	=	340,000 ,,
		1,084,000

The loss therefore amounted to 3·59 per cent.

A trial made on another estate gave the following result:—

Canes carefully weighed	8104 lb.
Begass ,, ,, ...	2475 ,,
Yield of juice	5629 ,,

or 69·45 per cent. of the canes operated upon; the juice polarised 98°, which gives a corresponding specific gravity of .. .. 10·6023

Add albumen and other extracts	0·1600
Weight per gallon	10·7623

$$\frac{5629}{10\cdot76} = 523 \text{ gallons} \times 98^\circ \times 0\cdot01635 = 838 \text{ lb. sugar.}$$

or 10·34 per cent. extracted of polarisable sugar.

The above canes weighed	8104 lb.
Deduct ligneous matter	810 ,,
Juice	7294 ,,

100 cc. weighed 106 grammes by polariscopic indication,
add 1·6 albumen, &c.

107·6 total weight.

7294 ÷ 10·76 = 677 gallons × 98° × 0·01635 = 1084·75 lb. of sugar in above canes, or .. .. 13·38 per cent.

Extracted as above	10·34 ,,
Left in begass	3·04 ,,
Taking juice in cane	7294 lb.
Do. extracted	5629 ,,
Left in begass	1665 ,,

1665 ÷ 10·76 = 154·7 gallons;
154·7 ÷ 24·75 lb. begass = 6·2 gallons of juice left in every 100 lb. begass.

To trace this loss to 100 lb. of begass, 100 gallons of water were added, and the begass thus saturated was thoroughly infused in a close vessel; when the liquor of saturation was tested by polariscope, it gave a reading of 6°, ∴ 106·2 × 6° × 0·01635 = 10·42 lb. of sugar left in 100 lb. begass, as against 6·2 gallons × 98° × 0·01635 = 9·93, showing that the juice left in the begass was quite as rich as the original cane-juice.

10·42 × 24·75 cwt. begass = 257·8 lb. sugar remaining unextracted out of 8104 lb. canes, or $\frac{257 \cdot 8}{8104}$ = 3·18 per cent., as against 3·04.

Some further trials may be summarised as follows:—

FIRST TRIAL.

12208 lb. canes
   60 per cent. 1st crushing
———
7324·80 lb. cane-juice
1208 lb. canes
———
4883 ,, begass and cane-juice
3662 ,, water added to equal juice left in begass
———
8545 ,, material going to 2nd mill
3270 ,, begass and 2nd juice sent to logie
———
2)5275 ,, water and juice obtained by 2nd grinding
———
2637 ,, juice equal to 1st
7324 ,, juice extracted by 1st mill
———
9961 ,, juice totally extracted
9961 ,, from 12,208 lb. gives
81·59 per cent.

100 lb. canes
10 ,, fibre
——
90 ,, juice.
60 per cent. 1st crushing
——
30 lb. left in every 100 lb. canes
12,208 lb. × 30% = 3662 lb. left in begass; and as every 100 lb. of canes operated on sent to the begass logie 26·79 per cent. (the difference between 100 and 73·21), we have sent to the begass logie 12,208 lb. × 26·79 = 3270 lb. of begass and 2nd juice.

The polarisation of original juice in this trial was 94·6°, and the corresponding specific gravity therefore .. .. 10·546
Add albumen and other extracts .. .. 0·160
———
Weight per gallon .. .. 10·706

9961 ÷ 10·70 = 931 gallons × 94·6° × 0·01635 = 1439 lb. sugar, or 11·79 per cent.

Canes as above	12208 lb.
Deduct ligneous matter	1220 ,,
Juice	10988 ,,

10988 ÷ 10·70 = 1027 gallons × 94·6° × 0·01635 = 1588 lb. sugar in 12208 lb. cane, or 13·01 per cent.

Extracted as above 11·79 ,,

Left in begass .. 1·22

Taking juice in cane	10988 lb.
Extracted	9961 ,,
Left in begass	1027 ,,

1027 ÷ 10·70 = 96 gallons ÷ 3270 lb. begass = 3 gallons of original juice left in every 100 lb. begass, together with 3 gallons of water, the proportion added in its reduction to second juice.

To trace again the sugar unextracted, 100 lb. of the begass were taken as before and infused with 100 gallons of water, the liquor of saturation when tested polarising 2·2°.

6 gallons solution in 100 lb. begass
100 ,, water

106 × 2·2° × 0·01635 = 3·81 lb. sugar left in 100 lb. begass, as against 3 × 94·6° × 0·01635 = 4·64.

3·81 × 32·70 cwt. begass = 124·58 lb. sugar remaining unextracted out of 12208 lb. canes, or $\frac{124 \cdot 58}{12208}$ = 1·02 per cent., as against 1·22.

SECOND TRIAL.

8943 lb. canes
60 per cent. 1st crushing

5365·80 lb. cane-juice
8943 lb. canes

3578 ,, begass and cane-juice
2682 ,, water added to equal juice

6260 ,, went to 2nd mill
2354 ,, begass and 2nd juice sent to logie

2)3906 ,, water and juice obtained by 2nd crushing

1953 ,, juice equal to 1st
5365 ,, extracted by first mill

7318 ,, juice totally extracted
8943 : 100 : : 7318 = 81·82 per cent.

100 lb. canes.
10 ,, fibre.

90 ,, juice.
60 per cent. 1st crushing

30 lb. juice left in every 100 lb. canes

8943 lb. × 30 % = 2682·9 lb. juice left in begass; and as every 100 lb. of canes operated on sent to the begass logie 26·33 per cent. (the difference between 100 and 73·67), there were sent to the begass logie 8943 lb. × 26·33 = 2354 lb. of begass and second juice.

The polarisation of original juice in this instance was 94°, and a consequent density of .. .. 10·5369
Add albumen and other extracts .. .. 0·1600

Weight per gallon .. .. 10·6969

7318 ÷ 10·69 = 684 gallons × 94° × 0·01635 = 1051 lb. sugar, or 11·75 per cent.

Canes as above	8943 lb.
Deduct ligneous matter	894 ,,
Juice	8049 ,,

8049 ÷ 10·69 = 752·85 gallons × 94° × 0·01635 = 1157 lb. sugar in 8943 lb. cane, or .. .. 12·93 per cent.

Extracted as above	11·75 ,,
Left in begass	1·18 ,,
Taking juice in cane	8049 lb.
Extracted	7318 ,,
Left in begass	731 ,,

731 ÷ 10·69 = 68 gallons ÷ 2354 lb. begass = 2·90 gallons of original juice left in every 100 lb. begass, together with 2·90 gallons of water, the proportion added in its reduction to second juice.

To trace as before the sugar unextracted, 100 lb. of the begass was infused with 100 gallons of water, the liquor of saturation when tested polarising 1·6°.

5·80 gallons solution in 100 lb. begass
100·00 ,, water

105·80 × 1·6° × 0·01635 = 2·76 lb. sugar left in 100 lb. begass, as against 2·90 × 94° × 0·01635 = 4·45.

2·76 × 2354 cwt. of begass = 64·97 lb. sugar remaining unextracted out of 8943 lb. of canes, or $\frac{64·97}{8943}$ = 0·72 per cent., as against 1·18.

So much for the decreased loss of sugar in the begass. There remain for consideration the questions of fuel and increased labour. With regard to the fuel, it must be remembered that in addition to the extra yield of juice from the cane, there is about 480 gallons of water for every hhd. of sugar. This will represent a total of 7000 lb. of water to evaporate, requiring about 11 cwt. of coals. At the same time, the heating power of the begass has been reduced. The additional manual labour is said to be covered by 32 cents (1*s.* 4*d.*) per hhd.

The relative cost of coal and value of sugar in imperfectly exhausted begass may be approximately stated as follows:—

1. The contents of 100 lb. of canes are:

10	lb.	begass
2	,,	refuse
15	,,	sugar
73	,,	water

Therefore, if all the juice of the cane were extracted, about 5 lb. of water would have to be evaporated for each 1 lb. of sugar contained in the cane; and there are 10 lb. of begass for the evaporation of 73 lb. of water.

2. The usual 60-per-cent. crushing of 100 lb. of canes gives:—

10	lb.	begass	combined.
30	,,	juice	
2	,,	refuse	
10	,,	sugar (assumed).	
48	,,	water	

In this case, 4·8 lb. of water have to be evaporated for each 1 lb. of sugar extracted; but as the 10 lb. of begass have 5 lb. of sugar left, and the quantity to be evaporated is reduced to 48 lb., the duty of evaporation is reduced from 73 to 48—at the cost of 5 lb. of sugar.

3. By the maceration process, 100 lb. of canes plus 16 lb. of water give:—

10·0	lb.	begass	combined.
8·0	,,	water	
13·5	,,	sugar (assumed).	
2·0	,,	refuse	
82·5	,,	water	

Here, 6 lb. of water (the theoretical duty of 1 lb. of coal) have to be evaporated for each 1 lb. of sugar; the 10 lb. of begass have still 1·5 lb. of sugar, and the water to be evaporated is increased to 82·5 lb. The additional water to be evaporated is then 34·5 lb. in excess of No. 2, as against a gain (assumed) of 3·5 lb. of sugar. Taking the water at 36 lb. in round numbers, this being the evaporative duty of 6 lb. of coal, the comparison is reduced to 6 lb. of coal *versus* 3·5 lb. of sugar. For comparison, the relative values may be assumed thus:—

3½ lb. of sugar at 5 cents (2½*d.*)	=	17·5 cents
6 ,, coal at 6½ dollars (27*s.*) per ton		1·8 ,,
Difference in favour of coal		15·7 ,,

This is the saving on each 100 lb. of canes by using the maceration process. Taking 10 tons of canes as the quantity required to make a hhd. of sugar, the saving per hhd. amounts to 35 dollars 16 cents (or 7*l.* 6*s.* 6*d.*). From this, must be deducted the interest on extra plant, wear and tear, and increased labour. It would appear from numerous statements that the total extra cost of procuring the extra yield of sugar is about 50 per cent. of the value of the extra sugar.

Some experiments on the comparative merits of maceration and ordinary processes were conducted by Fahlberg with a threefold object, and his statements reveal:—(1) The additional yield of juice, (2) the additional expenses per hdd. (of 1800 lb. nett) of begass sugar (i. e. 2nd extraction), and (3) the relative profit afforded by a hhd. of begass sugar and one of ordinary 1st extraction sugar.

The additional yield of diluted juice from the second mill was 10 per cent., which, added to 60 per cent. from the first mill, gives 70 per cent. as the collective return from 100 lb. of canes, the second mill thus giving an increase on the return of juice of 16·66 per cent. In 100 gallons of maceration juice, density 1·035, were 50 gallons of added water, which, deducted, left 50 gallons of original juice, density 1·07.

To arrive at the additional expenses for making 1 hhd. (of 1800 lb.) of begass sugar, it was necessary to conduct a double experiment—to watch the making of the single crushing sugar in one building, and the maceration juice in another, keeping a separate account of each (called respectively *a* and *b*), *a* juice density being 1·07, and *b* 1·035.

To make 12 hhds. (of 1800 lb. nett), took for *a* 24,000 gallons original juice; for *b*, 48,000 gallons diluted juice. The invested capital in plant may be put down thus: *a* at $100,000 (20,833*l.*); *b*, with maceration machinery, $150,000 (31,250*l.*). In each building were kept (1) a fuel account, (2) a labour account, and (3) an interest account.

1. Fuel Account.

a has 24,000 gallons original juice, density 1·07 (cold), and 2400 gallons of *masse-cuite*, density 1·48 (cold).

24,000 gallons of juice	=	256,800 lb.	juice.
2,400 ,, *masse-cuite*	=	35,520 ,,	*masse-cuite*.
Leaving		221,280 ,,	of water to evaporate.

If 1 lb. of coal evaporates 4 lb. of water ($\frac{2}{3}$ of the theoretical effect), 221,280 lb. water ÷ 4 = 55,320 lb. = 24·7 tons of coal.

To work a cane engine producing 24,000 gallons of juice, will require 4 tons of coals, which, added to the coals used in evaporation, make 28·7 tons of coals ÷ 12 = 2·4 tons per hhd., and at $8 (33*s.* 4*d.*) per ton, this is $19 20 (4*l.*) per hhd. fuel expenses.

b has 48,000 gallons of diluted juice, density 1·035, and 2400 gallons of *masse-cuite*, density 1·48.

The 48,000 gallons of juice	=	496,800 lb.	of juice.
The 2,400 ,, *masse-cuite* ..	=	35,520 ,,	*masse-cuite*.
Leaving		461,280 ,,	water to evaporate.

which, by the same calculation as in the case of *a*, will take 51·4 tons of coals.

To work two cane engines making 48,000 gallons of begass juice will require 8 tons per day, which, added to the fuel for evaporation, make 59·4 tons per day, or 4·9 tons per hhd., the total cost of the coals, at the same rate as above, being $39·2 (8*l.* 2*s.* 6*d.*) per hhd.

The average quantity of dry begass on an estate in Demerara (non-maceration) from 100 tons of cane, the crushing giving say 60 per cent. of juice, is :—

5·66	per cent. of	sugar, organic matter, and soluble salts.
10·00	,,	cellulose and some silicates.
15·66	,,	in all.

An average quantity of dry begass (maceration) from the same quantity of canes, the crushing giving 70 per cent., is :—

3·77	per cent. of	sugar, organic matter, and soluble salts.
10·00	,,	cellulose and some silicates.
13·77	,,	in all.

2. Labour Account.

Per day.	*a.* One cane mill. $ c.	*b.* Two begass mills. $ c.
Engine drivers	0 84	1 60
Boys	0 24	0 48
Feeding mill	0 96	—
Taking away begass	0 48	0 96
Liquor pump and cush-cush	0 48	0 96
Clarifiers	1 20	1 92
Subsiders scum	0 56	0 80
Boilermen (copper wall)	5 96	11 92
Syrup tanks	1 08	1 08
Firemen	1 12	2 24
Boiler feeding	0 92	1 64
Vacuum-pan boiler	1 50	1 50
Assistant	0 48	0 48
Sugar curing and packing at 80 cents a hhd.	9 50	9 60
Freight to Georgetown, at $1 per hhd.	12 00	12 00
Commission to merchants at 1 per hhd.	12 00	12 00
Weigher's fee	1 20	1 20
Engineer at the vacuum-pan engine	0 48	0 48
Overseers in the buildings	3 00	5 00
12 :	$54 10 (11*l.* 5*s.* 5*d.*)	64 86 (36*l.* 10*s.* 3*d.*)
Per hhd.	4 50 (18*s.* 9*d.*)	5 40 (22*s.* 6*d.*)

3. Interest Account.

a capital invested is..	$100,000 00	
Interest at 5 per cent. (estate making 1200 hhds.), per hhd.	4 17	(17*s.* 5*d.*)
b capital invested is..	$150,000 00	
Interest as above, per hhd.	6 26	(26*s.* 1*d.*)

The relative profits from begass and cane sugars are as follows:—

a fuel expenses per hhd. sugar were $19 20, less value of begass* as fuel $8 90	$10 60	
Labour	4 46	
Packages	5 0	
Oil, &c., &c.	0 16	
Interest on capital	4 17	
Total expenses	$24 39	(5*l.* 1*s.* 6*d.*)
b fuel expenses (coals only) per hhd.	$39 20	
Labour	5 30	
Packages	5 0	
Oil, &c., &c.	0 24	
Interest on capital	6 26	
Total expenses	$56 09	(11*l.* 13*s.* 8*d.*)

The above calculation deals only with the manufacture of sugar. The distillery and field expenses of both estates will be:—

a manufacturing expenses per hhd. are	$24 39	
Rum (42 gallons)	7 0	
Field and other estate expenses	60 0	
Total	$91 39	(19*l.* 9*s.*)
b manufacturing expenses per hhd. are	$56 09	
Rum (42 gallons)	7 0	
(No field and other expenses)		
Total	$63 09	(13*l.* 2*s.* 10*d.*)

The general expenses of a maceration plant—first mill, maceration, and second mill (the first mill expressing 60 per

* Two tons of begass = 1 ton of coals. From 200 tons cane (maceration), are got 27·54 tons daily = 13·77 tons coals, which, at above cost of $800, is $110 16; deducting packing, &c., of begass, $7 00, this leaves $103 16, or $8 60 per hhd.

cent.), are, for one hhd. (1800 lb.) of cane and begass sugars (85·7 cane and 14·3 begass), as follows:—

Fuel, with consumption of begass per hhd.	$14 68
Labour	4 59
Packages	5 00
Oil, &c., &c.	0 17
Interest on capital, say 5 per cent...	4 35
Cost of manufacture	$28 79
Rum (42 gallons)	7 00
To 85·7 per cent. reduced field expenses from $60 ..	51 42
Total expenses per hhd.	$87 21 (18*l.* 3*s.* 4*d.*)

1200 hhds. cane sugar .. .. .. }
500 puns. rum, 40 o.p. .. .. } at 91·39 $109,668 (22,847*l.* 8*s.* 4*d.*)

For a whole crop, made with maceration, producing 16·66 begass sugar, the expense would be, say:—

200 hhds. begass sugar, same quality as cane sugar .. ..
88·33 puns. rum, 40 o.p. same quality .. .. } at 63·09 .. $12,618 (2628*l.* 15*s.*)

Total $122,286 (25,476*l.* 3*s.* 4*d.*)
or an average of $87 34 (18*l.* 3*s.* 11*d.*) per hhd.

For a non-maceration estate, canes being equal, the total expenses would be:—

1200 hhds. cane sugar .. .. .. }
500 puns. rum, 40 o.p. .. .. } at 91·39 .. $109,668 (22,847*l.* 8*s.* 4*d.*)

or an average per hhd. of $91·39 (19*l.* 0*s.* 9*d.*), the difference in favour of maceration being $4·05 (16*s.* 10*d.*) per hhd., which on a crop of 1400 hhds. sugar and 583·33 puns. rum 40 o.p., would be $5670 (118*l.* 5*s.*), exclusive of 14·30 per cent. of "crop profit" over $127,956 (26,657*l.* 10*s.*), which is to come into account for 200 hhds. of begass sugar, with the complement of rum.

Diffusion.—All the processes described in the foregoing pages for extracting the juice from the cane have depended for success upon the more or less complete *rupture* of the cells containing the juice. The process now to be considered, and which is known as "diffusion," differs from them essentially, in dispensing with the breaking-up of the cells.

To explain this system, it is necessary to review the characters and properties of the several bodies composing cane-

O 2

juice. The constituents and their relative proportions have already been given (see p. 106). They may be classed under two distinct groups :—(*a*) "Crystalloid," including the sugar itself and the other "salts" which are capable of assuming a crystalline form; (*b*) "Colloid" (glue-like), embracing the gummy or mucilaginous matters which are not capable of crystallisation. In cane-juice, these two classes of bodies exist in most intimate association in the cells of the plant. Now these two classes are distinguished from each other by a remarkable physical fact, which forms the basis of all modifications of the diffusion system. This fact is the difference which they manifest with regard to the power of passing through moist water-tight membranes. The bodies belonging to the series (*a*), when dissolved in water, will pass through most animal and vegetable membranes (gut, parchment, plant-cells, parchment-paper, &c.), when there is water on the other side; those belonging to the series (*b*) are not possessed of that property. This method of separating bodies is termed "dialysis," "osmosis," or "diffusion," and the membrane which effects the separation is called a "septum" or "dialyser." The dead cell-walls of the sugar-cane itself form an excellent dialyser; therefore, by cutting the cane into convenient slices, and soaking these in water, the crystalloid constituents of the juice (including the sugar) will pass through the cells and into the surrounding water, while the colloid (gummy and albuminous bodies) will mostly remain within the cells. Thus the juice is at once more or less completely purified of these gummy and albuminous matters which, as already described on pp. 115–9, are the principal sources of trouble and loss in sugar-making, and is at the same time far less contaminated with the vegetable débris resulting from the mechanical breaking-up of the cane.

The sugar-cane is said to possess a great advantage over the beetroot with regard to diffusion, in that the pectose or nitrogenous matter is so arranged, in the secondary tissues of the cell, that water at a high temperature can be employed without interfering with the diffusion process, which cannot be done with the beet without injuring the cell-membranes.

For experiment, a quantity of cane slices $\frac{1}{16}$ inch thick and 3 to 4 inches long may be placed in a vessel with about the same quantity of water, when the following changes will take place. The water will force its way through the cellular membranes into the sugar cells, displacing a portion of the saccharine solution, which will pass out of the cells, thereby diminishing the specific gravity of the juice left in the cells, and increasing that of the water outside; and this interchange will continue until the water in the vessel has attained the same specific gravity as the liquid in the sugar cells: the diffusion is then complete.

Let it be supposed for instance that the juice in the cells has a specific gravity of 1·043 (equal to 12 per cent. by saccharometer), and the surrounding water a specific gravity of 1·000. When the diffusion is complete, the water will be found to possess a specific gravity of 1·023 (equal to 6 per cent. by saccharometer), and the now diluted juice in the cells the same. Consequently the complete exhaustion of the sugar from the cells can only be accompanied by fractional diffusion, that is, by substitution for the liquid obtained another of less specific gravity (or water itself); and this replacing of the more saturated liquid by a less saturated one must be continued until the desired degree of exhaustion is reached.

What is true of cane-juice, is also true of beetroot-juice, and in fact the chief application of the diffusion process has been in the beet sugar industry, and in that section it will receive extended notice. Nevertheless, several methods of applying the system to cane sugar have been introduced, and these will now be described.

The subject may be introduced by a brief historical sketch of the development of the process.

Although borrowed from the earliest stage of the beetroot industry, it was not till 1843 that the operation of slicing was applied to the sugar-cane. It was hoped that the cane, after having been sliced, dried, and ground to powder, might be preserved long enough unchanged in this condition to allow of its being transported to Europe, where not merely the whole sugar might be extracted at once in its purest form, but the ligneous portion would furnish an inexhaustible supply of fibre for the paper market. The dried cane powder, however, became altered on the voyage, and not only did great part of the sugar disappear, but the changes consequent on its decomposition discoloured the residuary fibre. But there was one result from this trial sufficiently noteworthy. It was clear that the cane could be sliced and dried in commercial quantities, and several of those concerned in the matter determined to extract the sugar on the spot; accordingly, more than one attempt was made to carry out the slicing, and apparently every obstacle was overcome, when the building erected for the plant was, unfortunately, burned.

One of the principal difficulties hitherto had been that of drying the sliced cane; to avoid this, in 1845, Constable and Michel introduced their method on the estate of Ste. Marie, the property of Major Bouscaren, in Guadeloupe. It was as follows:—The canes, which were sliced at the rate of 1 ton in twenty minutes, fell into metallic baskets each capable of holding that amount. The baskets were moved by a central crane, and around the crane, at equal distances, were placed 6 copper vessels, adjusted to receive the baskets when filled. These copper vessels were filled to such an extent with water, that when the basket, full of sliced canes, was lowered into any one, the liquid rose to the surface. The basket No. 1, with its contents, having been thus dipped into vessel No. 1, was allowed to remain immersed till such time as the sliced canes had parted (by displacement) with a due proportion of their sugar to the water in vessel No. 1; basket No. 1 was then hoisted out by the crane, and consigned to vessel No. 2, where a second proportion of sugar was displaced ; and so on throughout the series. In the meantime, a fresh basket, full of sliced cane, was consigned to No. 1 vessel, the liquid in which abstracted a further proportion of sugar, and so on, till the contents of the first vessel were as fully saturated with sugar as the law of displacement allowed, and the slices of cane in the first basket were proportionately exhausted.

This was virtually the old system of Dubrunfaut with its defects, viz. that the water was not easily kept at a suitable temperature ; that the whole sugar was not extracted ; and that, from the time which elapsed between slicing and exhaustion, considerable changes occurred in the saccharine fluid, which affected the quantity and quality of the result. These defects in principle did not, however, of themselves contribute much to the failure of the plan ; the system broke down in the subsequent evaporation, in which the heat employed was generated entirely from gas manufactured on the spot—an operation attended with such difficulties that the trials were given up after heavy outlay. This was much to be regretted, as the slicing process had shown that a much larger proportion of the sugar could be extracted from the cane than had been hitherto done in any other mode; even the 5-roller mills which had been started with sanguine hopes, during the preceding two years, had been successively abandoned.

A system so simple and yet promising such complete results was not destined to disappear without traces. In September, 1847, Davier, apothecary in chief to the French service at Basseterre, resumed the experiments of slicing and drying the canes, at the point where they had been left off in 1845. He found that by driving off about 33 per cent. of moisture from sliced canes, they became so friable as to be reduced, without difficulty, to a coarse powder, in which the colouring matter and albumenoid principles of the cane had become insoluble in water, while the saccharine elements were crystallised unchanged, and ready for immediate solution and extraction by water, either hot or cold. The former would have been the more rapid, but he met with an objection to its use, which, if not scientific, was at least practical. The vessels he employed were of copper, and transmitted the heat so rapidly, that the attendants were constantly burning their fingers; he did not consider it worth while to take any precautions to avoid this evil, as he found cold water sufficient for the purpose, and more economical. The process he adopted was the following:—Six upright cylinders of copper, about 4 feet high and 9 inches in diameter, were so arranged as to communicate with each other, and with a reservoir of water on a higher level; they were each furnished with gauges and stopcocks; 5 of these were filled with cane powder, and the last with animal charcoal—this was merely precautionary, but not essential to the work. Water was admitted into No. 1, and retained there for 20 minutes after the gauge showed that the vessel was full; it was then passed into No. 2, and so on. In practice, it was found that, on escaping from No. 4, the water had absorbed so much sugar as to mark 22·5° B., or about the density when syrup is usually consigned to the vacuum-pan; and that the cane powder first in contact with the water, viz. that in No. 1, was completely exhausted, even to the taste, that most convenient and reliable saccharometer, and represented what it was reduced to in reality—a mass of wet sawdust. At this stage of the process, it was removed from No. 1 and replaced by a fresh portion of cane powder. As this part of the operation was performed without interrupting the duties of the other cylinders, it is clear that two of the greatest desiderata had been attained, namely, the complete extraction of the sugar in a state of purity, and that by a continuous operation.

The mechanism thus employed by Davier in September 1847, appeared to leave little room for improvement. It was submitted to and approved of by the French Government, who commissioned the inventor to repair to Paris in the ensuing month of March to take the necessary steps for erecting a set of machinery on a larger scale on the French King's estate of Tremouillant, in Martinique. Fortune seemed thus about to crown Davier's laborious and successful trials; but, before his appointed hour of embarkation arrived, cries of "*Vive la République*" were ringing throughout the French islands, and the new process was shelved.

Since that, the Hon. H. S. Mitchell has several times, in conjunction with H. Warner, repeated the process of slicing and drying the sugar-cane, with exactly similar results, namely, the extraction of all the contained sugar by displacement with cold water, in about 1 hour and 20 minutes, in the form of a pure syrup, making between 22° and 23° B.

Warner next directed his attention to the slicing of the cane, to ascertain how far he could succeed in extracting the sugar without recourse to drying the slices. After repeated trials, conducted with every precaution, he succeeded in obtaining, by displacement, a liquor making 9° B. where the original juice of the cane marked 10° B.; this was a great success, but not equal in results to the mode where the slices were dried, because there was not only an original loss in not obtaining the whole sugar, but the juice had an opportunity of becoming changed to an extent that greatly increased the quantity of uncrystallisable sugar. This latter evil may now be mitigated by the use of small doses of antiseptics in the displacing water, so as to preserve the juice unchanged throughout the process of manufacture.

Slicing machines.—The first step in the diffusion process is to reduce the canes to thin slices. A machine for this purpose, which was introduced in 1879 by A. X. H. Jouin, of Paris, and U. J. Peay, of Havre, and which has been extensively adopted in the French colony of Guadeloupe, with most satisfactory results, is shown in Figs. 47, 48, 49, and 50.

It consists of a disc, the periphery of which, formed like a truncated cone, either simple or double, is armed with a series of blades, whose inclination, combined with that of the

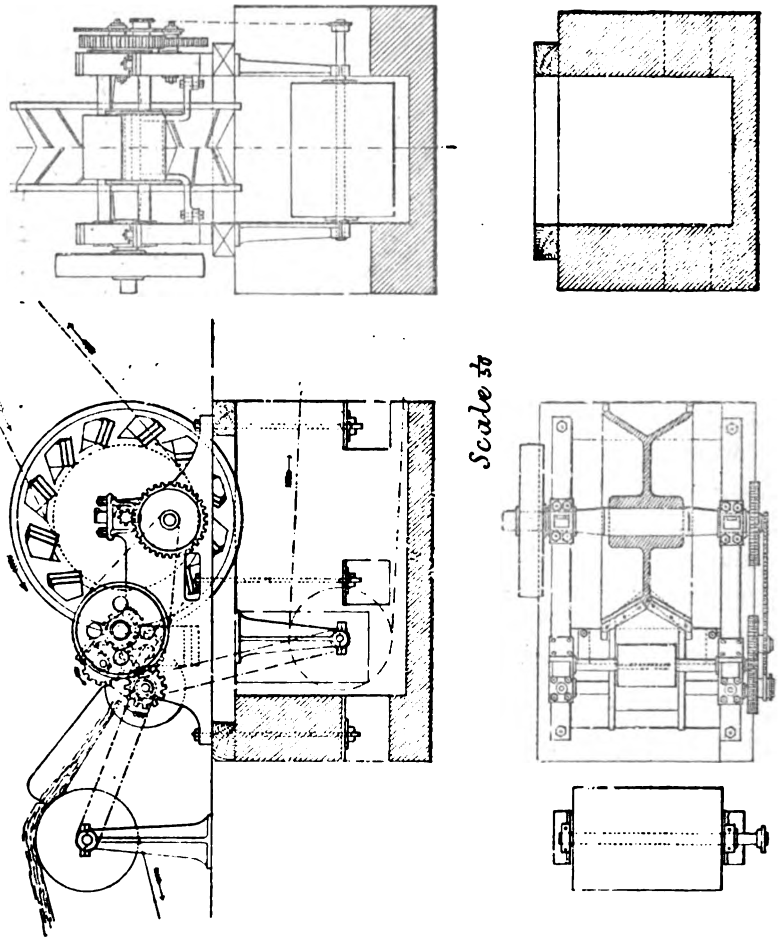


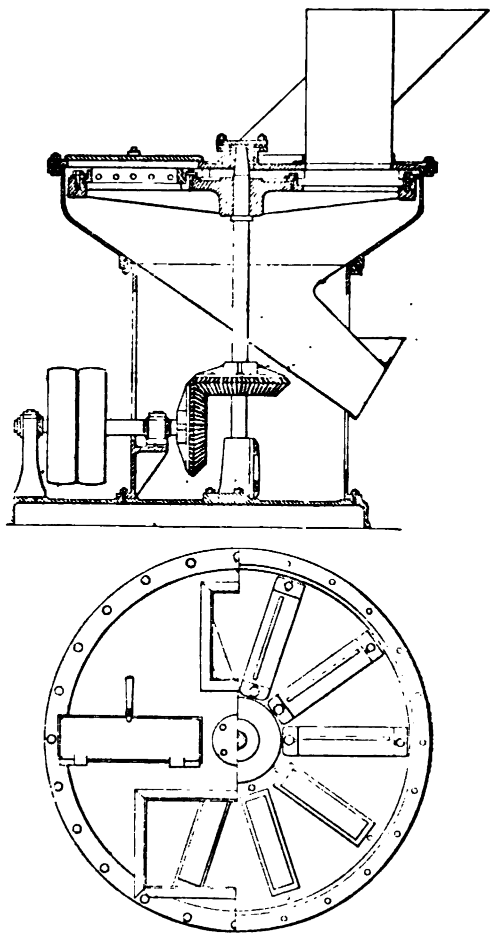
FIG. 48. FIG. 47. FIG. 50. FIG. 49.

Jouin et Peay's Cane Slicer.

periphery, is such that the sliced matters are driven by centrifugal force away from the wheel. A pair of feed-rollers, placed in front of the disc, pass forward the canes to be cut, at a speed proportioned to the capacity of the machine, and the thickness of the slices desired. The apparatus is supported on a foundation plate, which is itself fixed to the ground or to the floor of the works. A suitable cover surrounds the machine, to prevent the slices being scattered, and to make them fall into the pit below, whence they can be withdrawn in any convenient manner. An endless feed-apron conducts the canes to the machine, as in ordinary roller-mills. The slices measure 3 to 4 inches long and $\frac{1}{16}$ inch thick.

Manlove, Alliott, Fryer, & Co.'s cane-cutting machine (Fig. 51) consists of a horizontal disc, carried on a vertical spindle driven by a belt and bevel gear, and revolving in an upright circular casing, in the top or cover of which are two or more angled shoots. Through these shoots the canes are fed down on the surface of the revolving disc, which carries ten or twelve diagonal steel cutters, fixed in cutter boxes readily removable through doors in the casing cover, for the purpose of sharpening the knives. These

FIG. 51.



Manlove's Cane Slicing Machine.

knives revolve at a high speed, and rapidly reduce the canes into long oval slices, about $\frac{1}{20}$ inch thick, delivering them into a conical hopper arranged underneath the disc casing.

Bouscaren's system.—In 1876, Louis Frederic Gustave Bouscaren, son of the Major Bouscaren whose name was so early associated with this subject, introduced a system of applying the diffusion process to the sugar-cane, which is intended to overcome the difficulties hitherto experienced.

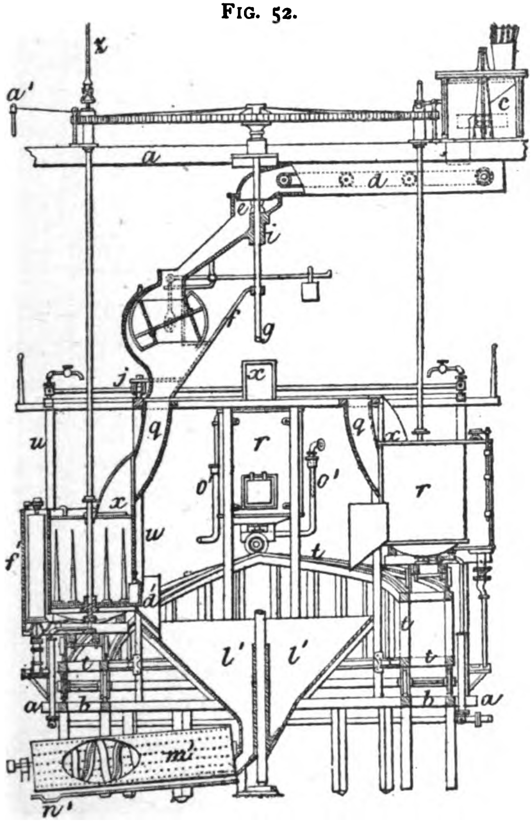
The cane as fast as it is sliced is automatically and promptly conducted in measured quantities to each in succession of a permanently connected circuit of open diffusors, arranged around the source of supply, and subjected to consecutive elevation and depression around the circuit, so as to cause the liquor to overflow by simple gravity from one to the other.

Each diffusor has a steam chamber or other means of heating its contained liquor, in order that the albuminous and other impurities in the freshly charged cane may be promptly solidified within the tissues, and before they have had time to mingle with the sugar.

Automatic elevation and depression of the several diffusors is obtained by supporting the entire circuit upon an annular double inclined tract, so connected with the engine as to be slowly and continuously rotated about its axis for this purpose, each diffusor being restricted to its proper place, and at the same time guided in its upward and downward movement within the series, by vertical guides. The bottom of each diffusor is connected with the top of the one next below it in the series by means of a "telescope" or other extensive pipe, whereby constant communication is preserved, notwithstanding the relative changes in elevation.

The apparatus further comprises provision for agitating the contents of each diffusor, so as to bring all parts into equal contact with the diffusion liquor, and facilitate its proper and equable flow; a series of straining diaphragms, both stationary and movable, and devices for keeping their meshes open, so as to retain all mechanically suspended impurities without interrupting the flow of diffusion liquor; provision for the temporary elevation of the strainers and agitators, to enable the complete discharge of the spent contents, and the thorough cleansing of each diffusor pre-

FIG. 52.

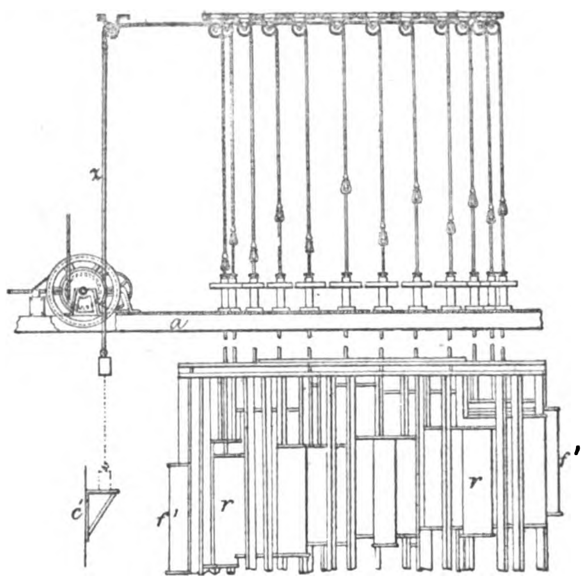


Bouscaren's Diffusor.

paratory to a new change, without interrupting the operation; and provision for the straining and delivery of the solid refuse.

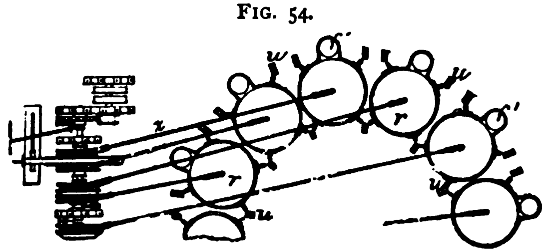
The general disposition and arrangement of the apparatus are such as to greatly reduce the time and labour occupied in the process. The automatic elevation of the successive diffusors enables the overflow to take place by the gravity of the

FIG. 53.



Group of Bouscaren's Diffusors.

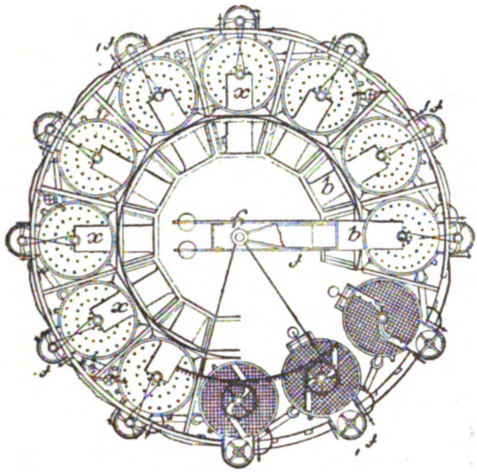
FIG. 54.



Hoisting Gear.

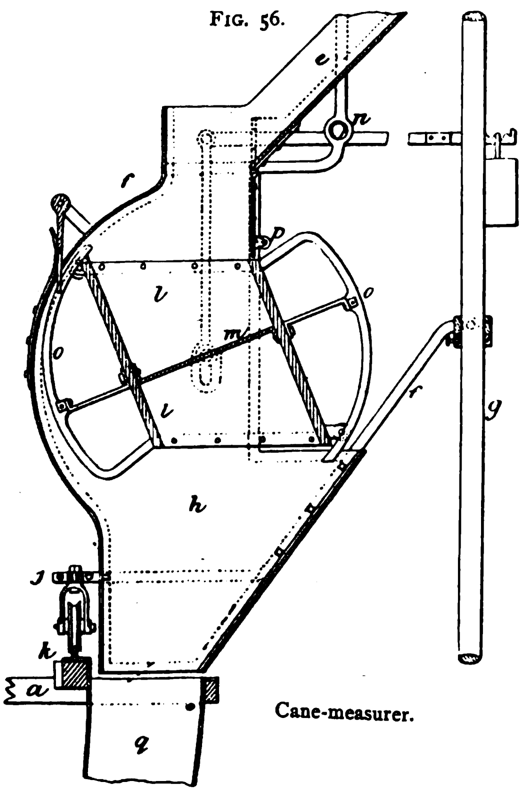
liquor in open vessels, from which the interior mechanism can be at any moment removed, thus rendering practicable (without interference with the continuity of the operation) the

FIG. 55.



Top View of Diffusor.

FIG. 56.

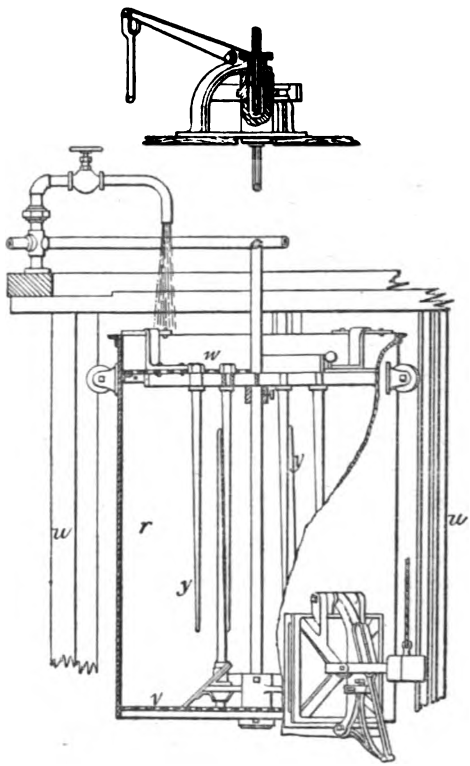


Cane-measurer.

frequent cleansing and inspection of each diffusor, and by this means securing exemption from fermentation.

Fig. 52 is an elevation partly in section of the diffusion apparatus; Fig. 53 an elevation of a group of diffusors and

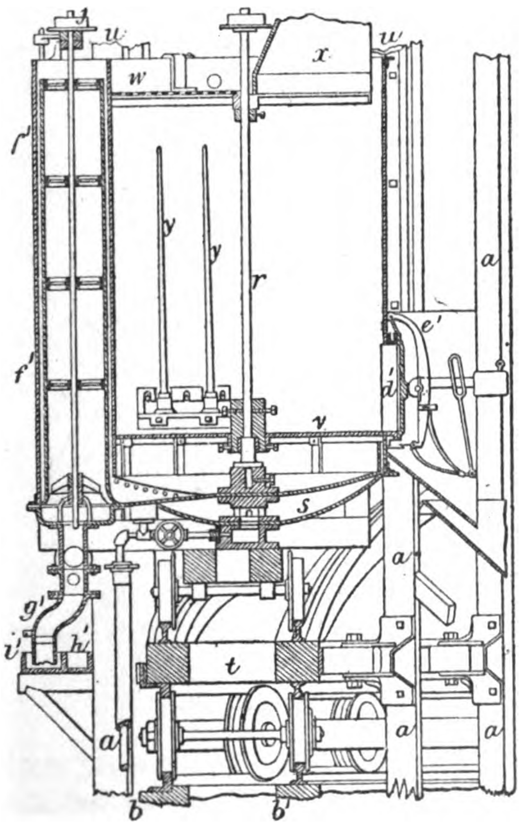
FIG. 57.



Section of Diffusor.

their agitator hoisting mechanism; Fig. 54, a top view, showing a portion of the series of diffusors, and of the agitators hoisting cables and apparatus; Fig. 55, a top view of the group of diffusors; Fig. 56, a vertical section of the mechanism for measuring and charging the sliced cane; Figs. 57 and 58, axial sections, in two different planes, of a diffusor and its accessories; Fig. 59, a top view of the agitator and one diffusor in position, with portions of the adjacent diffusors; Fig. 60, an end elevation, and Fig. 61, a top view, of a suitable form of hoist for the agitating and straining mechanism. Figs. 52

FIG. 58.

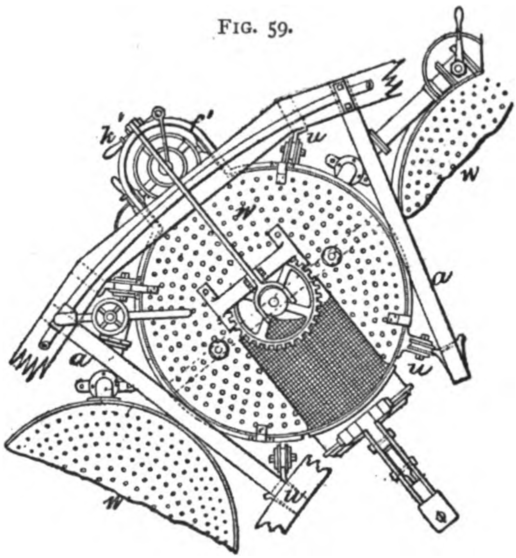


Section of Diffusor.

and 53 show a series of diffusors on a double inclined turn-table moving from left to right; and Figs. 57 and 58, a similar series on such a table moving from right to left.

The various operative parts are principally supported by a suitable frame *a*, and an annular track *b*. In order to ensure prompt, equal, and intimate contact of the diffusion liquor with every part of the cane, the latter is first cut obliquely across into thin slices, and instantly transmitted, in weighed charges, to each diffusor in consecutive succession around the circuit. *c* is any suitable cane slicing apparatus; *d*, an endless band to conduct sliced cane into the hopper *e* of the feeder *f*. The hopper *e* is supported by the shaft *g*; its lower end has a valve or hinged bottom, and rests upon the top of the spout *h*,

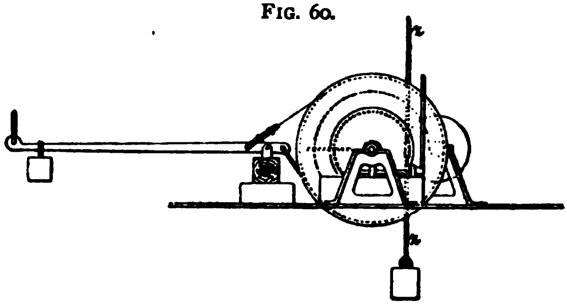
FIG. 59.



Top View of Agitator.

attached to a hanger or swivel *i*. The spout and hanger are collectively supported on one side by the shaft *g*, and on the other by the roller *j* upon the annular track *k*, so as to be revolvable at discretion of the operator in a horizontal plane about the common axis of the group of diffusors. The opposite sides of the spout *h* have each a vertical slot to receive the projecting ends of a horizontal axle or pair of trunnions passing through the centre of gravity of the receiver *l*, which is divided by a partition *m* into two symmetrical compartments, each of which constitutes by turn the receiving chamber of the automatic weigher and dumper. A pair of steelyards, each provided with the customary adjustable counter-weight, are

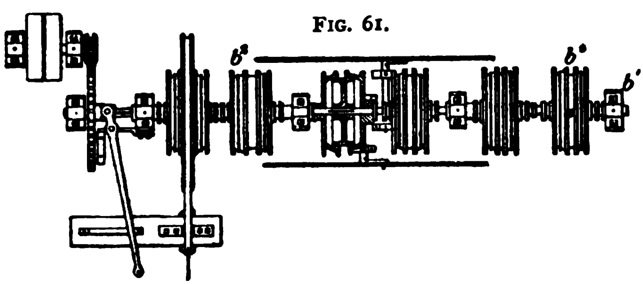
FIG. 60.



End View of Hoist.

fulcrumed to the swivel *n*, and, by being connected to gudgeons and rods, hold the empty receiver to its elevated position, as shown in Figs. 52 and 56. One or more projections from the spout *h* operate as a stop or detent, to prevent the rotation of

FIG. 61.



Top View of Hoist.

the empty receiver; they are hinged to the spout, and held to their normal positions by springs, so as to yield to the first impact of the receiver, and thus prevent concussion. A roller reduces the friction of the loaded receiver while descending in contact with the detent. The cams *o*, when the receiver is rotating, by turn impinge against a roller on the valve *p*, and serve to hold the latter shut until the receiver has completed one of its inversions. The sliced cane is delivered as measured into each in succession of a series of hoppers *q*, one to each diffusor, fixed to the frame *a* at such a height as to deliver into their respective diffusors at the lowest position of the latter. Each diffusor *r* is a vertical cylindrical vessel, open at top, and closed at bottom by a heating chamber *s*, which has no communication with the interior of the vessel.

The diffusors, in number sufficient to carry out the process (12 in the present illustrations), are grouped in a circle, and supported by wheels upon a double inclined turntable or rotary platform *t*, which itself rests upon and is guided by wheels occupying the annular track *b*. These diffusors are retained in place by vertical guides *u*, while being automatically and continuously elevated through three-fourths of the circuit, and more quickly depressed through the remaining one-fourth by the agency of the revolving platform *t*. Water at any desired temperature can be admitted by pipes and taps into the diffusors; and a pipe conveys steam to the chambers *s* through the medium of extensible branches. Each diffusor has two removable horizontal diaphragms of perforated sheet metal, wire gauze, or other pervious material, one *v* near the bottom, called the "straining" diaphragm, and one *w* near the top, called the "water-distributing" diaphragm.

Supports are so constructed as to hold the diaphragms immovable during diffusion, and yet to permit of their easy withdrawal in the intervals succeeding diffusion. On the side of each diffusor nearest the common centre of the group, each upper diaphragm *w* has an opening, protected by a curb or hood *x*. Each diffusor has at bottom, and coincident with its axis, a stud to support and centre the shaft of an agitator *y*, armed with brushes and scrapers to keep open the meshes of the straining diaphragm *v*. The agitator shaft is surmounted by a swivel attachment for a cable *z*, whose remote extremity is connected with a hoist.

Collars or other projections from the agitator shaft cause it, when lifted, to carry with it the entire straining and agitating mechanism of the diffusor proper, so as to leave the interior entirely clear when desired for inspection, cleansing, or repair.

Turning loosely upon the agitator shaft, within a fixed pedestal which holds it to a given plane, is a pinion, which, in common with its fellows upon the shafts of the other diffusors, gears with the large central wheel attached to the main shaft *g* at the common axis of the group. A clutch, having a handle a^1 within reach of the attendant, enables him to lock the pinion of any particular diffusor with its shafts, and to thereby put the agitator in motion.

The hoist for elevating the agitator *y*, and the diaphragms *v w*, may be constructed as follows:—b^1 is a horizontal shaft, attached to which at suitable intervals are drums b^2, in number equal to half the diffusors. The shape of each drum is that of two symmetrical truncated cones attached base to base. On each side of each drum is a friction-pulley, loose upon the shaft b^1, and moved on and off its drum by means of a lever, put within convenient reach of the operator. Around each pulley is wound, by two or more turns, the cable *z*, which is conducted over suitable pulleys to its proper agitator shaft. The free end of the cable *z* carries a weight sufficient to prevent the cable slipping around its pulley. A stop, or rest, by arresting the weight in its descent, causes the cable to slip on its pulley, and makes it impossible to hoist the agitator too high. The shaft is also provided with a brake, whose operating lever is placed under control of the attendant by means of a rope, and has a weight to hold the brake with force adequate to retain in the elevated position any one of the agitators. The shaft may be put in and out of gear by means of a clutch operated by a cord accessible to the attendant.

In its normal condition, the shaft is at rest with the brake on, and all the shiftable pulleys withdrawn from their drums, and turning loosely upon the shaft, following the motion of the descending or ascending diffusors. When an agitator is to be raised, its pulley is thrown over the friction-drum corresponding to it, the brake lever is lifted, and the clutch is thrown into gear, causing the elevation of the suspended agitator and diaphragms. When the proper height has been reached by the agitator, the clutch is thrown out of gear, and the brake, being applied, holds the agitator in place, all this being done without interfering with the other agitators, whose pulleys remain loose on the shaft.

The main refuse discharge opening d^1 of each diffusor is located with its bottom edge on a level with the straining diaphragm *v*, and is provided with a hinged door opening upward. Over the door hangs a wrought-iron yoke e^1, hinged at its upper end to the diffusor, and having at its lower end a hinged hook or latch, which catches behind a projection from the neck of the opening, and is held in position by a stiff spring. A pair of slotted links connect the yoke with the door. A forked or double lever, also hinged on the yoke, and heavily weighted at its outer extremity, is shaped at its inner extremities into cam-heads, which bear on the centre of the door, and cause it to press around its entire edge hard on an elastic seat or gasket which encircles the opening. By pulling with a shock on the cord attached to the end of the lever, a pin fastened to the lever, and working in a slotted arm attached to the tail end of the hook, causes the hook to become disengaged, so as to liberate the door, which may then be opened to any extent by simply continuing to elevate the cord, whose release at any moment reverses the above movements, and restores the door to its closed and locked condition.

Each diffusor has a bay or side-chamber f^1, whose lower portion communicates with that part of the diffusor proper which is underneath the straining diaphragm *v*. Journalled axially within the chamber f^1, is a revolvable cylindrical strainer, whose lower extremity has an annular lip or cup packing of leather or other elastic material, to prevent any escape of juice except through the meshes of the revolvable strainer. An orifice in the bottom of the chamber affords communication from the interior of the revolvable strainer to a pipe g^1, having two branches, one downward, and one in a lateral direction. These branches have valves; and the down-turned branch has a turn spout, which may be directed to discharge into either of two troughs, one of which (h^1) is for the concentrated juice, and the other (i^1) for the waste water employed to cleanse the diffusor after each emptying. The lateral branch extends upwards and telescopes on to a second pipe, which is fastened permanently to the next diffusor, and discharges into it over the top of the distributing diaphragm *w*. The rotation of the cylindrical strainer may be effected by belt and pulley, or other connection with the diffusor shaft, or by the hand of the operator. Brushes secured to the inner wall of the chamber f^1 operate to sweep the meshes of the revolving strainer clear of obstructions, and to preserve it in an open and permeable condition. The shaft j^1 of the strainer is prolonged downward, through and below its bottom bearing, so as to enable the strainer to be elevated without unshipping it wholly from its socket. This elevation may be effected by arms or handles k^1 connected with a collar upon the shaft, through the medium of a sliding and rotating rod. l^1 is a discharge funnel for the refuse that escapes through the vent d^1. The neck of this funnel may empty into a revolving perforated cylinder m^1 having a spiral rib or flange, which operates to retard the escape of the solid refuse sufficiently to afford time for the liquid portions to strain off through the orifices of the cylinder. The liquor which escapes from the strainer is conducted off by a drain n^1, and is either suffered to escape, or is collected in a tank for future use. The solid refuse escapes from the end of the strainer into a receptacle, or it may be caught in cars for removal to a drying shed or oven for conversion into fuel. The rotation of the turntable may be effected by a worm, which gears into an annular rack upon the table.

The apparatus is capable of being worked in different manners, one of which is as follows:—Suppose the rotation of the turntable to be continuous, with a velocity of one revolution in 2 hours, which will give 10 minutes for the period of time between two successive positions in the series of one diffusor. For the purpose of explanation, the diffusor which is for the time being at the summit of the double incline will be designated as No. 1, and that which occupies its foot as No. 10. Diffusors Nos. 1 to 9 inclusive have, in turn, received and yet retain their charges of cane, and are all full of cane and liquor to the level of their top diaphragms *w*, the cocks of all the connecting pipes o^1 being open. No. 1 is receiving cold water from the reservoir, and overflows into No. 2, which overflows into No. 3, and so on to No. 9, which is consequently receiving the liquor that has strained through 8 charges of cane of increasing richness.

The charge of cane in No. 9 has just been put in, and the charge in No. 1 (1½ hour old) is supposed to be entirely exhausted and ready for discharge. The attendant now closes the connection between Nos. 1 and 2, shuts off the supply of fresh water to No. 1, opens it to No. 2, and opens the discharge door of No. 1, so as to empty the latter. The cock of the discharge pipe of No. 9 is now opened, and a quantity of liquor equivalent to the quantity of juice contained in one charge of cane is allowed to strain out into the conduit h^1, which conveys it to the ordinary evaporating apparatus.

This liquor having been strained and worked through 9 successive charges of cane, of increasing richness, is supposed to contain the same percentage of sugar as the natural juice of the cane. If, on examination, it be found to contain a less percentage, the velocity of rotation of the turntable *t* should be diminished, so as to increase the length of time of diffusion. The discharge cock of No. 9 is then closed, and the contents of No. 9 are caused to overflow into No. 10, which should be at the same time receiving its charge of sliced cane. In the meantime, No. 1 (which has dropped on to the short incline) is being cleansed and washed; the cylindrical strainer *y*, and, if necessary, the agitator and diaphragms *v* and *w* are elevated, and the water and sediment remaining below the level of the door d^1 having been run out through the discharge pipe into the conduit i^1, and the elevated members replaced, the diffusor is ready for another charge.

Ten minutes having elapsed, No. 2 is found at the top of the incline, and No. 11 at the bottom, and the foregoing manipulations are repeated, No. 2 taking the place of No. 1, No. 10 the place of No. 9, and No. 11 the place of No. 10, upon the respective portions of the turntable. In another 10 minutes, the operation is exactly repeated, No. 3 assuming the functions of No. 2, No. 11 those of No. 10, No. 12 those of No. 11, and so on continuously, until the entire supply of cane has been worked up; the (for the time being) uppermost diffusor in the series receives a quantity of pure water equal to its capacity, less the volume which one charge of cane possesses in excess of its contained juice, and the lowest diffusor in the series furnishes a quantity of artificial juice equivalent to that of the natural juice in one charge of cane.

The water introduced to the series being cold or at its natural temperature, and only becoming heated when it approaches the place of discharge, whence it passes immediately to the evaporating apparatus, but little loss of heat is incurred. The temperature of the entering water may be regulated at the discretion of the operator. In order to ensure the solidification in the tissues of the soluble substances injurious to the sugar, especially of pectin, which is not coagulated by hot water alone, lime or some other suitable agent may be added to the water or liquor.

To illustrate the process, a series of 12 diffusors have been selected to make up a group or circuit, of which number there are at all times 9 consecutive diffusors on the ascending track, and which constitute for the time being a connected but shifting series, whose total difference in elevation is 54 inches, and in which each diffusor reaches its greatest altitude every 2 hours; but these numbers, distances, and periods may, of course, be varied as experience may direct; and the ascending and descending grades of the revolving track may be arranged for right or for left rotation.

Each diffusor may have a plurality of straining chambers, through which the liquor of each may be conducted before entering the succeeding one; and these straining chambers may either empty consecutively one into the other, or all simultaneously into a common conduit, and any one or more of them may be brought into service, at discretion of the operator, by simply lowering their respective screens.

The motion of the turntable may be either continuous, as described, or intermittent. The spout *h* may be prolonged downward, so as to discharge directly into the successive diffusors, and thus to render the hoppers *q* unnecessary. The entire system of agitating mechanism, with its necessary adjunct the hoisting apparatus, may be left out, and a greater number of diffusors used in this circuit, if necessary, thus increasing the number of changes through which the liquor is passed, and the time spent in the diffusion of one charge to compensate for the non-agitation of the pulp. A great simplification of the apparatus, with a corresponding reduction in its cost and in the power necessary to operate it, would by this means be obtained. In such an arrangement, each diffusor may be provided with a wire gauze basket, to receive the cut cane, and permit its ready removal when spent.

The process of diffusion has been described as immediately succeeding that of slicing, and the feeding mechanism has been arranged with special reference to prompt action on the heated liquor, so as to forestall fermentation, the operation being designed to be conducted upon the plantation itself, or in its vicinity; but it is manifest that if, by desiccation or otherwise, the cane can be placed beyond liability to deteriorate for a period sufficient for its transportation, the diffusion and subsequent processes might be performed elsewhere.

The apparatus, while especially designed for operating upon sugar-cane, is obviously applicable, in its essential features, to the extraction of sugar from the beet and other saccharine plants. It has been attempted to extract the sweet principles of the beet and sugar-cane by diffusion of their sliced or crushed particles in water sufficiently hot to solidify the albuminous portions, and at the same time to dissolve the sugar, the same liquor being applied to successive charges of material until the desired strength of saccharine solution has been obtained. Experiments of this kind on an extensive scale were made by the father of the inventor of the process just described, upon his sugar plantations in the island of Guadeloupe during 5 years, commencing in 1847; also experiments by Mesmay and others about the same time.

The results of experiments made at Monrepos, Guadeloupe, with an apparatus consisting of only 6 diffusors, prove that an artificial juice, having a density nearly equal to that of the natural juice of the cane, may be obtained; and that a period of diffusion extending to 1½ hour is quite sufficient for effecting the extraction of the whole of the sugar. The yield of white sugar in these experiments is said to have amounted to from 12½ to 13 per cent. of the weight of the cane.

Robert's system.—The name of Julius Robert is sufficiently familiar to those engaged in the beet-sugar industry, and his diffusion process has been submitted to trial by cane planters in several parts of the world. His system will be described at some length in the section on beet sugar. For its application to cane, the machinery required comprises a 45-H.P. steam engine, cane-cutters, diffusion vessels, and a heater.

The cane-cutters are 4, each consisting of a revolving disc of cast iron, 4 feet 6 inches in diameter, on which are fastened, in the line of radii, 6 knives, which, in their rotation, pass rapidly and in close proximity to another knife fixed horizontally near the disc. The canes are cut in slices by being pressed against the discs or knives by means of a hopper. The thickness of the slices is regulated by the distance between the knives on the disc and the fixed knife.

The knives can be easily removed for the purpose of cleaning and sharpening, and, as each disc moves independently of the other, only one cutter need be stopped at a time, and the work of slicing can go on uninterruptedly. A set of knives will run 24 hours without requiring to be sharpened, if the cane is not tough; but, in any event, it takes but a few minutes to remove the dull knives and replace them by others kept in reserve.

The cane slides through the hopper so as to strike the plane of the revolving disc at a suitable angle, in order to produce such chips as will expose the largest possible number of the central cells to the action of the liquids in the diffusion vessels. The reason for exposing the central cells in particular is that the sugar is said by some microscopists (notably Dr. Julius Wiesner, of Vienna) to reside chiefly in those cells. The cane-cutters of this description constructed by Franz Rebicek, of Vienna, make about 225 revolutions per minute. They effect a clean sharp cut, elliptical in shape, 3 to 4 inches long, and from $\frac{1}{8}$ to $\frac{1}{16}$ of an inch thick. The amount of cane sliced up by one cutter is estimated at a minimum average of 6000 lb. per hour.

The diffusion vessels are made of light boiler-iron with cast-iron bottoms. They measure 120 cubic feet, and contain about 4200 lb. of cane chips and 3250 lb. of water, 10 of them being required to form a battery. Each vessel is in connection with 5 pipes—one for water from the reservoir above, one to send juice to the heater, one to receive juice from the heater, one to discharge juice into the sugar-house to the clarifiers, and one to pass juice from one vessel to another. Besides this, there is one pipe direct from the boiler for steaming purposes, and one large pipe for discharging the water from the vessel before emptying the exhausted chips. The vessels have one manhole at the top, for receiving the chips; and another, 4 feet square, on the side next to the bottom, for discharging the exhausted chips. The concentrated juice sent into the sugar-house is drawn from the bottom of the vessel, and to prevent slices of cane from passing with the juice, each diffusion vessel is provided with a false bottom perforated like a sieve.

The heater is made of standard boiler-iron, and is in direct communication with the steam-boiler. It is used for heating the juice on its passage from one diffusor to another. The juice passes through a system of copper pipes fixed vertically in the heater, and which are completely surrounded by steam coming directly from the boiler. The temperature of the juice is indicated by a thermometer inserted in the top.

With regard to the working of the process, hydrostatic pressure alone is used in passing juice from one vessel to another, as well as through the heater and into the sugar-house, and this is obtained by a water tank of 1500 gallons capacity, placed about 20 feet above the diffusors, and connected with them by a large copper pipe. As fast as the canes are passed through the cutters, the slices fall on a carrier, which conveys them above the diffusion vessels, and from there, upon a movable carrier, which drops them through a sheet-iron funnel successively into each diffusor.

As soon as vessel No. 1 is filled with chips, and while No. 2 is being filled, direct steam is let into the bottom, until it has penetrated the whole mass of chips, and begins to escape at the top. Steam is then shut off, and water is let on from the tank above through the heater until the vessel is full, when the manhole is tightly closed. No. 2 being filled with chips and duly steamed, water is again let down from the tank through the heater into No. 1, driving the liquid by hydrostatic pressure out of No. 1 into No. 2 through the connecting pipe, which has in the meantime been opened. No. 3 is filled, steamed, and charged with juice through No. 2, in the same way. When No. 4 is filled with chips, cold water is let directly from the tank into No. 1, driving the juice which was in it through the heater into No. 2, and from 2 to 3 and 3 to 4. Next cold water is run into No. 1, and from No. 1 to No. 2, from No. 2 through the heater into No. 3, then directly into 4 and 5, and so on, care being taken to preserve the temperature of the last vessels filled at about 88° to 93° C. (190° to 200° F.). When the hot juice has passed through No. 7, it is considered sufficiently concentrated, and is discharged into the sugar-house; No. 1 is now emptied, and No. 2 becomes the first vessel in the battery, and the work goes on as before, there being always 7 vessels working, one vessel being emptied, and two being refilled; so that practically, when the work is in full operation, as fast as one vessel is filled, a charge of concentrated juice goes into the sugar-house, and one vessel with exhausted chips is emptied.

The discharging of the chips is done through the large manhole described as being near the bottom of the diffusor; the exhausted chips are received on a carrier, which drops them into the begass carts. The emptying of a vessel is accomplished by 2 men in from 6 to 8 minutes, including the opening and closing of the manholes. The filling of a vessel with chips requires 12 to 15 minutes.

The following table shows at a glance the status of each diffusion vessel at the moment of making the first discharge of juice to the clarifiers. It is also the normal condition of the battery in regular working order:—

No. of Vessel.	Temperature of Juice.	Specific Gravity.	Per cent. by Saccharometer at 63½° F.	Degree of Baumé at 63½° F.	Remarks.
I.	21° C. (70° F.)	1·00030	0·08	0·048	These figures correspond to cane juice of 7¾° B.
II.	29° C. (85° F.)	1·00310	0·80	0·44	
III.	32° C. (90° F.)	1·00544	1·40	0·80	
IV.	49° C. (120° F.)	1·01134	2·90	1·6	
V.	93° C. (200° F.)	1·01618	4·12	2·3	
VI.	87° C. (189° F.)	1·02537	6·45	3·6	
VII.	91° C. (196° F.)	1·04599	11·40	6·3	

High temperature exhausts the chips more rapidly, and coagulates the albumen in the cane, thereby rendering it insoluble, and causing it to remain in the chips. This will be recognised as an immense advantage, from what has been already (p. 116) said about the albumen being a generator of fermentation. As the diffusion juice can be kept a longer time than mill juice before any fermentation sets in, it is practically proved that the greater part of the albuminous and mucilaginous substances remain in the cells of the cane.

The density of the diffusion juice in the practical working of the apparatus is 1° to 1½° B. less than that of the juice of the cane, which gives an excess of water to be evaporated, amounting to from 16 to 20 per cent.; this entails an additional expense of about 17 cents (8½*d.*) for every 1000 lb. of cane, estimating wood at 3 dollars (12*s.* 6*d.*) a cord [a cord of firewood measures 8 ft. × 4 ft. × 4 ft. and weighs about ½ ton], and coal at 75 cents (3*s.* 1½*d.*) a barrel of 200 lb.

Prolonged trial was made of this process in Louisiana, but without success, for the apparatus has lately been broken up and sold. The results of operations conducted on a West Indian plantation are stated as follows. The weight of the cane was carefully registered during work; the quality of the cane was tested at intervals by passing a few canes through a small set of hand rollers, and the juice was weighed with a very delicate saccharometer. During the first week's run, the analysis of the mill and diffusion juices were as shown in the table following. To avoid misapprehension, it must be remembered that for every 100 gallons of mill juice, there were 113 gallons of diffusion juice, which accounts for the apparent higher rating by saccharometer in the former than in the latter:—

ANALYSES OF MILL AND DIFFUSION JUICE.

Mill Juice.		Diffusion Juice.
1·05746	Specific gravity	1·04620
11·80 per cent.	Crystallisable sugar	9·65 per cent.
1·68 ,,	Uncrystallisable sugar	1·38 ,,
0·62 ,,	Foreign substances	0·42
14·10 ,,	Saccharometer	11·45 ,,

The vessels were filled with about 4200 lb. of cane each, and from every vessel, 4290 lb. of diffusion juice were drawn off into the clarifiers; this is equal to 82·94 per cent. of undiluted juice or cane juice on the weight of cane. Therefore nearly 83 per cent. of juice was extracted, leaving 17 per cent. in the chips and refuse water. More juice could have been obtained by continuing the process, but there is a point beyond which it would not pay to go, and this is left to the discretion of the operator.

In the present case, this point was reached at 83 per cent., because, by drawing off more, less cane would have been worked up, and the greater amount of fuel required to evaporate the proportionally larger quantity of water in this juice would not have been paid for by the difference in sugar.

The juice on leaving the diffusion vessels was sent into a square tank for the double purpose of measuring it, and of regulating its flow into the sulphur machine. Before entering into the sulphur box, the juice had a light-amber colour, was clear and transparent.

On reaching the clarifiers, from the sulphur machine, the juice, through the bleaching agency of the sulphurous acid, had become much lighter. As this acid is not free from the dangerous power of producing invert (uncrystallisable) sugar, great care should be taken to lime the juice as soon as possible, for the purpose of neutralising this and the organic acids. After clarification, which was generally done with 0·12 to 0·20 per cent. of lime, the juice went to the kettles. The work up to this point was not very satisfactory, because there were too many stoppages, amounting to 4 hours out of 24. To obtain the best possible results, the work should be regular. In working up 60 diffusors per day, there ought to be 15 in each 6 hours, instead of which in this case there were sometimes 22 in 6 hours, and at another time only 11. In consequence, juice was sometimes on hand too long, and at other times the kettles gained so fast that juice had to be let out of the clarifiers before it was defecated at all. The result was more or less sediment in the syrup tanks.

During the first week's work, there were 987,945 lb. of cane cut. This cane contained 90 per cent. of juice, of which 83 were sent to the clarifiers; therefore the product was, calculating by the analysis above given:—

Crystallisable sugar	8·81	per cent.	on the weight of the cane.
Uncrystallisable sugar	1·25	,,	
Foreign substances	0·46	,,	

The loss of juice by clarification, skimmings, and sediment in syrup tanks amounts to about 6 per cent. on the weight of the juice, or 4·98 per cent. on the weight of the cane; therefore the amount of juice really obtained in green sugar was 78 per cent. on the weight of the cane. Of this,—

8·28 per cent. was crystallisable sugar.
1·17 ,, ,, uncrystallisable sugar.
0·43 ,, ,, foreign substances.

According to established analyses every 1 lb. of foreign substances in cane juice prevents the same amount of sugar from crystallising; and, furthermore, through the influence of great heat, long continued in open kettles, an additional amount of crystallisable sugar is converted into uncrystallisable sugar. To be on the safe side, double the amount of uncrystallisable sugar would represent the disturbing element in crystallisation of the sugar contained in the diffusion juice, the perturbing action of the heat being included.

The following is an abstract from the report of the first week's run, from October 26th to October 31st, 1875, the amount of sugar-cane worked up being 987,945 lb.:—

Density of Mill Juice. (Saccharometer.)	Density of Diffusion Juice. (Saccharometer.)	Yield of undiluted Juice on the Weight of the Cane.	Sugar Obtained. In hhds. 1st Product.	Sugar Obtained. In hhds. 2nd Product.	Sugar Obtained. In lb. 1st Product.	Sugar Obtained. In lb. 2nd Product.	Sugar Obtained. Total in lb.	Molasses Obtained. Barrels.	Molasses Obtained. Gallons.	Molasses Obtained. Lb.	Total Sugar and Molasses in lb.	Percentage of Sugar on the Weight of the Cane.	Percentage of Molasses on the Weight of the Cane.
14·10	11·45	82·92	29	14·5	35,595	16,111	51,710	100	4249	50,778	102,484	5·234	5·193

The second sugars did not have sufficient time to granulate and to settle, consequently much of the sugar of small grain passed through the centrifugals into the molasses, as is proved by analyses of them showing far more sugar than there ought to be:—

ANALYSES OF MOLASSES.

79·29	per cent.	dry substance by saccharometer.
20·08	,,	water.
63·83	,,	crystallisable sugar.
12·38	,,	uncrystallisable sugar.
3·72	,,	foreign substances.
100·00		

The results here given are by no means creditable to the process. Assuming the molasses to contain ⅓ of its weight of sugar, instead of nearly ⅔, the figures would indicate a yield of 0·55 lb. of sugar per gallon of juice, while 1·1 to 1·2 lb. would be nearer the proper quantity.

The amount of water required to work the diffusion apparatus is about one ton to every ton of cane, and it is important to have pure water, as it has a great influence on the quality of the juice. If water were used containing more or less organic impurities in a partial state of decomposition, it would add to the juice similar elements of fermentation to those which the process has been devised to leave in the cells of the cane.

It will be possible to save about 6 or 7 per cent. of the water used, if, instead of emptying the water from the vessel containing the exhausted chips, it is forced by pressure into the next vessel.

The advantages of diffusion are not all stated by merely saying that more juice is obtained from a given quantity of cane. All sugar-makers know that the juice from the mill deposits its mechanical and other impurities in what are called "receiving-boxes." It is impossible to draw off all the clear juice without admixing part of those impurities; hence clear juice is lost with the sediments.

This loss in the settling-boxes is avoided in diffusion juice. The juice comes from the vessel as a clear transparent amber-coloured liquid, which does not need any settling. When reaching the clarifiers, with the mill juice, a vast amount of albumen is skimmed off, which is another source of loss; whereas with the diffusion juice, the clarifiers require no skimming. Again, the deposits by the action of lime in the clarifiers are in much greater proportion in mill juice than in diffusion juice; and in the "grandes" (in boiling juice in the open kettles), the amount of skimmings is not one-fifth of what it is with mill juice. All these little losses in mill juice are prevented in diffusion juice, and explain the additional gain over that obtained directly from the mill.

A peculiar difference exists between mill juice and diffusion juice, in so far as the latter requires a longer time to crystallise after it has been brought to syrup. Besides this,

Analyses of Canes Grown in the Aska District, Ganjam, Madras, East Indies.

Analyses made in the first fortnight of March on Ripe Cane. Average sample of chips from the cutting of whole bundles, weighing 100 to 120 lb., taken for analysis.

	A Good Average Bundle.			A Bundle of Picked Cane.			A bundle of Cane deteriorated by drought, less 2 feet of Top.
	2 feet Top.	2 feet Middle.	2 feet Root.	2 feet Top.	Next 2 feet.	Last 3 feet.	
Begass proper	7·63	8·47	8·3	7·58 {Fibre, &c. 7·36 Silica, Lime, & trace Iron 0·22}	8·65 {Fibre, &c. 8·19 Silica, Lime, & trace Iron 0·24}	8·29	8·47
Sugar	10·63	13·31	13·37	9·49	13 64	13·85	10·41
,, uncrys. ..	2·64	1·51	1·54	2·43	0·736	0·71	5·20
Ash	0·307	0·259	0·233	0·545	0·363	0·349	0·352
Water	78·334	75·612	76·122	79·484	75·628	75·945	75·152
Unknown ..	0·459	0·839	0·455	0·471	0·983	0·856	0·416
(Sugar to Unknown) Juice	92·37	91·58	91·7	.. 92·42	.. 91·35	91·35	90·53
	100·000	100·000	100·000	100·000	100·000	100·000	100·000
The Expressed Juices Analysing—							
Apparent Solids i. e. °Balling	**15·2**	**17·4**	**17·0**	**14·0**	**17·2**	**17·2**	**17·9**
Sugar	**11·51**	**14·55**	**14·58**	**10·27**	**14·93**	**15·11**	**11·38**
,, uncrys. ..	**2·86**	**1·65**	**1·68**	**2·63**	**0·806**	**0·775**	**5·68**
Ash	**0·333**	**0·283**	**0·255**	**0·59**	**0·398**	**0·381**	**0·385**
Unknown ..	**0·497**	**0·917**	**0·485**	**0·51**	**1·076**	**0·934**	**0·455**
Equal to, in the 100 Apparent Solids:—							
Sugar	**75·72**	**83·62**	**85·76**	**73·35**	**86·8**	**87·84**	**63·57**
,, uncrys. ..	**18·81**	**9·48**	**9·88**	**18·78**	**4·68**	**4·50**	**31·73**
Ash	**2·19**	**1·62**	**1·50**	**4·21**	**2·31**	**2·21**	**2·15**
Unknown ..	**3·28**	**5·28**	**2·86**	**3·66**	**6·21**	**5·45**	**2·55**
	100·00	**100·00**	**100·00**	**100·00**	**100·00**	**100·00**	**100·00**

Remarkable.—The large quantity of uncrystallisable sugar in the top, as compared with the rest of the cane, and the large quantity of "unknown" in the middle as compared with the rest of the cane.

THE BEGASS, WATER, AND SOLIDS OF ASKA CANES.

	Tops. Begass.	Tops. Water.	Tops. Soluble Solids.		Middle and Root. Begass.	Middle and Root. Water.	Middle and Root. Soluble Solids
Analysis of one bundle	*7·76	*76·1	16·14	Analysis of one bundle, topped for sugar-house..	*8·57	*77·18	14·25
	*7·76	*80·7	11·54		*8·00	*76·68	15·32
	*8·00	*80·32	11·68		*8·93	†74·77	16·30
	*7·00	†79·988	12·962		*8·40	†75·20	16·40
	30·52	317·108	52·322		33·9	303·83	62·27
Average	7·63	79·277	13·08	Average	8·47	75·96	15·57

	Middle. Begass.	Middle. Water.	Middle. Soluble Solids.		Root. Begass.	Root. Water.	Root. Soluble Solids.
Analysis of a bundle—three analyses of the tops of which appear above	*8·68	†75·6	15·72	Analyses belonging to the three top and two middle analyses ..	*8·74	*76·44	14·82
	*8·63	†75·7	15·67		*7·64	†76·48	15·88
					*8·50	†75·80	15·70
	17·31	151·3	31·39		24·88	228·72	46·4
Average	8·65	75·65	15·7	Average	8·3	76·24	15·46

Therefore, having on a bundle the separate average analyses of

	Begass.	Water.	Soluble Solids.
Middle—two analyses	8·65	75·65	15·7
Root—three ,, ...	8·3	76·24	15·46
The body of the cane, by separate analyses of its middle and root, has an average analysis of	8·47	75·95	15·58
And the average of four analyses of a simply topped bundle was	8·47	75·96	15·57

And since the body of the cane is 5 ft. to the top 2 ft., the average analysis of the whole cane is—

	Begass.		Water.		Soluble Solids.
Tops	7·63 × 2 = 15·26	..	79·277 × 2 = 158·554	..	13·08 × 2 = 26·16
Body	8·47 × 5 = 42·35	..	75·96 × 5 = 379·80	..	15·57 × 5 = 77·85
	57·61		538·354		104·01
Average	8·2		76·94		14·86

And Begass =	
Fibres and cellulose	8·0
Inorganic — chiefly silex and lime ..	0·2
	8·2

* Determinations when actual, marked *; when by difference, marked †.

COMPOSITION OF THE BEGASS.

	Just out of Diffusor.	Begass proper,	After Drying, ready to be used as Fuel.	
Mineral matter of begass	0·33 }	Begass proper,	2·33	
Fibre and cellulose ..	11·17 }	11·5	77·14 }	Combustible matter, 82·214 per cent.
Sugar	0·41	..	2·85 }	
,, ...	0·076	..	0·526 }	
Gums, albumen, &c. ..	0·245	..	1·698 }	
Ash	0·066	..	0·456	
Water	87·700	..	15·000	
	100·000		100·000	

The water in the dried begass varies from 5 to 17 per cent.

ANALYSES OF SUGARS MADE AT THE ASKA WORKS BY THE ROBERT DIFFUSION PROCESS.

	From Uncharcoaled Cane Juice.				From Charcoaled Juice. Using a dense char of 62 lb. per cubic foot in proportion of about 0·6 times the weight of dry sugar obtained.			
	Masse-cuite.	"Aska."	B.		Masse-cuite.	B.		
Sugar	76·000	95·500	90·500	99·600	80·000	..	99·500	99·100
,, uncrys.	12·740	2·650	0·230	0·240	11·920	..	0·210	0·470
Ash	1·507	0·306	0·103	0·036	1·917	..	0·067	0·072
Water	5·110	1·000	0·150	0·100	5·290	..	0·035	0·080
Unknown ..	4·643	0·544	0·017	0·024	0·873	..	0·188	0·278
	100·000	100·000	100·000	100·000	100·000	..	100·000	00·000

"Aska" is the masse-cuite simply spun, B and ◇B are made by washing the "Aska" while in the centrifugals with about ½ gallon of water to 150 lb. and are marked according to grain and colour. The ◇A is of 1877 manufacture, and hence the comparatively large quantity of glucose, the excess being derived from the cane sugar, changed under the influence of damp and heat during the long storage.

it is evident that through the continued application of high temperature, a partial change of crystallisable sugar into invert sugar is produced. This is proved by the great excess of molasses.

The begass obtained by the diffusion process forms an excellent material for paper-making. The chief drawback to diffusion is the large quantity of water required, which represents a proportionate extra evaporation and extra cistern space; but the larger yield of sugar is said to more than compensate for the extra cost.

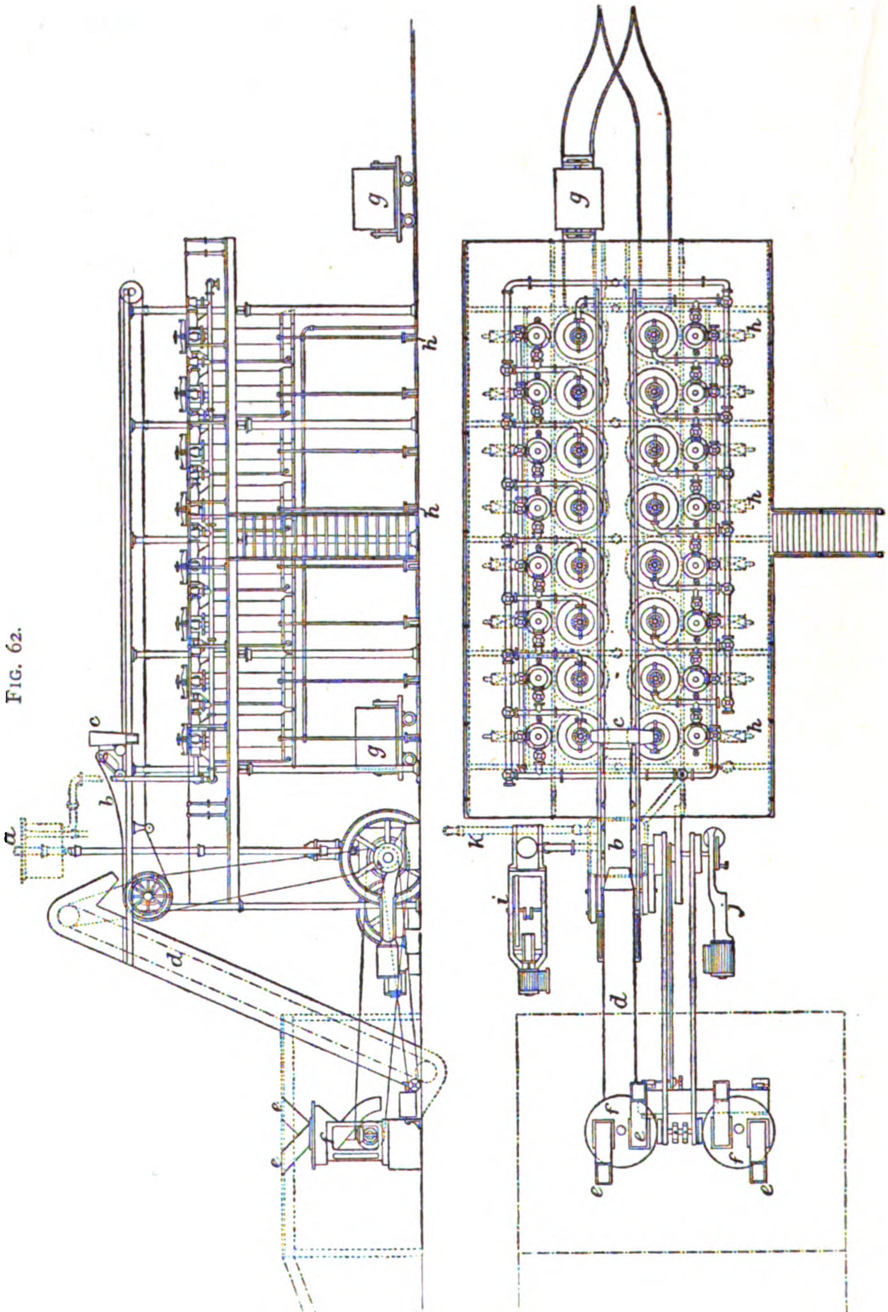
It will be interesting here to introduce a tabular notice of the working of the Robert process at the Aska sugar factory, in Madras (see pp. 228–9).

Fig. 62 shows the general arrangement of diffusion plant, as made by Manlove, Alliott, Fryer, & Co., Nottingham. The canes are delivered on the cutting platform, in the floor of which four shoots are arranged. Through these shoots the canes are fed downwards to the cutting machines, shown in detail on Fig. 51. The cane slices, about $\frac{1}{20}$ inch thick, are delivered in a continuous stream on a carrying band, by which they are conveyed to an elevator and raised to the top of the diffusion house, where they are delivered on another carrying band with a special discharging arrangement, consisting of a truck with two side shoots and two rollers, over which the band is made to pass in such a way as to cause the slices thereon to be thrown forward clear of the band into one of the side shoots, which delivers them into one of the sixteen diffusion vessels. These, with their accompanying juice heaters, are fully described hereafter. The cutting machines, elevators, and carrying bands are driven by a horizontal steam engine. The water tank at the top of the building is supplied by a specially designed water pump, and from this tank the water is led to any one of the vessels which may happen to be freshly charged, or for washing purposes.

The process of working is as follows:—

Any one vessel of the series having been filled with fresh cane slices through the top door, the cover is screwed down and the proper quantity of water is admitted from the overhead tank through the tubular heater. The succeeding vessel is then filled with fresh slices, the cover replaced and a valve opened to allow the diluted juice from the previous vessel to be forced into the same through a second heater by means of a further supply of water admitted into the previous vessel

FIG. 62.



General Arrangement of Diffusion Plant.

from the overhead tank. A third vessel is then filled with slices and the liquid contents of the second vessel are forced into it by means of a further supply of water admitted into the first vessel, the thin juice from which replaces the liquid in the second vessel. This process is repeated as often as desired, say from 12 to 16 times, so that when the last vessel of the series has been filled with fresh slices and the diluted juice from the previous vessel has been admitted into it, the cane slices in the first vessel are almost completely exhausted, and the necessary water for forcing the liquid is admitted direct to the second vessel. The first vessel is thus thrown out of work, the liquid contents are run off, the bottom of the vessel is dropped, and the spent slices are allowed to fall into a waggon, to be removed to the drying ground. When it is desired to economise water, the final charge of very diluted juice in the first vessel of the series may be forced into the second by means of compressed air, instead of being run off to the drain, the empty vessel is refilled with fresh chips, and now becomes the last vessel of the series, the juice and liquor from the vessel filled immediately previous are admitted into it, and the compressed air or water supply is run into what was previously the second vessel of the series. In each case the liquid on its way from any one vessel to the next has to pass through a heater which raises it to the necessary temperature, thus dispensing with the use of direct steam in the vessels themselves.

The condensation water from the heaters is withdrawn by steam traps. The hot concentrated liquor from the last vessel of any series is drawn off at a density of about 6° B. to the clarifiers, where it is treated in the usual manner.

The diffusion vessel (Fig. 62) consists of a vertical cylindrical steel shell, with conical top or mouthpiece, closed by a door so arranged that by slacking the central screw it can be readily slung out of the way of the charging hopper. The bottom of the vessel is formed of a conical casting carrying a dished steel door, on which is fixed a perforated false bottom. This door is provided with a balance-weight, and is supported by a special design of cross-bar, on moving which a few inches the door will drop out of the way of the descending slices, thus admitting of a discharge opening equal in diameter to that of the whole vessel. A water-tight joint is made between the door and the bottom casting by means of a flexible hydraulic ring. Another arrangement consists of a flexible pipe let into a recess in the bottom casting, and by filling this pipe with water under pressure a satisfactory joint can be obtained. A vertical tubular juice-heater is attached to each vessel. This heater consists of a shell of cast-iron or steel with top and bottom boxes and covers, the upper cover easily removable for the purpose of cleaning. The heating surface consists of solid drawn brass tubes, fixed in brass tube-plates, with special means to counteract the effects of an unequal expansion. A thermometer is also fitted on the top cover to ascertain the temperature of the juice in the heater. The water or juice enters the heater by means of either of two stop valves shown at the top of the same; it then passes downwards through the tubes into the bottom of the vessel, where, by means of a perforated plate, it is distributed upwards through the contents, and escapes through the perforated plate at the top of the vessel, and by means of a branch on the top casting into the next vessel of the series, or to the clarifiers, as the case may be.

The heater is supplied with high-pressure steam through a valve at the top, a branch pipe and valve being also fitted to admit of steam being blown into the vessel when it has just been charged with fresh slices. A cock fixed at the lowest part of the heater admits of the diffusion vessel and heater being completely emptied when desired. The condensation water from the heater is withdrawn by means of a steam-trap.

The following summary of a lecture delivered in July 1887, at Georgetown, Demerara, by Quintin Hogg, after a visit to the Aska works, conveys much additional information on this very important subject :—

"In the diffusion house at Aska, which was the first we entered, there are five slicers, of which four are 6 feet in diameter, furnished with six knives each, and run at 200 revolutions per minute. Those slicers were made on the spot by Mr. Minchin, with the exception of the disks, which were cast in Calcutta, and he estimates their cost at 40*l.* sterling—as against 200*l.*, the price he was asked by an English engineer. The fifth slicer was 5 feet in diameter, but is rarely or never used. Two of the 6-feet slicers are kept always at work, and each runs through 60 to 70 tons of cane in the 24 hours, working continuously, or, say, 3 tons per hour each. As, however, constant stoppages are necessary for the purpose of changing and sharpening the knives, an operation which at Aska takes about an hour, three cutters are kept in harness, two of which are as a rule running while the third is either at rest or having its knives changed. I mention these details somewhat minutely, as it was the complete break-down of the cutters furnished by the Sangerhausen people which brought our experiments at *Nonpareil* to a standstill; and I wish to show you that the worst that can happen to us in this respect is having to adopt the Aska pattern of cutter instead of that furnished by the Sangerhausen Company. The rest of the machinery consists of a diffusion battery of 12 cells, each cell containing ¾ ton of cane chips, and holding 400 gallons of water when empty, or 200 gallons when filled with chips. Then there is a sulphur box, very similar to what we use in this colony, and measuring tanks for ascertaining the proper charges to draw from the battery; six defecators, holding 450 gallons each, of the old French kettledrum pattern, and a range of filter bag presses used at the rate of one bag for every ton of diffusion juice passed through them; two concretor batteries of eleven and twelve plates each respectively; a double effet, containing 1720 square feet of heating surface; two vacuum pans striking about 7 tons, and 3 tons of dry sugar; nine under-driven centrifugals of the old Manlove and Alliott pattern, and the usual *masse-cuite* boxes. In addition to these there is an immense range—or, perhaps, I should say, several immense ranges—of other boxes for receiving the second *masse-cuite*. These boxes are only constructed of wood, and the sides do not make the smallest pretence of being watertight; the bottoms are slightly V shape, and are caulked and perforated with holes. The inside of these boxes is lined with bamboo matting, and the second *masse-cuite* is discharged into them. They find the molasses drain quite sufficiently through this matting to enable them to bag the sugar and sell it without passing it through the centrifugals. The consequence is that they get a very large return of sugar from their second *masse-cuite*, 3 cubic feet giving them as a rule 1½ cwt. of molasses sugar. I have brought a large number of these mats with me, intending to try how they will work in Demerara. It must be borne in mind, however, that in order to obtain the white sugar made at Aska, considerable washing is necessary in the centrifugals—(only 41 to 44 per cent. of white sugar is obtained from the *masse-cuite*)—the consequence of course being that the molasses is of exceptionally good quality. The distillery is furnished with two continuous French stills, and rum-making there produces such good results that Mr. Minchin is quite careless as to the quantity of sweets he sends to his liquor loft. The scum and bottoms of the boxes are all remorselessly sent off to the distillery, so that no attempt is made to use filter presses or to obtain the best possible sugar results from the juice. The return in rum is from 30 to 40 gallons per ton of sugar. I am sorry that I had no means of getting the molasses and juice properly analysed. As it is I am unable to describe the constitution either of one or the other, or to state the percentage of crystallisable sugar left in molasses. The motive power consists of one 12 H.P. engine, with a cylinder of 14 inches diameter, and 3 feet stroke. This drives the cutters, the two elevators connected with the cane chips, and the grind-stone Then there is a large beam engine of 25 H.P. (nominal) which works the pans, the steam water pumps, and the centrifugals. There is also an 18 H.P. horizontal engine which drives the pumps for the double effet, and one water pump. In addition to these there is a horizontal engine with double-acting pump, which drives a single effet of the ordinary Rillieux type, which, however, is scarcely ever used. The boilers are eight in number—two multitubular by Mirrlees, 14 feet long by 7 feet 6 inches in diameter; two single flue Adamson boilers, 30 feet by 6 feet 6 inches; two smaller single-flue boilers, 20 feet by 6 feet; and two boilers made from old char cisterns bolted together, one of which is 74 feet long by 5 feet in diameter, and the other 36 feet 3 inches in length and 5 feet in diameter. Neither of these two latter has any flues, the fire simply playing round the outside. I may mention that the large 74-feet boiler is worked up to 36 lb. pressure, and is used to supply steam to the diffusion battery. Of these eight boilers six are kept in use for all purposes, and these six boilers with engines of a nominal capacity of fifty-five horses furnish the whole motive power for the Aska works. The fuel used is wood of good quality, fully equal to good courida as supplied in this country. I have estimated it as being worth about one-third of its weight in coal. Huge stacks of this wood are kept piled in the various large yards enclosed by the factory, and its cost at the furnace door was 3 rupees 4 annas per ton. Taking three tons of wood as equal to one ton of coal, the cost of the fuel is about 10 rupees, or 1*l.* in silver currency, or say 15*s.* in gold, per ton of coal. Labour is, of course, very cheap, a man's pay being about 2 annas, a woman's 1 anna and 4 pies, and a child's 1 anna. As an anna in nominally worth 1½*d.* in silver, these wages represent in gold only about 2¼*d.* per day for a man, and less than 1½*d.* for a child. The following is a list of the labourers employed inside the Aska works: it being borne in mind that diffusion is necessarily a continuous process, it will be understood that the list includes two gangs which relieve each other every six hours, so that one-half of the people mentioned in the subjoined table are resting while the other half are at work:—

LABOURERS IN ASKA WORKS.—*February* 1887.

DEPARTMENT.	Maistries, i.e., Mechanics or Headmen.	Coolies.	Boys.	Total.
Cane cutters	2	20	4	26
Diffusor fillers	2	6	6	14
,, emptiers	2	12	2	16
Truck for slices	2	8	4	14
Diffusion engine	..	2	..	2
Oil men	..	2	..	2
Sulphur box and measuring tanks	..	4	2	6
Water pumps	..	..	2	2
Six defecators	2	4	2	8
Bag filters	1	8	..	9
Concretor trays	4	..	4	8
,, stokers	2	8	4	14
,, juice cistern	..	2	..	2
Water floor	..	2	..	2
Double and single effet	2	..	..	2
,, ,, engine ..	..	2	..	2
Syrup cleaner	..	2	2	4
Large engine	2	..	2	4
Boilers (6 at work)	2	20	..	22
Head maistries	2	..	..	2
Second do.	2	..	..	2
Mechanics for cutters	2	..	2	4
Pan stage	2	2	..	4
Centrifugals	2	22	8	32
Coolers	..	2	..	2
	33	128	44	205

"To go a little more into detail as to what is done in this factory. In the first place, the canes are all grown by the neighbouring peasantry, and perhaps the best proof I could possibly give you as to the financial results of diffusion may be found in the fact that Mr. Minchin is able to pay three dollars and thirteen cents (\$3·13) per ton for his canes, though their juice only stands at barely 8½° Beaumé. Yet he is one of the few sugar manufacturers not complaining of the present depression of the times. The canes are brought to the factory door in bullock carts, bound into bundles of, say, about 28 lb. each, which bundles are stacked end on in sheds immediately contiguous to the cutters. About eight coolies are constantly employed taking these bundles on their heads and putting them on a platform 7 to 8 feet high on which stands the mechanic who feeds the slicers. This man takes a knife, cuts the trash band binding the bundle together, and gathering a small armful of canes, puts them into the hopper, down which they appear to be drawn by the rotary motion of the knives. No pressure was needed on the part of the man feeding. These vertical cutters give none of the trouble we experienced with our horizontal cutters at *Nonpareil*. In connection with these machines Mr. Kollmann's advice was something as follows:—'Mind you keep your knives sharp; you must have a mechanic for this work, and he may just as well be employed in doing his work as in eating rice. The very instant therefore that the slices begin to show the least sign of being torn or jagged instead of being cleanly sliced, the machine must be stopped, the knives taken out to be sharpened, and the spare cutter set to work.' Another great point is that the slices should be as thin as possible. Mr. Minchin aims at having his one millimetre, say the 32nd of an inch in thickness; as a matter of fact they as a rule more nearly approach to two millimetres than to one, but the latter was the ideal desired. These slices fall on an endless band which runs in front of all the machines, and discharges on to another sloping carrier by which the slices are carried up to the floor above and discharged into a large wooden hopper. From this hopper they fall into a wooden truck which stands on a weighing machine and contains just one-half of the ordinary charge of a diffusion cell. As the diffusors hold 1725 lb., each waggon was loaded with chips of half that weight, and was then slid along a little wooden tramway and its contents shot into the diffusor that was being filled. The moment this was done two coolies jumped into the diffusor and pressed the chips down with their feet. Two or three minutes afterwards a second truck-load arrived and was dealt with in a similar manner. The diffusor was then screwed up and instantly attached to the battery. Of the twelve cells only about nine were as a rule kept at work; and a cell was filled and diffused and emptied on an average every eight minutes throughout the week. Mr. Minchin gave me a very interesting account of how very different his results were when he first started diffusion twenty years ago. It appears that the Aska works were in those days in a rather bad way, and Mr. Minchin took advantage of sick leave to visit Europe and endeavour to gain information of any suitable appliances for improving the financial condition of the works of which he was then manager. He traversed Germany and France without seeing anything which he thought he could adapt to his own factory; but in Austria he came across M. Julius Robert who had just invented diffusion and was struggling to convince the beetroot manufacturers of its suitability to their needs. We all know that it has since then proved itself to be the saviour of beet. Mr. Minchin firmly believes that it is destined to be the saviour of the cane also. So struck was he with what he saw in Austria that he went back to London, got the sanction of the consignees there, and instantly started for Aska, where he constructed a diffusion battery for himself, consisting of vats very similar to what we use in our liquor lofts, only of somewhat smaller diameter. These vats contained about two tons of canes which, when exhausted, were discharged through a door in the side, the whole arrangement being so crude that in those days it took some twenty minutes to fill a diffusor, twenty minutes to exhaust the chips, and twenty minutes to discharge them—processes which, as I have already said, are now completed in eight minutes. It may, I think, interest you to have a statement of the temperatures and densities at which the Aska battery is worked. I took several notes of the condition of the various vessels during my stay there and will give you a few samples. I will ask you to bear in mind that in every case No. 1 means the cell containing the fresh juice, from which therefore the liquor is being drawn for the clarifier loft; while Nos. 8 or 9 represent the cell containing the exhausted chips, and which, therefore, is about to be discharged. I must ask you further to remember that the Aska battery is discharged by what is known as "the wet process"; that is to say, the bottom of the cell is taken away and the 1725 lb. of exhausted chips and 200 gallons of hot water are allowed to fall out as they please. The disadvantage of this process is that you waste 200 gallons of hot water every time you empty a diffusor. At *Nonpareil* we have the dry process; that is to say, we force the hot water from cell No. 9 into cell No. 8 by means of compressed air, and when that has been accomplished we take away the bottom of the diffusor and let the comparatively dry chips fall out. Here then was the state of the battery when I arrived at Aska: No. 1, 124° F.; No. 2, 140; No. 3, 164; No. 4, 186; No. 5, 205; No. 6, 212; No. 7, 205; No. 8, 200; No. 9, 190. You will observe that No. 1 is the lowest in temperature, because the hot juice has just come into contact with the mass of cold chips, through which it has to pass on its way to the clarifier loft. There is also a desire to let down the heat in the last two or three vessels, partly to avoid wasting heat, and partly because the chips if at boiling point would scald the bare feet of the coolies who have to handle them down below. Here again is a statement showing the density of the juice in the battery cells before drawing off the liquor:—

No. 8	0·00 deg. Balling.
" 7	0·26 " "
" 6	0·86 " "
" 5	1·86 " "
" 4	2·40 " "
" 3	3·40 " "
" 2	5·10 " "
" 1	7·62 " "

"You will please note that the above densities are all corrected to a normal temperature of 63° F., and you may further note that whereas vessel No. 1 shows a density of only 7·63° Balling, which is about equal to 4·2° Beaumé, yet the liquor was discharged from that vessel into the clarifier at 11·75° Balling, or 6·5° Beaumé, the reason for this being that, on the Aska battery at any rate, the apparatus for ascertaining the density of the juice requires you to draw your sample from the extreme top of the vessel where the density is lowest. Indeed I found that the density of juice drawn from the top of any vessel really indicated the density of the juice at the bottom of the preceding vessel, and so on. Here is another statement giving the temperature and density of the battery just after the discharge of the 220 gallons of thick juice to the clarifier :—

Vessel No. 1—208°	Fahrenheit	.. ..	9·732 Balling.
" " 2—212	"	.. ..	5·55 "
" " 3—212	"	.. ..	3·632 "
" " 4—206	"	.. ..	2·629 "
" " 5—203	"	.. ..	1·317 "
" " 6—187	"	.. ..	0·364 "
" " 7—140	"	.. ..	0·02 "

"Vessel No. 1 in this case discharged its juice into the clarifier at 11½° Balling. These three statements will, I think, enable you to form some idea of the normal temperature and density of the juice in the Aska battery. I may mention, however, that we very rarely got the diffusion juice into the clarifier as high as 6° Beaumé. As a rule it was about 5½°, the cane juice being 8½°, which amounts to about 60 per cent. dilution as against the 30° per cent. which the Sangerhausen firm have guaranteed to me as a maximum. Mr. Kollmann obtained about 87½ per cent. of the weight of the cane by diffusion, and he considered that he threw away only about 2½ per cent. of the juice in his water. This juice showed no acid reaction when tested by litmus paper. The cane slices, however, did show a slight reaction—they coloured the paper about as much as one's finger discolours it when gently laid on a strip of litmus.

"Another point which must be mentioned in connection with diffusion is that at Aska they always draw rather more than the entire contents of a vessel from the battery. For instance, at Aska, the vessels hold just 200 gallons of juice in addition to the 1725 lb. of cane. Mr. Kollmann never drew less than 220 gallons, and when the juice got a trifle sweeter he sometimes took as much as 235 gallons, experience having taught him if he failed to do that he might lose a small quantity of his sweets when he discharged his chips and water. He impressed upon me especially that if any accident brought me to a standstill with my battery the temperature of the various vessels should be kept above 160° and below 200°; above 160° because at that temperature fermentation cannot take place; below 200° because he found that if the juice was kept stewing in the battery for any length of time at that high temperature it always gave trouble in the pans and showed a falling off in the return of *masse-cuite*. I especially asked both Mr. Kollmann and Mr. Minchin about the water question. They both laid stress on the desirability of having good water; but, added Mr. Minchin, 'that is equally true of the water with which you supply your boilers. If I could afford it I would filter all the water that went into my diffusion battery, and I would also treat the water which went to my boilers in the same way.'

"He told me that two or three years ago, when they ran very short of water at Aska, he used all his condenser water —I mean, not condensed water, but the water which was pumped through his condensers for diffusion, and found scarcely any appreciable diminution of sugar as the result.

"I may further mention that, a few months ago, while they were trying diffusion in Australia in connection with a plant erected by the *Fives-Lille* people, they ran short of water and actually used over and over again the liquid—I can hardly call it water—which they obtained by passing the exhausted chips through their mill. Of course, this must have been full of impurities, yet the proprietor of the estate was so pleased with the results which he obtained, even under such adverse circumstances, that he has, I understand, ordered a second battery from the *Fives-Lille* people. The water usually used at Aska is perfectly clear river water, and it goes from the battery into the sulphur boxes perfectly clear, resembling very fine hock in colour, and as different from the green liquid which we get from our mills as anything can possibly be.

"Mr. Minchin knows that the moment the smallest tendency to cloudiness, or an appearance of feathery streaks, occurs in his diffusion juice, that something is going wrong with his battery. The diffusion juice is drawn from the battery into the measuring tank, passes through the sulphur boxes, where about 60 lb. of sulphur are burnt in the 24 hours, and runs into the defecator holding 450 gallons, where 1¾ gallons of lime water, standing at 15° Beaumé, is added, and the liquid is brought up to boiling point. Very little skimming is necessary, and the scum was so small in quantity that the product of 450 gallons could all be taken away in a single galvanised bucket.

"Mr. Kollmann explained this absence of scum by saying that the bulk of the mucilage and albumen was left in the chips. Albumen coagulates at 160° F., and as the battery there is worked above that temperature the bulk of the albuminous matter becomes fixed in the chips. 'You won't know,' said he to me, 'what a good thing you have got in diffusion until you come to deal with the juice.' From the defecators the juice, standing at about 5½° Beaumé, was run through bag filters, 180 being kept at work for 24 hours and purifying the product of about 140 tons of cane. I got some of these bags just as they were being changed, and we weighed the slush found in them. From 13 lb. to 15 lb. of wet mud were taken from each of them, and this when dried gave only 5 lb. of hard dirt as the result of say 1 ton of diffusion juice. This shows, I think, that no very large amount of impurity could have been left in the juice; so the absence of scum cannot be explained in that way. The juice was then run from the concretor battery. It generally went on the battery at 5½° Beaumé, and after remaining 7½ minutes *in transitu* came off at 11° Beaumé. Two batteries easily performed the whole work. Indeed on an average 50 per cent. of the juice was evaporated by these trays. The juice went on clear and came off clear, and was not appreciably darkened by the fierce heat of the trays, no change of colour having taken place other than that which necessarily occurred through the change in density. As I was very desirous of finding out the fuel cost of returning the juice to its original density, Mr. Kollmann made an experiment one week, carefully weighing every pound of fuel burnt under the concretor trays, and taking his juice off at as nearly as possible the same density as the mill juice, viz. at 8½ B. We found it took 12½ tons of wood to deal with the juice from 100 tons of canes; and as 100 tons of canes gave at least ten tons of sugar, it follows that less than half a ton of coal per ton of sugar was burnt in undoing the very heavy dilution practised at Aska, although that dilution is just double what the Sangerhausen firm guarantee me.

"To put the matter in another way. At *Nonpareil*, if we diluted the product of my daily task of 400 tons of canes to the same extent as is done at Aska, I should require a triple effect of 5500 square feet of heating surface to take out the water which I had put in. If, on the other hand, I diluted only to the extent of 30 per cent., I should require a triple effect with a total heating surface of 2600 square feet to restore my juice to its original density.

"While on the question of fuel, I may as well sum up all I have to say on the matter. I have already said that six boilers are kept constantly fired at Aska, and I have given you a description of their make. The total fuel consumed in the Aska works, apart from the foundry—that is to say, for the concretor furnaces, the boiler, and the distillery—averages throughout the crop, 6 tons of wood to 10 tons of cane. Six tons of wood mean, I suppose, about 2 tons of coal, and 10 tons of cane mean 1 ton of sugar; and that in a factory where dilution is carried to its extreme extent, and no great desire is shown to save fuel or make the most out of the sweets. In addition to this, the chips were dried and burned, about one-half of them during diffusion season and the other half after its close. I estimate the chips consumed during the diffusion season to be equal to about 25 tons of wood, not a very material item spread over 1000 tons of sugar.

"When the juice leaves the concretor trays standing, say at 11° Beaumé, it is taken into the double effect, which evaporates as nearly as possible one-third of a gallon per square foot per hour, and is brought there to a density of about 25° or 26° Beaumé. It is then struck, 400 gallons at a time, into a kind of eliminator, where it is brought to boiling point five or six times, much as we used sometimes to deal with our juice in the old-time clarifier days. The syrup is then left for about 15 minutes, after which all except the extreme bottom is run to the syrup tank, whence it is drawn to the vacuum pan in the usual way.

"The *masse-cuite* is boiled up to 50° Beaumé, and struck out into iron boxes. It is very good in appearance, and has scarcely any molasses on its surface. In from 24 to 48 hours it is dug out with shovels, pugged, and run through the centrifugals. As white sugar is desired, ¾ gallon of water at least is used for each centrifugal, and steam is turned on whenever needed. As a result they obtain from 41 to 44 per cent. of pure white sugar. The molasses is boiled up, and struck into the bamboo-lined boxes which I have described. In the event of a specially dry molasses sugar being required, they sun their second product for 5–6 hours on the roof of their factory before they bag it. As a rule, however, the sugar is simply taken from the boxes and sent into consumption. From the sample on the table you will see that it is decidedly superior to the ordinary molasses sugar shipped from this colony.

"In default of a good local market, they simply store their sugar, and refine it as soon as their 100-days' diffusion season is over. When refined, it yields 45 per cent. of pure white sugar, the molasses reboiled gives a further 7 or 8 per cent., and the remaining 48 per cent. of the *masse-cuite* is sent to the distillery.

"Owing to these various methods of dealing with the second sugar, it was difficult to get an absolutely exact return of the second quality of sugar resulting from the canes. All through there was perfectly plain sailing as far as the *masse-cuite* was concerned. This *masse-cuite* weighed 93½ lb. to the cubic foot, and 13 to 14 per cent. was obtained from the canes, the juice averaging 8½° B. This I take to be fully 20 to 25 per cent. more than we get in this colony from similar canes.

"Before I leave this part of the subject, I should like to impress upon you that the ordinary average Aska work produces one ton of sugar from four punts of canes, although the juice in their canes is slightly inferior to the average juice in this colony. To put this in other words; they average 1 ton of sugar from every 10 tons canes; and two-thirds of this sugar is pure white, the balance being good molasses sugar.

"Now, as to *Nonpareil*, I do not mean to go into any great detail on this subject. It will be sufficient for me to tell you that, owing to the faulty construction of our cutters, 108 tons of cane, which ought to have been sliced in six hours, occupied 48 hours in cutting, and the juice, which ought to have been run through the battery in about 1½ hour, was kept stewing sometimes at over boiling point, for more than 24 hours, and when it was discharged into the clarifier loft it had to remain for another long period before we got sufficient for the triple effect to deal with. Altogether, juice which ought to have been dealt with in 6 hours had to remain for 52 hours before we got it into *masse-cuite.*

"No words of mine are necessary to tell you that a trial conducted under such circumstances is no trial at all. I should not have been surprised had we got very little sugar from our experiment. As a matter of fact, however, we obtained just 20 per cent. more *masse-cuite* than we got from a similar quantity of canes passed through our mill, the return of *masse-cuite* in the one case being 14·63 per cent. on the weight of the canes, while the *masse-cuite* obtained from the same weight of canes by our mill was 12·14 per cent.

"I am sorry to say that the Sangerhausen people omitted to put in a weighing apparatus, in spite of my having warned Mr. Schultz on the subject. The consequence was, that we had to subject our canes to a great deal of handling, and to delay our process while this handling was going on. The result, both when we tried diffusion and when we tried milling, was very apparent, for the canes which, before we had pulled them about, transporting and weighing them, gave us a quotient of purity of 95, after being handled gave us a quotient of purity of only 82 when we sliced them for diffusion, and 84 when we crushed them in the mill, the glucose having been increased by no less than 2½ per cent.

"Our trial was, I considered, so far satisfactory that it showed us that in spite of very adverse conditions diffusion gives us almost the exact increase over mill returns which I calculated as probable from what I had seen at Aska. It showed us also that the battery could be manipulated by our own people without difficulty.

"And finally, it laid altogether one bugbear which has been prominently brought forward by advocates of the mill. I refer to the disposal of the chips. This was really a serious matter, for at *Nonpareil*, when in full work, we should have to deal with two tons of chips every eight minutes, and Mr. Kollmann warned me at Aska that this was by far the most serious difficulty with which I should have to contend. So much did I fear this that I sent out half a mile of wire tramway for the purpose of sunning and burning the chips, as I had seen done by human labour at Aska. To our great relief, however, we found that our mill, the trash turner of which had been slightly raised, took our chips readily, and redelivered them to us containing only 55 per cent. moisture, and therefore in a state to form excellent fuel. They were thrown into our green-megass furnaces, and as soon as these were got warm, the chips burnt readily. Mr. Llewellyn Jones is of opinion that we may now safely count upon this difficulty having been overcome, though it is possible that some slight modification in the arrangement of the furnace bars may be advisable.

"I have only two points more to refer to, and will then conclude. In the first place, I was disappointed with the colour of our diffusion juice. We used bush water instead of the beautiful river water at Aska; but Mr. Kollmann had told me we should probably find this thoroughly filtered by passing through the diffusors, his idea being that the chips themselves would take up the impurities in the water. I do not know whether the long exposure to a high temperature injuriously affected the juice; probably it did; but when it got to our clarifier loft it was not nearly as clear and bright as I hoped it would be.

"My second remark is with reference to the cutters. We found that the description of cutter furnished by the Sangerhausen people at first would not work at all; the cush-cush being thrown to the edge of the disc accumulated there till it formed such a powerful brake that you could not pinch the machine round even with crowbars. Mr. Jones obviated this by cutting small openings at the edge of the machine and making a simple arrangement for throwing out the cush-cush, thus preventing the machine from coming to an absolute standstill. At the same time, however, we were very much interfered with all through our trials by the accumulation of cush-cush and of shreds of cane on the outer portion of the knives. Probably not less than from 15 to 20 per cent. of the cutting surface of the knives was rendered useless by this cause. Then we found that these horizontal cutters required to be fed with considerable force, or they would not take the canes at all. As a matter of fact, these horizontal cutters, which were expected to slice 200 tons of canes each in 24 hours, actually got through only one-eighth or one-tenth of that quantity, while they required six men to feed them, whereas the Aska machine easily sliced 60 tons in the 24 hours, and only needed one man at the hopper. By the terms of my contract it is the business of the Sangerhausen people to supply me with proper cutters, and until they have done so I shall of course resume my ordinary milling operations, merely using the interval to put on a hydraulic apparatus to our large mill so as to provide a safety valve in the event of a bolt or other hard material getting between the rollers, which, as they are set nearly metal to metal, when the exhausted slices are passing between them would be especially liable to a big smash in the event of any hard substance getting mixed up with the begass."

The following notes on the fuel question in the diffusion process are taken from a paper by J. M. C. Paton, published in the *Sugar Cane*, May 1886:—

During the last few years the attention of cane-sugar planters has been called very strongly indeed to the urgent need for improved methods of dealing with the cane, and the most economical means of extracting as large a proportion as possible of the crystallisable sugar it is known to contain.

The diffusion process having proved such a decided success in connection with beet-root sugar, it is only natural that the question of its adoption for dealing with cane should receive considerable attention.

The experiments recently carried out in Java appear to have excited much interest in that country, but after reading Mr. Sargent's translation of the report of the committee, as it appeared in the *Sugar Cane*, there does not appear to have been any very new light thrown upon the matter.

No one who had paid attention to the subject can have doubted that a large percentage of juice would be extracted by diffusion as compared with ordinary crushing in mills, but the question of fuel at once crops up, and almost in every case it has been sufficient to cause planters to hesitate before adopting an otherwise tempting process.

It may be taken for granted that there is no difficulty in the slicing of the canes and the extraction of an amount of juice equivalent to 80 per cent. on the original weight of the cane. It may also be taken for granted that this 80 per cent. of original cane juice will be diluted with sufficient water to bring the diffusion juice up to the weight of the cane from which it has been extracted. The figures will of course vary slightly under different conditions, but the above result is easily obtainable, and will serve as an average for purposes of comparison with other methods of juice extraction.

Enthusiastic believers in diffusion as the grand remedy for the present state of things usually underestimate the real proportion or effect of the added water. The usual line of reasoning is somewhat as follows:—A good mill will give us say 70 per cent. of juice, or 70 lb. of juice from 100 lb. of cane. By employing the diffusion process it is possible to get 80 per cent. or 80 lb. of juice from 100 lb. of cane. It is true the 80 lb. will have had 20 lb. of water added to it, so that the diffusion juice will weigh 100 lb., and of the 100 lb. of diffusion juice only 20 per cent. is added water, consequently one-seventh more sugar will be obtained and there is only 20 per cent. more water to be evaporated.

The above mistake is made so frequently that it appears desirable to call attention to it, and to point out that the quantity of extra fuel required for working sugar cane by the diffusion process is likely to be a serious question when it has not been fully anticipated and provided for.

Those who advocate maceration or double crushing with mills, usually speak of very large percentages of juice, but it may perhaps be better at present to compare diffusion and ordinary crushing.

Taking 70 per cent. as good work for a mill, and taking the *masse-cuite* as equal to 20 per cent. on the juice, we see that from every 100 lb. of cane the mill will give us 70 lb. of juice, from which, after evaporating 56 lb. of water, we obtain 14 lb. of *masse-cuite.*

Taking diffusion juice as equal in weight to the cane, and presuming that 80 per cent. of the original juice is obtained, then the quantity of *masse-cuite* will be raised from 14 to 16, while the amount of water to be evaporated will be raised from 56 to 84 lb. We have 2 lb. increase in the yield of *masse-cuite,* and we have to evaporate 28 lb., or 50 per cent. more water.

In round numbers the amount of added water is about two and a half times as much as it is represented or thought to be.

In a good modern sugar factory, fitted with heavy mills, economical boilers, triple-effect evaporating apparatus, &c., it is found that the crushed cane furnishes sufficient fuel for all purposes, and it is nothing unusual for a large quantity of begass to be left over at the end of the season.

In factories which have not yet been furnished with modern appliances for effecting economy in fuel, it is found that a considerable sum has to be spent on fuel, and from half a ton to a ton of coal for a ton of sugar is not uncommon, in addition to the whole of the begass.

Taking the begass as being just sufficient to evaporate the water from the mill juice, it is clear that if diffusion is adopted it will be necessary to at once provide wood or coal equal in evaporative power to at least one-half of the whole of the begass, or in other words, 50 per cent. more fuel will have to be provided.

The above presumes that the chips from the diffusors will be equal in evaporative power to the megass from the ordinary mill, but unfortunately this is not the case.

The chips as discharged from the vessels are fully charged with water and contain at least as much as the original cane. Up to the present time no practical method of drying the chips has been discovered, and even when small quantities are dried by long exposure to the sun, it is found that as a fuel it is much inferior to ordinary megass.

So great is the practical difficulty of dealing with the enormous bulk of soaking wet cane chips that it may be considered certain that it will cost more to handle and dry them than they are worth as fuel, even when they are eventually rendered fit for burning.

It is quite probable it may in the end be found actually more economical from a financial point of view, to get rid of the chips in any possible way, and to provide other fuel, such as coal or wood, for all purposes of evaporation and manufacture.

Unless these points are fully appreciated it is extremely likely that any planter adopting the diffusion process will be much disappointed with the financial result, to say nothing of the annoyance and worry caused by an insufficiency of fuel and the consequent interruptions to the work.

The amount of capital invested in a sugar estate is so large, and the interests at stake so important, that owners as a rule display a very conservative spirit whenever any radical or sweeping alteration is proposed. It consequently becomes most important that when so serious a question as the adoption of diffusion is contemplated, that there should be no hopes held out as inducements unless there is every reason to feel satisfied the results in actual practice will be fully equal in every particular to what was anticipated or promised.

There are now many crushing mills at work, giving a result equal to over 70 per cent. of juice from the cane, but a still larger number are giving probably nearer 60 per cent. The owners of the latter have still such a large field for improvement before them, without leaving the beaten track, or the adoption of plant which has not yet received general approval, that it is not likely the subject of diffusion would have such a keen interest for them as it has for those who have already adopted most of the improved methods of working, and are already reaping the benefit of their foresight and enterprise.

It will always be much easier to adopt the diffusion process when arranging an entirely new factory, than when it is desired simply to replace a crushing mill by a diffusion battery. The reason for this will be at once apparent if the increase in the amount of water to be evaporated, and the altered condition or character of the fuel are taken into account.

Any sugar planter about to erect an entirely new factory, and intending to adopt the diffusion process, will be most likely to arrive at a satisfactory result if he will from the first totally ignore the value of the cane chips as fuel, and at once have the furnaces and boilers arranged to work entirely with coal. Modern appliances to secure economy both in fuel and steam, are so efficient, that an improved result, from a financial point of view, may be looked for even under these conditions.

Looked at simply as a process for extracting a large percentage of sugar from the cane, diffusion is beyond question a great success, but most planters are more anxious to make money than to make sugar, and consequently the whole matter hinges on the question—will it pay? This, in its turn, hinges almost entirely on the question of fuel.

The friends of diffusion will do it much injury if, in their great admiration for the process, they lose sight of, or underestimate the importance of this point. Unless the fuel question is boldly faced, and amply provided for, nothing but disappointment will result, and the result of one failure will be to frighten any who may be at present thinking seriously of adopting the process.

It is unfortunate that little or no reliable information with regard to this most important question of fuel is available. Reports on experiments with diffusion machinery usually go into great detail when endeavouring to show exactly, to a fraction of one per cent., what increase will be found in the quantity of sugar contained in the diffusion juice, but they pay little or no attention to the consumption or other points in connection with fuel, although any uncertainty about this latter subject may result in the entire sweeping away of all gain arising from increased production.

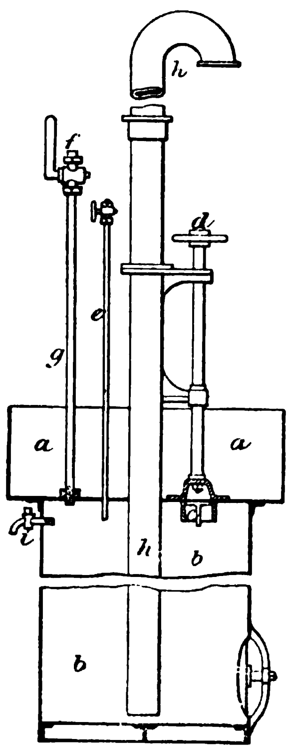
It may, however, be taken for granted that it is quite possible to erect a new factory to work with the diffusion process, which will, after making all necessary allowance for fuel, still show a better financial result than is likely to be obtained from an ordinary mill plant. How far this will be true of an altered factory which has previously been working with a mill, will depend entirely on the way in which the alteration has been designed and carried out, or in other words, on how nearly the old factory has been made to resemble the new one in the arrangements and proportions of its details.

Pumps and Substitutes.—As the apparatus by which the juice is extracted from the cane is generally situated on the ground floor of the building where the operations are conducted, it becomes necessary to consider what means shall be adopted for raising the juice into the other vessels where it is to undergo purification and concentration. Though the subject does not apply specially to sugar-making, yet it is one which demands great attention from the sugar-maker.

For many years, planters contented themselves with ordinary force-pumps, worked from the mill; but these possessed many disadvantages, among which might be included their limited capacity, the churning of the liquid and consequent admixture of air, and the contamination of the liquid with the grease used in their lubrication.

Gradually the *monte-jus* (or "juice-raiser") began to be copied from the French manufacturers. This useful apparatus is made in many forms, one of which is shown in Fig. 63. Its construction and mode of working are sufficiently simple. The body of it consists of two chambers *a b*, separated by a steam-tight diaphragm; the upper chamber *a* receives the juice to be elevated while the charge in the lower chamber *b* is in course of elevation, and it is made of suitable capacity for that purpose. When the lower chamber *b* is empty, the valve *c* is raised by turning the handle *d*, while the tap of the air-pipe *e* is opened. The juice contained in the upper chamber *a* immediately descends through the valve *c*, any air that may have been imprisoned in the chamber *b* escaping through the air-pipe *e*. This air-pipe extends about 6 inches into the lower chamber *b*, for the purpose of ascertaining when the chamber is sufficiently full, the escape of air through the pipe *e* being, of course, stopped as soon as the juice reaches its lower end. The cessation of the whistling noise made by the air rushing through the end of this pipe *e* constitutes

FIG. 63.



Monte-jus.

the signal for screwing down the valve *c*, to prevent any further flow of juice into the lower chamber *b*. The air-tap is then closed, and the steam-tap *f* of the steam-pipe *g*, communicating with the boilers, is opened, when the empty space between the surface of the juice and the top of the lower chamber *b* is immediately filled with steam, which at once commences to drive the juice out through the discharge-pipe *h*. As this pipe is carried down to within a short distance of the bottom of the *monte-jus*, nearly the whole of the contained liquor is forced out of the lower chamber *b*. As soon as any indications of steam appear at the mouth of the discharge-pipe, the steam-tap *f* is shut, and the valve *c* and air-tap *e* are opened to let in a fresh charge.

It will thus be seen that the action of the *monte-jus* is exceedingly simple, only one precaution being necessary, viz. to shut the valve *c* through which the juice is running, in time. If the juice be allowed to reach the top plate of the chamber *b*, the steam, when let in through the pipe *g*, will mix with and boil the juice, but will not elevate it; considerable difficulty and delay sometimes arise from this circumstance. As a precaution against carelessness, an overflow-tap *i* should be fitted to the shell of *b*, a few inches below the top, so that the superabundant juice might be drawn off. The cane juice, as it comes from the *monte-jus*, is said to be sufficiently warmed to retard fermentation on its way to the clarifiers.

While this instrument remains by far the most generally-adopted means of raising cane-juice, its superiority has not been unchallenged. It has been objected that its interior is not readily accessible, and that it is therefore difficult to keep clean, whereby fermentation may be caused in the juice by the presence of accumulated dirt within the *monte-jus*. It is also urged that the liquor is diluted by the admixture of condensed steam.

Hence, in many cases, the *monte-jus* has been replaced by centrifugal pumps. In favour of these, it is advanced that there are no valves or other mechanism to become a refuge for dirt, no air nor steam is forced into the liquor, and, with properly adjusted arms, the juice is raised in a solid column without churning. Many statements, however, point to the fact that the churning is often seriously worse than with the *monte-jus*. In the best central factories, steam in the *monte-jus* is replaced by air under a pressure of 60 lb. per square inch, thus obviating most of the drawbacks that have been complained of.

Large numbers of pulsometers are now employed in sugar factories for raising juice, being well adapted to the work, owing to the absence of all moving parts except simple valves.

CHAPTER IV.

DEFECATION AND CLARIFICATION.

HAVING, by any of the methods just described, succeeded in extracting as much as possible of the juice from the cane, the next operation is to eliminate from that juice all the matters which are to be regarded as impurities from the sugar-maker's point of view, in other words, everything except the sugar and the water holding it in solution. What the impurities consist of has already been described (see p. 106). Their proportions will vary with circumstances, much depending upon the method of extraction employed.

Preliminary straining.—First of all, unless the juice has been extracted by the diffusion process, it is necessary to remove the gross impurities derived from the breaking up of the canes, and known in Guiana as "cush-cush." This may be done by a series of strainers, arranged so as to be easily removed, cleaned, and replaced.

One of the best contrivances for straining is a modification of the endless wire-web strainer, not essentially different from the endless wire web on which the rag-pulp of paper-works is received, and on which it is agitated and filtered from a great part of its water,—only that at the paper-works the valuable part of the mixture remains on the web, while here the solid part is to be rejected, and the filtered part retained as valuable. The straining web is of fine wire-gauze, and revolves on three horizontal rollers, two of which are on the same level, as the upper angles of an inverted V, the third being at the lower angle, and immersed in a vessel of water. The greater part of the "cush-cush" is removed from the web by a scraper set almost in contact with the web, just after it has turned over the roller in its descent. The web then descends into the water, and is washed, and finally any matter still adherent is removed by a brush so set as to be in contact with the web as it rises out of the water. A clean surface of wire gauze is thus at all times present to receive the stream of juice; an effective straining is always obtained with much less wear and tear of gauze web than occurs from the frequent scrubbing required by the webs of ordinary straining-boxes, and the extremely careless way in which this scrubbing is generally performed. The wire-gauze in common use varies from 40 to 60 threads per inch, but it can be obtained of 80 threads, and, if copper wire-gauze, of 90: the finer the gauze the better, provided the rate at which the web travels is such as presents a clean surface as fast as is necessary, and the scraper, brush, and water in the trough, are all carefully looked to and kept in order.

The strained juice is received in a shallow tray placed immediately under the horizontal part of the straining web, and passes from thence by a gutter to the clarifier.

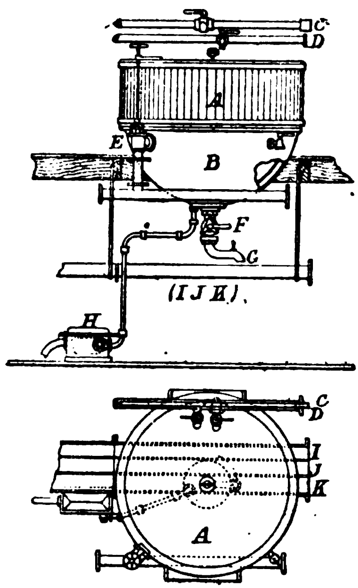
The chief agencies hitherto introduced for effecting the cleansing of the juice are heat, chemical action, and filtration. Their application will now be considered in succession.

Heat.—Heat alone exercises considerable beneficial effect in checking acidity, that is to say, scalding the juice prevents acetous fermentation setting in, probably by destroying the particular fungoid germs which are the necessary accompaniment (presumably the cause) of that fermentation; also, by evaporation, a portion of acids holding the albuminous matters in solution are driven off, whereby the albumen is coagulated and rendered insoluble. But heat is most valuable as an aid to the action of chemical preparations upon the juice, increasing the energy of the reactions set up, and thus greatly reducing the duration of the operation. Hence heat is now universally availed of in recognised processes of defecation and clarification.

Steam defecators and clarifiers.—As the degree of heat employed is a matter of vital importance, it is most conveniently employed in the form of steam, that being readily controlled.

Figs. 64 and 65 represent respectively an elevation and plan of a steam defecator made by Fawcett, Preston, & Co., Liverpool. The part B is composed of a copper, spherically-shaped lining, mounted in a cast-iron casing, to which high-pressure steam is admitted. The upper part A is a light curb of copper or iron to give capacity, and is clothed with lagging to prevent escape of heat. C D are pipes for juice and water; E is the steam-cock; F the cock for drawing off the defecated contents; and G a swivel-mouthpiece to direct the contents of the defecator as required into the clear-juice gutter, the turbid-juice gutter, and the washings-gutter. As the steam condenses in the double bottom of the defecator, the water flows away through the condense-water box H.

FIG. 64 AND FIG. 65.

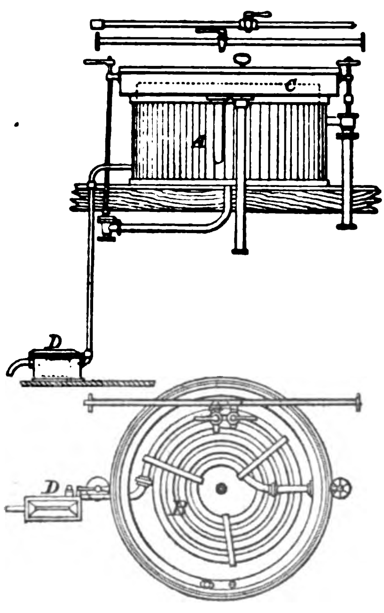


Steam Defecator.

Lately many planters have adopted another system of defecating. Instead of providing 4, 8, or 12 separate defecators, with corresponding equipment of double bottoms, cocks, and pipes, they establish a powerful juice-heater, or vessel full of tubes fixed between two tube-plates. The steam is outside the tubes, and the juice from the mill traverses the space inside the tubes. If the mill gives 1500 gallons of juice per hour, a heater with 300 square feet of surface will deliver the whole into say 3 empty tanks of 500 gallons each; there the juice is defecated and left to subside. By using a juice-heater and 3 tanks, the same result is obtained as by a costly steam-boiler working at high pressure and 4 very costly defecators with their mountings.

Figs. 66 and 67 represent elevation and plan of a steam clarifier and evaporator, made by Fawcett, Preston, & Co., Liverpool, which is used for treating the syrup after it leaves the triple-effect (see p. 324). It is a cylindrical vessel provided with a steam-worm B fitted in the lower part; at the upper part, a border and gutter is formed, into which the scum is brushed as it rises on the syrup. The condensed steam in the shape of hot water passes through the box D, which has a float and cock to prevent uncondensed steam from passing uselessly away. The exterior A is lagged to economise steam by preventing the syrup from cooling. Every means must be adopted to save heat and fuel in a sugar factory, as it may be stated generally that 240 H.P. of steam are required to make a ton of sugar per hour, or 20 H.P. per hour for 12 hours; and in many sugar-producing countries, coal at the furnace-mouth costs 3*l.* a ton.

FIG. 66 AND FIG. 67

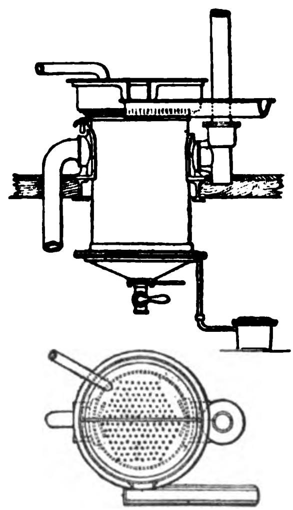


Steam Clarifier.

The open-top juice-heater or sap warmer, made by

Manlove, Alliott, Fryer, & Co., Fig. 68, consists of a strong vertical cylindrical wrought-iron shell with tube-plates at top and bottom, top distributing chamber with vertical division, and a conical bottom with large clip valve and run-off cock admitting of the heater being emptied and the bottom chamber readily cleaned out. The heating surface consists of a large number of solid drawn brass tubes of small diameter, with special fixing in the tube-plates, which latter are arranged to admit of the expansion of the tubes without leakage. Exhaust steam from the factory engines is admitted into the vertical chamber surrounding the tubes, and the condensation water is withdrawn automatically by means of a steam-trap. Any surplus steam not utilised escapes to the air through a back pressure valve loaded to a few pounds above atmospheric pressure. Raw juice from the mill is pumped up into one of the divisions of the top chamber, passes downwards through a brass strainer and through one-half of the tubes into the bottom chamber, thence upwards through the remaining half of the tubes into the top chamber, from which it overflows into a gutter or pipe, and is led off to the clarifiers. Any sediment collecting in the bottom chamber is withdrawn by the clip-valve already mentioned. The tubes can be cleaned at any time without interfering with the flow of juice. This heater can be readily inserted into any existing length of gutter in a factory without altering the present levels of the machines, and at the end of the day's work the few gallons of liquor remaining in the heater can be run off into a bucket and carried

FIG. 68.

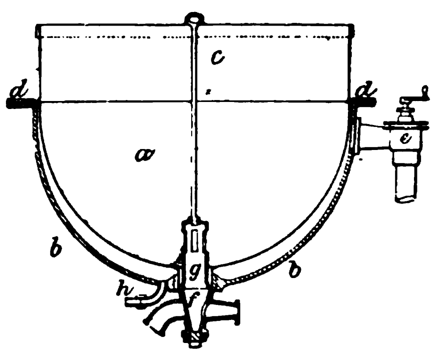


Open Juice-heater.

to the clarifiers or led down into the scum tank. In the many factories where this heater has been adopted, a marked saving has been effected in the number of clarifiers used and the time required to treat juice in them. An exhaustive series of experiments carried out with an ordinary closed-topped heater showed that the efficiency of the heating surface fell off nearly 30 per cent. in the course of half-an-hour's work, thus demonstrating the urgent necessity of providing in all such heaters means for cleaning the tubes at short intervals, and without throwing them out of work.

Fig. 69 is a section of a steam clarifier 5 feet in diameter. It consists of a hemispherical copper pan *a*, hammered out of

FIG. 69.

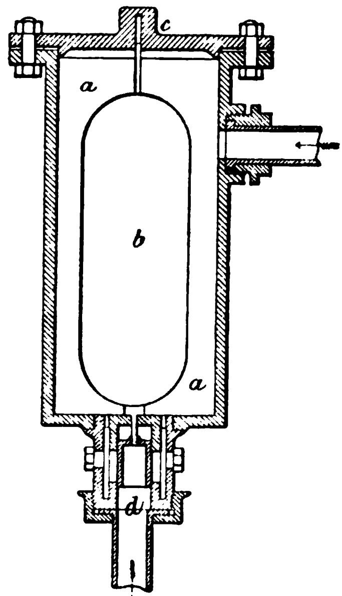


Section of Steam Clarifier.

one piece of metal, and fixed by a flange laid off to an outer cast-iron pan *b*, the space between the two pans forming a steam-jacket. A copper light-course *c* is fixed on the top, and a wrought-iron ring *d* is laid on the flanges, the whole being bolted through with $\frac{7}{8}$-inch bolts, 4-inch centres. At the side is attached a valve *e* for regulating the supply of steam; and a gun-metal two-way cock *f* is fitted at the bottom, the smaller branch for drawing off clarified juice, the larger for the scum. The gun-metal plug *g*, with copper rod and handle, ground into the top of the cock *f*, is withdrawn when the scum and heavy matters are to be let out. At the bottom of the cast-iron pan *b*, is inserted a small wrought-iron pipe *h*, by which the water is carried off to the condense-box.

Fig 70 shows a section of the self-acting condense-box, through which condensed water from the various vessels passes on its way to the boiler-feed cistern. The cast-iron box *a* is fitted with a cover *c*; *b* is a copper float, with a pin at the top which slides vertically in a groove in the cover *c*. The float is connected at bottom with a simple valve arrangement *d*, which it opens when a sufficient quantity of water has accumulated in the box to raise it. The condensed water can thus flow away without any escape of steam.

FIG. 70.

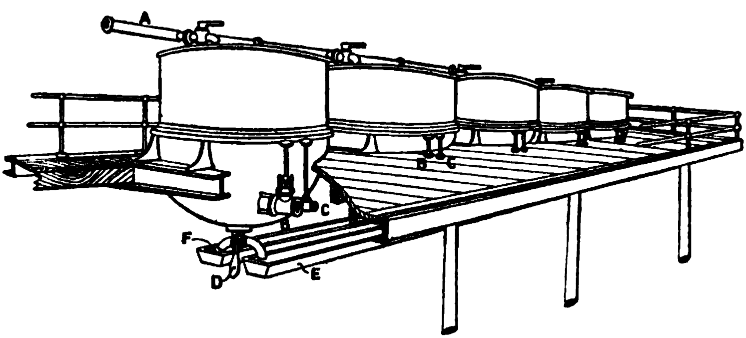


Condense-box.

The use of the clarifier may be described in general terms as follows. The juice in the clarifier is raised to a temperature of 80° C. (176° F.), and sufficient milk of lime is added to neutralise the acid in the juice. The heat is then continued till a scum, consisting of impurities present in the juice, has risen to the surface, and appears about to crack. The time occupied in this should be about 10 to 12 minutes from the commencement of the operation. The steam is then shut off, and the liquor is allowed to subside for 15 to 20 minutes, when the scum will be found to remain at the top; some heavy matter will have fallen to the bottom, and between them will be the clarified cane-juice, clear and of a pale straw-colour. The clarification being complete, the two-way cock is first turned on to the smaller aperture, until the top scum begins to appear; the cock is then turned to the large way, and the plug is taken out. The heavy matter at the bottom and the top scum are conveyed to a cistern, whence they are placed in bags, and any juice remaining in is squeezed out, leaving only a small portion of solid matter behind.

Fig. 71 shows a series of hemispherical clarifiers, with double bottoms, as made by Manlove, Alliott, Fryer, & Co.,

FIG. 71.



Double-bottomed Clarifiers.

Nottingham. This type of clarifier consists of a cast-iron hemispherical outer bottom and copper inner bottom, usually made strong enough to allow of steam of the full pressure of the factory boilers being admitted to the space between them. The parallel sides are made of brass, with a strong rolled rim at top. The cast-iron bottom is provided with feet, which serve to carry the clarifier on the staging. An arrangement of 5 such clarifiers is shown. A is a copper pipe conveying raw cane juice from the juice heater, or direct from the juice pump on the mill, and is fitted with a large gun-metal cock for filling each clarifier. As soon as the copper bottom is covered with juice, steam is admitted by the valves B or C—

B for exhaust steam from factory engine, and C for high-pressure steam direct from the boilers. The clarifier is filled to within a few inches of the top, lime or other chemical is added, and the heating is continued until a thick scum forms on the top, which, after a time, cracks and begins to break up. Steam is then shut off, and the sediment is allowed a few minutes to settle to the bottom.

The discharge cock D is fixed on a heavy gun-metal neck fitted to the copper bottom, and extending through the cast-iron bottom, with suitable means for obtaining a steam-tight joint at outlet. The upper part of the neck is furnished with a hollow plug, extending nearly to the top of the clarifier, and provided with a handle by which it can be lifted out when desired. A series of slots are formed in the plug a few inches above the bottom of the clarifier. The cock D being opened, the clear juice flows out through the slots, plug, and cock, and into the clear juice gutter E, which carries it to the settling tanks. This is continued until the level of the juice in the clarifier falls to the level of the slots, and the dirty juice begins to appear. The cock is then shut off from the clear juice gutter, and opened to the foul juice and dirt gutter F, and the plug is withdrawn, when the remaining sediment and scum is run off into F, and thence to the scum room for treatment.

To obtain the best results from such clarifiers, the depth must not exceed a certain proportion of the diameter. A clarifier of large capacity may be made very cheaply of small diameter, with high parallel sides, but of course at a great sacrifice of heating surface and efficiency in working.

Chemicals.—Of these the most important and hitherto most widely used is slaked lime; following it come sulphite of lime, sulphurous acid, lead acetate, and sundry special compounds, as well as antiseptics.

Lime.—The word "defecation" implies the removal of the fecular matter, or the breaking up of the albuminous compounds. This is effected to a certain extent by heat, which evaporates a portion of the acid holding the albuminous matters in solution, whereby the albumen is coagulated and rendered insoluble. But this result is much more completely attained by the simultaneous application of a strong alkaline earth, such as lime, which combines with the liberated acids. It must be borne in mind, however, that any excess of lime beyond what is required to neutralise these acids, will re-dissolve the coagulated albumen, and preserve it in a state of solution, until the excess of lime is again neutralised by addition of acid. The operation, which is called "tempering," is thus obviously one of extreme delicacy.

The first point to be ascertained, when any pretence is made to working on a rational system, is the exact amount of lime required by a given quantity of cane-juice. A simple method of doing this has been described by Dr. John Shier, in a little pamphlet published by Griffin & Sons, Garrick Street, Covent Garden, London, who are also makers of the apparatus employed.

A bottle containing exactly 250 septems ($\frac{1}{40}$ gallon) of juice is filled with the filtered cane-juice, the specific gravity of which has just been taken. If any air-bubbles are present, they are got rid of by causing the bottle to overflow. By pouring out a little of the juice, or displacing it by introducing a glass rod, the surface of the juice is made to coincide with the mark on the neck of the bottle, and the outside of the bottle is wiped. The contents of the bottle are then transferred to a beaker. A spirit-lamp is kindled, and screened by a tinplate cylinder provided with a grate. On the grate is placed the beaker with the cane-juice, and the whole is surrounded with a tinplate cylinder, to protect the lamp from currents of air. The cane-juice is stirred occasionally with a glass rod till it boils. After boiling for about a minute, a graduated septem measure is filled to zero (0°) with clear saturated lime-water, and the lime-water is poured from it to the cane-juice, a few drops at a time, till a drop of the juice, applied by the point of a glass rod to a slip of neutral litmus-paper, neither reddens nor blues it, but simply wets it without changing its colour, just as distilled water would do. (The indications of the test-paper are extremely delicate, and it takes some practice to accustom the eye to judge of very slight changes of colour.) This may be called the point of neutrality; when it is attained, the beaker is taken off the lamp, and its contents are allowed to settle for a minute.

If a coagulum, consisting of pretty large flakes, is seen floating about in the perfectly transparent although slightly coloured liquid, and readily separating and subsiding to the bottom of the vessel, the point of proper clarification has been attained,—that is to say, the point of neutrality and the point of proper clarification coincide. The exact number of septems of lime-water used is then noted. If, however, the flakes are small, and do not readily separate from the juice, and the juice is not perfectly transparent, it is not in a condition to filter readily, and, on boiling, would throw up scum, and thus lead to loss of juice—in a word, it is not properly clarified.

The beaker is replaced over the lamp, its contents are again brought to a boil, and more lime-water is added, in small portions at a time, till the indications of proper clarification, as above described, are attained. The juice will now be capable of ready filtration, and, although transparent, will have a deeper tint than if excess of lime had not been required in clarification. The total number of septems of lime-water being noted, the calculation as to how much quick-lime is required for a given number of gallons of juice is easy:—Thus, suppose 250 septems of cane-juice to have required 20 septems of lime-water to bring it to the neutral point, and 10 more to the point of proper clarification, then $30 \times 40 = 1200$, the number of septems of lime-water that

1 gallon of juice would have taken; but every septem of saturated lime-water at the temperature common in tropical boiling-houses contains 0·00862618 of a grain of quick-lime, therefore $1200 \times 0·00862618 = 10·351416$ grains of quick-lime required by a gallon of juice; and it is merely necessary to multiply this amount by the number of gallons' capacity of the clarifier, to find the weight, in grains, of the lime required by the charge of the clarifier. Thus, if the clarifier contained 500 gallons, it would with such cane-juice require 5175·7 grains, or, in round numbers, 11¾ ounces of good quick-lime.

Dr. Shier has compiled a very useful little table, showing the quantity of quick-lime in avoirdupois ounces and drams necessary to be added to 100 gallons of cane-juice, to clarify it properly, according to the indications of the lime-water test:—

Test.	Quick-lime.		Test.	Quick-lime.		Test.	Quick-lime.	
septems.	oz.	drams.	septems.	oz.	drams.	septems.	oz.	drams.
5	0	6¼	37	2	14¾	69	5	7
6	0	7½	38	3	0	70	5	8¼
7	0	8¾	39	3	1¼	71	5	9½
8	0	10	40	3	2½	72	5	10¾
9	0	11¼	41	3	3¾	73	5	12
10	0	12½	42	3	5	74	5	13½
11	0	14	43	3	6¼	75	5	14¾
12	0	15¼	44	3	7½	76	6	0
13	1	0½	45	3	8¾	77	6	1¼
14	1	1¾	46	3	10	78	6	2½
15	1	3	47	3	11¼	79	6	3¾
16	1	4¼	48	3	12½	80	6	5
17	1	5½	49	3	13¾	81	6	6¼
18	1	6¾	50	3	15	82	6	7½
19	1	8	51	4	0¼	83	6	8¾
20	1	9¼	52	4	1½	84	6	10
21	1	10½	53	4	3	85	6	11¼
22	1	11¾	54	4	4¼	86	6	12½
23	1	13	55	4	5½	87	6	13¾
24	1	14¼	56	4	6¾	88	6	15
25	1	15½	57	4	8	89	7	0¼
26	2	0¾	58	4	9¼	90	7	1½
27	2	2	59	4	10½	91	7	2¾
28	2	3¼	60	4	11¾	92	7	4
29	2	4½	61	4	13	93	7	5¼
30	2	5¾	62	4	14¼	94	7	6½
31	2	7	63	4	15½	95	7	8
32	2	8½	64	5	0¾	96	7	9¼
33	2	9¾	65	5	2	97	7	10½
34	2	11	66	5	3¼	98	7	11¾
35	2	12¼	67	5	4½	99	7	13
36	2	13½	68	5	5¾	100	7	14¼

The column marked "test" shows the number of septems of lime-water found by experiment to be required to clarify 250 septems of cane-juice. Opposite the number thus found, and under the head of "quick-lime," is given the weight of quick-lime necessary to clarify 100 gallons of the particular cane-juice submitted to the test.

For example the case before supposed may be taken, where the experiment requires 30 septems of test-liquor. Against 30 in the table, stands 2 ounces 5¾ drams, which is the weight of quick-lime required by 100 gallons of the cane-juice. If the quantity of juice is 500 gallons, then 2 oz. 5¾ drs. multiplied by 5 gives 11 oz. 12¾ drs.

As a rough general rule, the proportion of one septem of lime-water to 250 septems of cane-juice is nearly equal to 1¼ dram of quick-lime to 100 gallons of cane-juice. Hence the number of the test, multiplied by 1¼ dram, gives the weight in drams of quick-lime required for 100 gallons of cane-juice. This result is, however, 1 per cent. too little.

The test should be frequently repeated.

In the experimental test just described, saturated lime-water is used, because it is easy to have it of uniform strength; but on the large scale, to use lime-water would entail enormous dilution of the juice, and great waste of fuel in the subsequent evaporation. Hence so-called "milk" or "cream" of lime is resorted to. The lime used must be thoroughly burned, quickly slaked with clean water (enough water being used to impart a creamy consistence), and carefully filtered through a very fine wire sieve, in order to remove all fragments of flint and unburnt and unslaked lime. The weight of these impurities removed must be deducted from the amount of quick-lime (unslaked lime) originally taken. It must be remembered that quick-lime can only be kept in perfect condition in closed vessels.

It is possible that a still better and more exact graduation of the quantities of lime to be employed might be effected by using a solution of sucrate of lime prepared by dissolving hydrate of lime (slaked lime) in strong syrup to saturation. Such a solution may be settled, decanted, or filtered off clear, keeps well in close vessels for a long time, and contains a large quantity of lime in solution. The small experiment just described, by which the quantity of milk of lime to be added is settled, might be performed by means of a titrating solution made by diluting to a known extent some of this same sucrate syrup. The quantity of this dilute sucrate necessary to clarify a given sample of juice would indicate directly the quantity of strong sucrate syrup necessary for the clarification of the whole of the juice to be treated, so that the operation might be made both more rapid and more exact, and the operator would be rendered independent of any discrepancies arising from impurities in the lime used or those arising from the relation of the strength of the lime to that of the lime-water employed for testing as at present.

The juice being tested as to its density and acidity, and the milk of lime being prepared, the twin process of defecation and clarification may commence. There are several ways of carrying it into operation.

One of the most simple, and practised on many estates, is that known as the process of "cracking." It necessitates the use of two or more clarifiers, and is conducted as follows. The strained juice is admitted into the clarifier till sufficient has accumulated to prevent any injury by heat. Fire is then made under the clarifier (or steam is admitted into the jacket or coil), and by the time it is full of liquor, the temperature will have risen considerably, probably to about 54° C. (130° F.). The temper lime is then added, thoroughly incorporated, and the heating is continued. A thick greenish-yellow scum soon appears on the surface, and rapidly increases in thickness, changing colour at the same time from exposure to the air; as the temperature approaches the boiling-point,—say at about 79° to 82° C. (174° to 180° F.)—numerous minute air-bubbles rise up, and form a frothy layer under the thick scum. By and by these air-bubbles force their way at a few points through the dark dirty-looking scum, which soon cracks in several places, and the white frothy bubbles appear in the cracks. When this point has been attained, the heat is quickly withdrawn, and the contents of the clarifier are allowed to rest for 15 to 30 minutes or more. Ebullition is carefully avoided, because it would break up the floating scum, and diffuse it through the mass of the liquor.

The time allowed for settling depends on a variety of circumstances—the nature of the juice, the proper apportioning of the lime, and the time that can be allowed consistently with getting through a good day's work. After settling, there is found a layer of coagulum still at the top, and another layer at the bottom, while the great body of the liquor is tolerably bright and transparent, with a wine-tint more or less deep, and with a quantity of minute flakes floating thickly in it. If it is hazy from minute, generally diffused, solid particles, the operation is incomplete; and either the heat has not been great enough to clarify, or the lime has not been used in sufficient quantity. After standing as above described, the clear liquor is run off into the evaporating apparatus; the scum and sediment, with the considerable quantity of juice that invariably accompanies them, are usually carried to the skimmings-cistern, to be used in setting up liquor for rum.

When the clarifier has either a coil of steam-pipe or a steam-jacket, it is much more manageable, and it is generally so arranged that little loss of time occurs, for as soon as there is enough liquor in the clarifier to render it safe, the steam is turned on in such measure as to attain the desired temperature by the time the vessel is full of liquor. Fire-clarifiers are generally discharged by a stopcock near the bottom till the liquor begins to run muddy. Steam-clarifiers are discharged by a valve in the bottom in connection with a tube that rises

4 to 6 inches above the bottom, so as to disturb the sediment as little as possible.

This method is open to many grave objections, the principal of which are the following:—(1) That clarification is very rarely attainable below the boiling-point of the juice; the consequence is, that the juice wants brilliancy and transparency, and has minute, light, floating particles, which render the process of filtration extremely slow and unsatisfactory. (2) This finely-divided floating matter is thrown up as scum during the concentration, causing much waste of juice in the skimmings.

To overcome these drawbacks, Dr. Shier introduced the following modification. The strained juice is admitted into a clarifier, and boiled briskly for 5 minutes; the scum that rises is constantly beaten down by a wooden or wicker plunger. While boiling, the proper quantity of temper lime is added, this temper lime being mixed with a proportion of clay batter, gypsum, or whiting batter; the boiling is continued for a few minutes, with constant stirring and beating down the scum. Neutralisation being effected, the whole contents of the clarifier are rapidly withdrawn into a subsider, and left till all the coagulated flocculent matter has subsided to the bottom of the vessel. The clear juice is drawn off without disturbing the sediment, and passed through a filter into a cistern. Here any excess of lime which may have been used is corrected by the very careful addition of dilute sulphuric acid, the quantity of acid necessary being previously ascertained by a simple test, such as recommended before applying the lime to the juice. It is best for the juice to be exactly neutral, but the safest course is to cease adding acid when the alkaline reaction becomes extremely feeble. Were the lime left in considerable excess, the sugar would be dark coloured; were the acid in excess, the grain would be fine and soft, and part of the sugar would become inverted to the uncrystallisable condition. The advantage of adding clay or other heavy matter to the temper lime is to cause the impurities to form a sediment which may be filtered off, instead of a scum which needs skimming. It is said to effect a great saving (20 per cent. is spoken of) of juice.

The clay batter is best prepared by digging any stiff adhesive clay containing little sand, from such a depth as to be free from roots, and as free from organic matter as possible. This clay should be well dried in the sun, crushed to powder, and squeezed through a wire-gauze sieve of 10 to 14 threads to the inch. Clean water is put into any appropriate vessel, and the sifted clay is poured into it gradually, mixing it well up, till the whole is of the consistency of cream or batter. From 4 to 8 gallons of this batter, mixed with the ascertained quantity of cream of lime, would go to a clarifier of 500 gallons of cane-juice. When gypsum or whiting is used in place of the clay, they must be in very fine powder.

Howard's process, patented in 1812, is strongly recommended by Wray. It is as follows. The juice is strained on its way to the clarifier, and is then gently heated; for each 100 gallons of juice, 2 ounces of finely sifted quick-lime are made into a cream with water, and added to the clarifier; the whole is well stirred, and the temperature is allowed to rise to 82° C. (180° F.), until a thick crust forms on the surface, and shows a disposition to crack. This may occupy 15 to 20 minutes after the addition of the lime; if it is very slow in forming, the heat may be raised to 93° C. (200° F.), but not beyond. When the crust has formed and shown signs of cracking, the fire is stopped, and the liquor is allowed to rest for 10 minutes, when it is drawn off through a fine strainer into a second vessel, often called the "precipitator."

Here the firing is urged till the liquor has a temperature as high as is possible without actual boiling. Meantime the rising scum is constantly skimmed off, as long as it appears. The liquor may then be boiled, continuing the skimming for 10 or 15 minutes; after which, the skimmer is laid aside, and Howard's "finings" are added. The finings are well stirred in, and the boiling is prolonged for another 2 or 3 minutes, when the whole is thoroughly agitated, and quickly run off into a fining-cistern or subsiding tank, and allowed to rest for 2 to 6 hours before passing through charcoal filters into the evaporators.

The "finings" are prepared in the following manner. Well burnt lime is slaked with boiling water so as to form a "cream"; to this is added an equal bulk of water, and the mixture is boiled for some minutes, until the lime assumes the appearance of fine curd; the extraneous matter is then washed away, and the lime and liquor are run through a fine sieve. The next part of the process is to dissolve, in 6 gallons of water, about 2½ lb. of alum for every cwt. of solid sugar (say 100 gallons of cane-liquor) that is to be refined, adding to such solution about 3 oz. of whiting (purified chalk) for each 3½ lb. of alum, the mixture being stirred until effervescence ceases. It is then allowed to subside, and the solution (containing sulphate of potash, which is very injurious to sugar) is drawn from the precipitated matters (which are alumina and sulphate of lime). After this, the precipitate is put with the prepared lime-curds, and shaken up with the water they retain, the whole being agitated during the effusion. The curds are to be in such proportion, that paper stained with turmeric shall barely change its colour by immersion in the mixture, and shall recover its former yellowness when dry.

The finings, being thus carefully prepared, are suffered to settle to the bottom of the vessels they are contained in; and after draining off the supernatant liquor, are placed upon blankets, supported in the manner of a filter, and the moisture is drained off, until the mass begins to contract, and cracks on its surface; the finings are then fit for the clarification of the liquor. Addition of cane-liquor to them is made in such a proportion as will bring it to a creamy state, and then the whole is mixed equally into the cane-liquor to be fined. The clarified cane-liquor is suffered to remain for several hours before the bright liquor is drawn off from the finings. Any one can make the finings, without any difficulty. The object is to procure sulphate of alumina free from potash and ammonia (which alum also contains). The alumina greatly assists the purifying action of the lime. The same idea is carried out in the alum process of refining described further on.

Lime bisulphite.—The bleaching and cleansing action of sulphurous acid led to experiments upon its applicability to the defecation of cane-juice, and the first form in which it was employed was as a compound with lime, known as bisulphite of lime. One of the most successful methods of using it has been that adopted by Dr. Shier, in British Guiana, and is as follows:—About 1 per cent. or even less of solution of lime bisulphite is added to the juice as soon as possible after it is extracted, or even while it is being extracted. Heat is then applied, and after the juice has been boiled and stirred for a few minutes, a mixture of cream of lime and clay batter is added. The exact quantity of cream of lime is ascertained by a preliminary test, as described on p. 268, sufficient only being used to produce actual neutrality. After boiling for 5 to 10 minutes, and beating down the scum, the contents of the clarifier are run into a subsiding-vessel, and thence filtered out for concentration. The subsidence is not efficient without the addition of clay batter, or some similar weighting matter, but the syrup has a very fine colour, and gives a superior-looking muscovado sugar. An objection is the high price of the lime bisulphite.

Sulphurous acid.—The next step was the separate introduction of the lime and the sulphurous acid into the juice. This system has grown into very wide use in the United States, West Indies, and other places, and has been the subject of several patents and much litigation. Its invention is generally ascribed to Dr. Icery, of Mauritius. There are two principal ways of carrying it into effect:—(1) By first passing sulphurous acid gas into the juice, and then adding lime; this is known as Col. Stewart's process, patented by him in Louisiana and most of the West Indies, and recently adopted in Egypt and elsewhere. (2) By first adding the lime, and then passing the sulphurous acid gas; this is Beanes' system, chiefly employed in Cuba, but also in Java and Australia. The effect is probably precisely identical in both cases. The first-described plan is by far the most commonly resorted to, and hence will be selected for description, the arrangement used at the Aba-el-Wakf (Egypt) factory being chosen, as presenting some improved modifications.

As fast as the raw-juice tank is filled, its contents are raised into the clarifiers, steam at a pressure of 60 lb. per inch being turned on as soon as the copper bottoms are covered. When the juice begins to boil, it is stirred with a copper pipe, through the lower perforated end of which sulphurous acid gas is injected, and allowed to dissolve in the juice, till the colour of the latter becomes considerably lighter, and a decided separation of the flocculent matter takes place. The proper quantity of sulphurous acid to be added varies with the state of the canes and the weather, and can only be determined by practice. Approximately, a clarifier of 450 gallons would require the combustion of $\frac{1}{10}$ lb. to $\frac{1}{2}$ lb. of sulphur.

The sulphurous acid is forced into the juice by means of a pump driven by a small independent engine, the speed of which can be adjusted to the quantity of gas required. The gas is generated by the combustion of crude sulphur in an oven, the air necessary for the purpose being sucked through by the pump; and, as the combustion depends on the supply of air, and the latter on the speed of the pump, the whole apparatus is self-adjusting.

When the factory was first started, the gas was introduced into the raw-juice tank; but it was found that the supply of juice was much too irregular to admit of the necessary accuracy being attained as to the quantity of gas injected, and therefore the arrangement just described was adopted.

As soon as the boiling juice is sufficiently "gased," milk of lime, mixed with China clay, is added at the rate of ½ gallon to 3 gallons per clarifier, until the liquid is ascertained by the litmus-paper test to be perfectly neutral. The liquid is then let out by cocks in the bottoms of the clarifiers into subsiders, where it is allowed to stand till the impurities have settled down, when it is decanted by means of sliding overflows into the clarified-juice tank. After the juice is properly clarified, it is perfectly clear, and about the colour of sauterne wine. The whole operation of clarifying and subsiding takes about 1½ hour; the subsidence and decantation occupy about 40 minutes; hence, the 12 subsiders, having a capacity of 450 gallons each, can readily get through 8100 gallons of juice per hour.

The lime used is the ordinary produce of the native limestone; it is of good quality, and is mixed in two circular tanks, fitted with agitators. The contents of one of these tanks is allowed to subside, so as to yield clear lime-water, used in washing down the cane-mills, juice-gutters, and pipes. The milk of lime from the other has a density of about 10° B., and is mixed in the proportion of 9½ parts by weight of cold water to 1 part of lime; an equal weight of China clay is added to assist mechanically in carrying down the impurities.

The scum which collects in the bottom of the subsiders is let out by valves, and runs down gutters to either of two tanks, from which it is filled, by means of 3-inch indiarubber hose, into linen bags placed in hydraulic presses. The juice is then separated from the solid scum. The solid scum forms about 5 per cent. of the weight of the raw juice. The clear pressed-out juice is pumped at once into the clarified-juice tank, and the solid refuse is thrown away. The subsiders are washed down by a hose at the end of each operation, the foul water being run off through wash-out valves and pipes.

The clarifiers, 6 feet 6½ inches in diameter, and 2 feet 6 inches deep, up to the skimming-lip, hold an actual working charge of 450 gallons of cold juice. They consist of copper pans 1 foot 6 inches deep, bolted into cast-iron steam-jackets, and surmounted by galvanised-iron cylinders, 1 foot 6 inches deep, in which skimming-overflows, 2 feet wide, are formed. The heating surface of each is 52·58 square feet. Steam at 60 lb. pressure is admitted by 2½-inch valves, and the condensed steam is taken off by self-acting traps, one to each clarifier. The juice is let out by 4-inch cocks, worked by levers placed beyond the hand-rail over the subsiders; and ½-inch pet cocks to ascertain the state of the steam-jacket and let out any air, complete the equipment.

Steam is turned on as soon as the copper bottoms are covered; the juice, usually at the temperature of 22° C. (72° F.) when pumped in, begins to boil in about 20 minutes, and is kept boiling about 5 minutes. A small portion of the impurities floats on the surface, and is skimmed off at the lips provided for the purpose, whence the skimmings flow by suitable shoots to the tanks which receive the rest of the scum.

The mean power of these clarifiers in heating water to the boiling point proved to be:—

Mean duration of experiments	24 minutes.
Mean initial temperature of water	19° C. (67° F.)
Mean steam pressure	42·1 lb. 143° C. (289° F.)
Mean weight condensed steam	742 lb.
Mean weight of water heated	4,558 lb.

	Lb.		
Units of heat in condensed steam	742 × 990 =		734,580
Heat spent in heating copper	840 lb. × 145 × 0·095 =	11,571	
,, ,, cast iron	2,828 lb. × 145 × 0·129 =	52,900	
,, ,, wrought iron	567 lb. × 145 × 0·113 =	9,200	
,, ,, water	4,558 lb. × 145 =	660,910	
		———	734,671

Units of heat per square foot per difference of 1° per hour in heating water .. .. 210·2

Loss in heating clarifier, by radiation, &c., &c. .. 11·1 per cent.

In some other experiments with a clarifier of similar construction, but of only 12 gallons capacity, the trials were carried further, and the rate of boiling was ascertained as well, both for water and syrup, the latter being a solution of 9 lb. of molasses and 4 lb. of sugar in 90 lb. of water, equal to juice at about 8° B. The results were:—

	Water.	Juice.
Units of heat per square foot per difference of 1° per hour, heating	260	219
,, ,, ,, ,, ,, ,, evaporating	606	521

As usual, in both water and juice, heat was transferred about 2⅓ times more quickly in boiling than in heating, no doubt in consequence of the greatly more rapid circulation; and in both operations, the addition of 14½ per cent. of sugar seems to have reduced the efficiency of the surface by about 15 per cent.

The subsiders, 12 in number, corresponding to the clarifiers, are plain cast-iron tanks, 6 feet square and 2 feet 6 inches deep, with outside flanges and angles rounded to a 4-inch radius for facility in cleaning. Each tank is fitted with a brass 5-inch Appold overflow, actuated by a quick-threaded screw and hand-wheel, for the purpose of decanting the clear juice, which is discharged into a wrought-iron tank running across the mill under all the subsiders; while for letting off the scum, and for the subsequent washing, two 3-inch brass plugs are provided, connected, the one with the scum-gutters, and the other with the waste-water pipes. The clarified juice takes about ½ hour to subside, the China clay added with the lime assisting mechanically in carrying down the impurities. Hydrants with 1-inch indiarubber hose, and brass nozzles and cocks, are provided for washing out the clarifier and subsiders, and for sluicing the stages.

Sulphurous acid gas is generated in a cast-iron D-shaped muffle, 5 feet long and 12 inches wide. A small grate under it allows the hearth to be heated in order to start the combustion of the raw sulphur; and the admission of air is regulated by a sliding cover closing up one end of the retort. The raw sulphur is introduced through a small door in the end cover by a scoop 1 inch wide, similar in form to those used for charging gas-retorts. About 62 feet of 3-inch cast-iron cooling-pipe, provided with numerous cleaning-doors for removing any flowers of sulphur that might distil, conducts the gas to two duplicate double-acting pumps, having cylinders of 12-inch diameter and 12-inch stroke. These are worked by belts with fast and loose pulleys from a counter-shaft actuated by a 4-horse oscillating donkey-engine, which, during crop, is used exclusively for the gas pumps, whose speed is thus easily regulated. The pumps are entirely of iron with indiarubber flap-valves, and they appear to stand very well against the action of the sulphurous acid.

From the pumps, the gas is led into a receiver containing about 114 cubic feet, or 144 times the capacity of one pump, and from thence it is carried by a 3-inch main under the clarifier stage, a 1-inch copper branch rising between each pair of clarifiers, and terminating in a cock and indiarubber hose fitted with a copper stirring-pipe, the extreme end of which is finely perforated, to allow of a uniform distribution of the gas through the body of juice in the clarifier. A loaded valve permits the escape of any excess of gas clear of the roof.

The greatest quantity of sulphur used is ¼ lb. to a clarifier of 450 gallons of juice, or 5 cwt. of sugar. Oxygen does not alter its volume in combining with sulphur to form sulphurous acid: the latter gas measures 59 cubic feet to ½ lb. of sulphur, whose combustion therefore results in 29½ cubic feet of mixed sulphurous acid and nitrogen gases, to which must be added at least as much excess of air, or, say 59 cubic feet in all, at a temperature of 15½° C. (60° F.) The factory, in full work, ought to yield 14 clarifiers per hour, for which 3½ lb. of sulphur are required, producing 413 cubic feet of gas, or rather, 475 cubic feet at 66° C. (150° F.) which is about the temperature at which it reaches the pumps; hence about

6 revolutions per minute will deliver all that is required. The pumps were purposely made of large dimensions, as the quantity of gas necessary had not been certainly determined at the time the factory was designed.

The skimmings from the clarifiers and the scum from the subsiders are run into two circular wrought-iron tanks, fitted at their lower ends with 3-inch cocks and indiarubber hose, by means of which the two hydraulic presses are charged. These consist of cast-iron boxes 4 feet square and 12 inches deep, surmounted by inverted cylinders 18 inches in diameter and 2 feet stroke, with 12-inch trunks, the lower ends of which carry the upper pressing-tables. The scum is run into linen bags, about 12 inches wide and 5 feet long, ranged in 3 or 4 layers, with galvanised-iron gratings between them. As each bag is filled, its mouth is twisted up and laid back over itself. When the charge is complete, the water pressure—derived from the ordinary supply of the factory, under a head of 45 feet—is turned on by a common sliding-valve, forming part of the cylinder of each press, and the moderate pressure of 2¼ tons on an area of 16 square feet thus obtained is sufficient to express all the juice. The juice runs into a small tank, from which it is immediately pumped by a donkey-engine into the clarified-juice tank under the subsiders.

When the scum is sufficiently dry, the slide-valve is reversed, and the upper table is raised, to permit the bags to be taken out and emptied of the solid residue. It was supposed that this scum, like that obtained from ordinary clarification, would readily drain through coarse cloth, and a battery of filters was prepared accordingly, with one hydraulic press to finish the drained refuse. The addition of china clay, however, completely changed the nature of the scum, converting it into a puddle, which retained the juice obstinately until subjected to a moderate pressure. The one hydraulic press proved insufficient for the new method which had to be adopted, and so a large portion of juice had to be thrown away with the scum. In the sugar-factories of our colonies, and in those of other countries, the scum is generally run into the distillery together with the molasses, so that comparatively little attention has been paid to perfecting machinery for separating juice from scum.

The specific action of sulphurous acid (whether introduced in the gaseous form, or liberated from a combination in the juice) is threefold: (1) It prevents fermentation, (2) it decolorises, and (3) it causes a coagulation of those albuminous matters which are not affected by heat. These constitute the advantages to be derived from its use. On the other hand, it is so readily absorbed by the juice (up to 33 times the volume of the juice) that it can easily be applied in excess. Laboratory experiments indicate that about $\frac{1}{10}$ lb. of sulphur per 450 gallons should suffice, but this is usually exceeded in practice; the lime required for its neutralisation amounts to about 4 per cent. of the quantity necessary for tempering in the ordinary way, that is to say, an extra 4 per cent. of lime is consumed. Care is needed to prevent oxidation of the sulphurous acid to sulphuric acid, as the latter most injuriously affects the crystallising power of the sugar; consequently sufficient lime must always be added to ensure that any sulphuric acid formed shall immediately combine with the lime, to produce the insoluble solution of lime, which falls to the bottom.

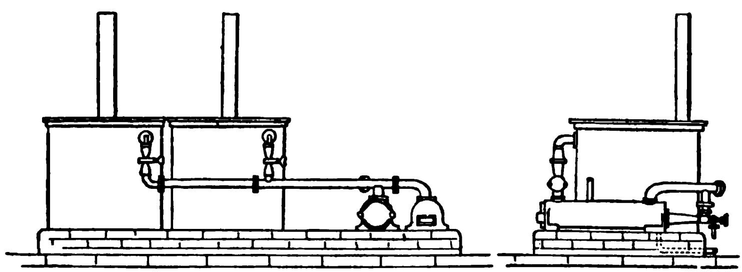
By the use of sulphurous acid in conjunction with lime, it is possible to produce a grey or almost white "grocery" sugar (that is unrefined, or so-called "raw," "brown," or "moist" sugar); but it must not be supposed that the whiteness of the product will compare with that of refined sugar, nor that the employment of sulphurous acid will render refining unnecessary for the preparation of a pure-white sugar.

It is found to be often advantageous to assist the action of the sulphurous acid by the addition of a little permanganate of soda or potash. These salts are powerful oxidisers, transforming the harmless sulphurous acid to the injurious sulphuric acid ; but the latter, if formed, seems to immediately attack the lime and potash (or soda) present, combining with them to produce insoluble sulphates, and thus having no opportunity to affect the crystallisability of the sugar.

A statement showing the practical results of the sulphurous acid process will be found in the chapter on Complete Factories.

The arrangement of sulphurous gas apparatus, as adopted by Manlove, Alliott, Fryer, & Co., consists (Fig. 72) of a

FIG. 72

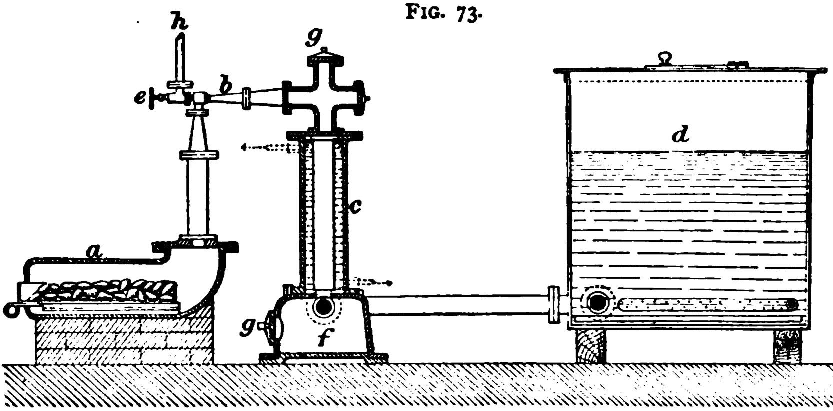


Manlove & Alliott's Sulphurous Acid Plant.

D-shaped cast-iron muffle or furnace, in which the sulphur is placed in a wrought-iron tray and burned with a limited air supply. The sulphurous acid gas passes from the muffle through a cast-iron pipe to a steam injector, by which it is forced through a cast-iron cooler, consisting of a circular chamber surrounded with water, and having at one end a space in which the flowers of sulphur are deposited. From the top of this condenser the gas is led by a pipe to the gassing tanks containing raw cane-juice, through which it is distributed by means of a perforated lead pipe, thus securing the full bleaching effect of the gas upon every part of the juice. The supply to each tank is controlled by a special flexible valve little liable to be damaged by the action of the gas, and the tanks are covered and fitted with manholes and ventilating pipes; the gas pipes also are arranged with covers readily removable to facilitate cleaning.

An apparatus for saturating cane juice with sulphurous gas, as made by Körting Brothers, Queen Street, London, is shown in Fig. 73. The sulphur is burned in the vessel *a*, and

FIG. 73.



Körting's Sulphurous Acid Saturator.

the gas produced is drawn off by the steam-jet exhauster and blower *b*, sufficient air being drawn in to support combustion. The gas is forced through the cooler *c* and clearing-box *f* into the saturating pan *d*. The cooler consists of a jacketed tube, the gas passing through the inner tube in one direction, while water circulates through the outer tube in an opposite direction. Any particles of sulphur or other solids suspended in the gas fall in the clearing box. The handle *e* regulates the action of the whole apparatus by controlling the supply of steam coming through *h*. Doors for cleaning the pipes are provided at *g*. The whole plant is small, simple, inexpensive, and regular in action.

Lead acetate.—Many years ago, Dr. Scoffern employed the subacetate of lead ("sugar of lead") as a defecating agent, and many inventors have since improved upon his method of manipulation. This salt carries down all impurities as a precipitate, leaving sugar in solution, and any possible excess of the lead salt is thrown down as insoluble sulphite by the injection of sulphurous acid. Quantities of sugar were prepared by this process, without any injury resulting; but an outcry against the poisonous nature of lead acetate, and the dread that some might be accidentally left in the sugar, caused the process to be officially condemned. Lead certainly was present in the sugar, but it is not known whether it was in a poisonous form or not.

Ehrmannite.—With the Bernard-Ehrmann process an immediate saving may be effected by the means it affords of producing on the estate the finest qualities of sugar, and such as would realise the highest price in the consuming markets, and at a cost scarcely in excess of that for producing the lower qualities usually made. Mauritius has long been recognised as one of the most scientific and advanced of the sugar-producing colonies. We may therefore say, without fear of contradiction, that a process which is now universally employed in Mauritius may unhesitatingly be adopted in other places; for such a rapid development could only have arisen from causes that have produced an economy in working, or the production of a more valuable class of sugar; both these advantages are claimed by the inventors for their process, and substantiated by the results obtained. Some of those well experienced in the question of cheapening the cost of cane sugar have come to the conclusion that the chief advantage to be gained is by having recourse to methods of operation hitherto employed only by the refiner. Mr. Santiago Dod, in writing in the 'Nueva Era,' takes this view of the question, and writes, "But our argument will have greater force the moment he shall have at his disposal a much simpler, a more economical, and more perfect process, such as the discovery made by Mr. Ehrmann."

The process was made known and introduced into the West Indies by Messrs. E. Packard & Co., of Ipswich, who solely at their own cost of upwards of £750 brought Mr. Ehrmann from the Mauritius, so that the process might be practically demonstrated by him in nearly every British and French West Indian colony.

The advantages proved to be attained by the use of Ehrmannite may be recapitulated as follows:—(1) Increased yield of sugar, (2) improved quality of sugar, (3) proportion of molasses reduced, (4) great economy effected, (5) necessity for charcoal filters obviated, (6) superior clarification obtained, (7) more lime may be employed in defecation, (8) the evils of over-tempering counteracted, (9) the cost of the reagents is recovered in the value of the precipitate for manuring the next crop, (10) greater proportion of first-quality sugar produced.

The experience of several years' work in the Mauritius has brought out the weak points in the substances originally employed, and enabled the inventors to ascertain accurately the exact requirements when practising on a large scale and in the largest factories, where the most perfect and delicate machinery has to be dealt with. It was found necessary that the precipitant should be as pure as possible, and with a minimum combination of extraneous matter; further, that the earlier method of applying it in the form of a powder caused some trouble by its imperfectly dissolving, and thereby causing irregularity in the work, hence the new form—"Ehrmannite"—was adopted, it being readily and entirely soluble in water or in cane juice, and, therefore, it could be much more easily and accurately dealt with, the effect of the addition of a solution of Ehrmannite being at once ascertainable, and further additions may be made, as required, with great nicety. Ehrmannite possesses a further great advantage in causing a more bulky precipitate than any other substance, giving no incrustation on the tubes of the triple effect, and yielding a higher class of sugar.

The following instructions for the use of Packard's Patent Ehrmannite, for the purification of cane juice, are issued by the inventors:—

Sulphurous acid, in the proportion of 1 lb. of SO^2 for 100 gallons of juice, is introduced into the juice, either in a gaseous state or in aqueous solution. After allowing a contact of at least 30 minutes, Packard's Ehrmannite is added in the proportion, at a minimum, of 1 lb. for 100 gallons of juice. After stirring the liquid, in order to have the acids perfectly mixed with the juice, lime is added in such a proportion as to allow a very slight acidity to persist in the juice, which is then heated and defecated as usual. The scums being much more bulky than by the ordinary processes, more care must be taken in order to separate them from the limpid juice. In Mauritius, the juice being heated to boiling point in the defecators, the scums divide in two parts, one of which rises at the surface of the liquid and is removed by means of scummers, whilst the other part sinks to the bottom and is separated by allowing the juice to run into large subsiders, where the solid particles remain and the limpid juice runs out. After passing through the subsiders, the juice is concentrated and crystallised as usual.

The *modus operandi* above specified may be altered and modified in order to adapt the process to the different installations of the sugar houses, and in this respect no special directions can be given.

It is also practicable to use phosphoric acid after the defecation. In this case the juice, after being treated as above by sulphurous acid, is reduced to perfect neutrality by the addition of a sufficient proportion of lime, and, after heating and scumming, a proportion of Ehrmannite is added, so as to restore the juice to a slight degree of acidity.

Yellow Crystals.—The beautiful "yellow crystals" which are brought from Demerara owe much of their brilliant colour and transparency to particularly careful treatment at the defecating and clarifying stage, in other words, to the delicacy of the tempering. The temper used is lime-water rather than cream of lime, the density being only 10° B. instead of 17° B., and preference is given to rain-water over trench-water. The clarifier is filled with already-sulphured juice. The latter is tested repeatedly while it is entering the clarifier, and while lime is being added, to ascertain the exact quantity of lime necessary to neutralise it. A very few careful trials are required before the correct proportion can be ascertained. When it is known, the whole quantity of lime is introduced before the clarifier is one-quarter full in subsequent charges.

The exact proportion of temper is decided primarily by the neutral reaction on test-paper, and secondarily by the appearance of the limed and thoroughly agitated juice when settled in a foot-glass. The filled foot-glass is placed in the light and where it will not be disturbed, and the contents are allowed to subside for 5 minutes. The appearance wished for in the cleared liquor is brilliant transparency combined with a golden colour. The right quantity of lime is that which will give this result, though the liquor may be a trifle alkaline to the test-paper. Perfect results are only to be got from perfect juice. When the juice is inferior, colour must be sacrificed for transparency, and lime must be added till transparency is attained, even though the colour may be intensified to light-red. The most careful and reliable man in the factory should be selected to count out the pints of lime-water into buckets ready for the clarifier. It is necessary to guard against too light a colour, which is sometimes compatible with good transparency in the case of superior juice, but will result in a green-coloured sugar. Over-tempering causes the sugar to turn greyish-brown when cured. The treatment of the liquor in the vacuum-pan will be dealt with under the proper head.

Bloomer.—This term is applied to a preparation of chloride of tin, which is sometimes employed in colonial factories to give a yellow tint to crystal sugars, especially for Demerara crystals, or sugars made to resemble them.

The bloomer is added in the pan to the *masse-cuite* during the boiling, or in some cases it is used in the centrifugal machine. The bloomer is not in itself a colouring matter, but the results obtained by its use are due to its action upon the sugar, and are somewhat uncertain in their character.

Golden Bloom.—This is an organic colouring substance of a harmless character, and possessed of a high tinctorial power, which is used for the same purpose as "bloomer." It is sold in the liquid condition, and after it has been diluted with water the sugar is sprinkled with it, and is then well mixed either by shovels or by passing through a revolving mixer. This colouring matter produces a beautiful golden yellow shade of any required intensity, and is largely employed by English refiners in the manufacture of imitation Demerara crystals, and also in the colonies. The sole manufacturers are A. Boake Roberts & Co., Stratford, London, E.

Filtration.—Filtration of the juice must be considered a necessary adjunct to the defecation by heat and chemicals, its object being the removal of the matters rendered insoluble by these operations. Many kinds of filter and filtering medium are in use.

The employment of brown coal in the filtration of sugar liquor deserves consideration. The patent (No. 1985, 1884) of F. Kleemann, Schoeningen, Germany, claims the use of peat or brown coal, by adding it in a fine state of division to the sugar liquor, or by causing the liquor to pass over it in a pulverulent condition. The best method of using the brown coal or lignite is to add it in the form of a fine powder to the raw sugar liquor in the blow-up. The liquor should have the gravity of 28° to 30° Baumé, and be kept stirred at 160° F. with the lignite in it for at least 15 minutes. The proportion of lignite necessary is dependent upon the gummy matter in the sugar, and may be determined easily by a preliminary test on the small scale. Some sugars filter quickly and brightly with 5 parts, while others require as much as 20 parts per 100 parts by weight of raw sugar. The liquor is filtered through filter-presses, and with the proper proportion of brown coal runs steadily for 30 to 40 minutes, when the chambers become filled with cakes of brown coal. By stopping the supply of liquor to the filter-press and delivering hot water instead, the saccharine matter is washed out of the cakes. If they are from the filtration of good or medium sugars, they may be used over again in the filtration of lower grade sugars; if, however, they are from sugar, such as Java Stroops or Jaggery, they are unfit for further use, and may be employed as fuel.

The extraordinary absorptive power of the brown coal enables it to influence the liquor in two important ways; first, it retains the gummy matter and other mechanical impurities, and permits the liquor to pass through the cloth of the press without any trace of dimness; and, second, it absorbs also a notable proportion of the soluble extractive matters and salts, and decolorises the liquor, so that its colour, on coming from the filter presses, is in some cases only one-half, and in others only one-third, of the colour of the liquor as filtered through the ordinary Taylor bag-filters. Licenses for the use of this process have been taken by several refiners in this country and in America, and it has been used for the filtration of the sugar-juice especially in Demerara. Supplies of brown coal may be got from Germany and from Bovey Tracey in the south of England.

From a recent report addressed to the United States Department of Agriculture, it would appear that this process when tried with cane-juice gave results which were of a disappointing character.

Other methods of filtration will be described in the chapter on Refining.

CHAPTER V.

CONCENTRATION AND GRANULATION OF THE JUICE.

WHEN the cane-juice has been reduced to the condition of a solution of sugar (with some salts as impurities) in water, by the aid of one or several of the processes described in the last chapter, it has next to be deprived of such a proportion of its associated water as will permit the sugar to assume a solid (usually crystalline) and transportable form. This is the operation implied by the terms "concentration" and "granulation." It may be effected either by heat or by cold. Both methods will be described, but the former is by far the more generally adopted, and has been subjected to the greatest number of modifications.

Principles.—While the primary object of concentration is undoubtedly to get rid of the useless water, and form a solid material, the purification of that material by the mere act of crystallisation must not be overlooked. By this act of the particles of the substance coming together to form a definite solid, they leave in solution those bodies which are present in too small proportion to admit of their crystallising out, as well as those which are altogether incapable of crystallising. The crystals, when freed from their mother-liquor, must be considerably purer than the original solution from which they have formed.

Crystallisation is the property which many bodies (including cane-sugar) possess of assuming a definite solid form out of a saturated solution when cooled. It is based upon the power of water to hold these bodies in solution in a degree varying with the temperature, this power (in most instances) increasing with the temperature. Thus if a gallon of hot water is made to dissolve as much cane sugar as it is capable of holding in solution at the temperature exhibited, and this so-called "saturated solution" is cooled, the decreasing solvent power of the water compels the sugar to separate from it in crystals. These crystals are not composed of sugar only; they are a combination of sugar and water. But the water is chemically combined, and cannot be driven off without decomposing the sugar; consequently this so-called "water of crystallisation" is regarded as an integral part of the substance, and the crystals are looked upon as pure bodies. The size of the crystals depends partly upon the conditions under which they are formed, these conditions being chiefly the duration of the operation, the bulk of water present, and the agitation or quiescence of the liquor.

In concentrating the liquor to the condition of a saturated solution, it is necessary to bear in mind the changes which cane sugar suffers when subjected to heat. First it melts; then, if the heating be continued slowly and regularly, it parts with successive molecules of water, becoming converted into a number of uncrystallisable non-saccharine bodies, and ultimately into "caramel," a dark-brown substance used for colouring porter and other liquids. This conversion will take place in concentrated solutions, as well as in the dry state. As the evaporation proceeds, the mass thickens, and the difficulty of equalising the temperature of the mass increases, with the consequent liability of certain portions becoming transformed into caramel.

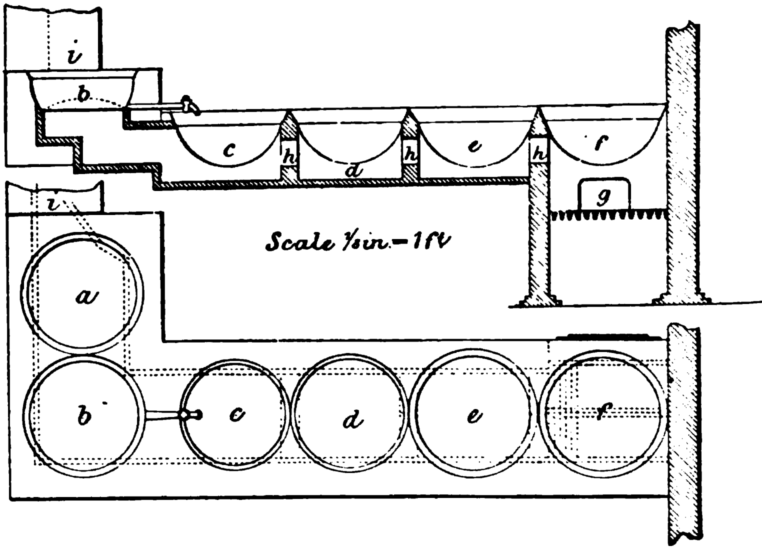
Another change which is constantly proceeding in the liquor is the inversion of crystallisable sugar into uncrystallisable. This is caused by the presence of pre-existing uncrystallisable sugar, acids, and mineral salts, and is favoured by exposure to the air and heat. The consequence of these changes is "molasses," which may be regarded as an artificial product, composed of uncrystallisable sugars, and coloured by caramel. The value of molasses being far below that of sugar, the prevention of its formation is one of the chief aims of modern improvements in sugar-making plant.

It may be mentioned here that the inversion of sugar during concentration of the syrup is said to be prevented by the introduction of superphosphate of lime into the juice before boiling. There is no evidence forthcoming as to the practical utility of this plan; but it is useful to state that phosphoric acid (unlike all other acids) appears to possess the valuable property of facilitating the crystallisation of sugar, and the superphosphate process therefore would seem to be based on good ground.

By Heat.—The means by which heat is applied to the evaporation of cane-juice vary most widely, as the following pages will show.

Open Pans heated by Fire. — The earliest and crudest system of evaporation was the "copper-wall" or "battery" of open pans called "teaches" (taches, tayches, &c.), as shown in Figs. 74 and 75. The first two pans *a b* of the series are the clarifiers, which have already (p. 264) been described. Thence the juice flows into the teaches *c d e f*, which are simply sheet-copper pans set in masonry on a descending plane. Thus as the juice becomes concentrated, each lower pan is filled up with liquor from the one immediately above it, until the density of the liquor in the "striking-teach" *f* is such as to permit granulation, when the thick crystallisable mass is ladled into shallow wooden vessels, and conveyed away to be "cured." By the oldest method, the liquor was ladled throughout the series. More recently an improvement was introduced, consisting of a copper pan or dipper, fitting inside the striking-teach *f*, and having at the bottom a large valve, opening upwards and worked by a lever. The dipper is attached to a crane, which commands the striking-teach and the gutter leading to the coolers. This greatly economises time. The furnace *g* for heating the series is set under the striking-teach *f*; the heat passes by the flues *h* to the chimney *i*, or to the boiler flue. It is preferable to have the furnace-mouth at the end, instead of at the side as shown.

FIG. 74 AND FIG. 75.



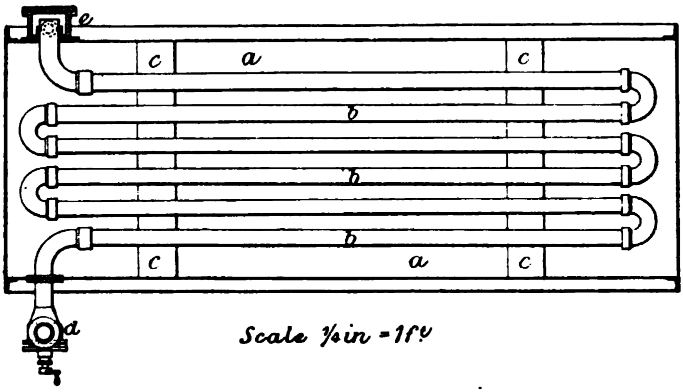
Fire-heated Open Pan.

In working a battery, the only difficulty is determining the exact moment when the boiling of the "sling" in the striking-teach must cease, or in other words, the exact moment when to make a "skip"; great skill and experience are required to decide the correct boiling time suitable for each kind of juice. The main point is to bring about crystallisation in the sling in as great mass as possible after it cools; for if the sling be taken out of the teach too soon, there will be seen in it, after cooling, only a few large irregular crystals, and a quantity of sugar will be left in the molasses; on the other hand, if the sling has been allowed to boil too long, a sticky mass of very tiny crystals and syrup will result, from which the molasses cannot be drained off at all, or only with great difficulty, and from which it will be impossible to obtain clean, dry, and hard crystals. An experienced "wall-man" knows, from the appearance of the waves and bubbles, the approach of the striking point; but if a test is wanted, the best perhaps is the following:—Take a tin cup of the boiling sling, and pour a spoonful of it into a glass of clear water; if, after a minute's cooling, the sling can be formed into a ball which does not stick to the fingers, and which slightly flattens itself on the bottom of the glass by the mere weight of its descent on being dropped in, the correct period has arrived for striking.

The continued use of the copper-wall is an illustration of the extreme backwardness of the cane sugar industry in many places. In the first place, the process is very wasteful of fuel; its next drawback is the amount of labour required and the length of time occupied; thirdly, it is impossible to avoid considerable waste of liquor in the sloppy manipulation; and finally, the proportion of molasses produced is intensified by the churning up of the liquor and consequent admixture of air, and by the irregular and uncontrollable action of the heat upon the surface of the metal with which the liquor is in contact. The temperature prevailing in the striking-teach is not less than 110° to 113° C. (230° to 235° F.) in any part, and is necessarily much greater at the bottom of the boiling mass. It is therefore not surprising that liquor showing 10 per cent. of inverted (uncrystallisable) sugar in the first pan, should have 22 or 23 per cent. by the time it is finished in the striking-teach.

Pans heated by Steam.—The simplest form of steam evaporating-pan is shown in plan in Fig. 76. It consists of a rectangular wrought-iron tank *a*, at the bottom of which is a series of copper steam-pipes *b*, connected by gun-metal bends brazed to them, and carried on wrought-iron supports *c*. The tank is fitted at the side with a steam-valve *d* at one end of the steam-pipe range; at the other side is a cast-iron box *e*, fitted with a wrought-iron pipe, for the escape of the condense-water to a condense-box. This form of evaporator presents a large heating surface, with facility for cleaning. By passing the ends of the steam-pipe range at *de* through

FIG. 76.



Steam-heated Pan.

stuffing-boxes, the pipes can be turned up, and all parts of the interior of the tank be readily cleaned, a matter of no small importance, if acidity and consequent excess of molasses are to be avoided.

Steam under Pressure.—The concentrating-pans erected at Aba-el-Wakf for the Khedive of Egypt, are of somewhat novel construction. The clarified juice, when it has fallen to a temperature of about 71° C. (160° F.), is run into the concentrators. These are 5 in number, each consisting of a copper tray, 23 feet long and 6 feet wide, heated by a steam boiler beneath and forming part of it, and covered by a sheet-iron casing which confines the steam evolved from the juice. The steam boilers work under 60 lb. pressure; they are the same size as the trays, and 12½ inches deep, the lower side being flat like the trays, and connected to them by screwed stays spaced 6 inches pitch. From the bottom plate hang 204 water-tubes, 3½ inches in diameter and 18 inches long, and

263 tubes of the same diameter but 4 feet long, each tube having inside a cast-iron circulating pipe.

The heating surface of each tray is increased by 495 vertical nozzles screwed into it; these nozzles are of brass, cast very thin, and slightly tapered. Their mean external diameter is 2⅛ inches, and they project 4½ inches above the plate. The sheet-iron cover is 3 feet 8 inches high at the crown, semi-cylindrical in form, the ends also being of the same curve. It is surmounted by a steam dome 2 feet in diameter and 5 feet high, from which issues a 9-inch steam-pipe governed by a slide stop-valve. Two 2¾-inch pipes rise from the copper plate, and, passing through the sheet-iron cover, terminate in 4-inch lever safety-valves, which permit the escape of excess steam from the boiler. Two 6-inch safety-valves placed at the top of the dome perform the same office for the steam evolved from the juice. Three 5-inch plate-glass peep-holes, and a wash-out valve and cock, are also fitted to the juice-tray. The clarified juice is brought from the trough under the subsiders by a 5-inch copper pipe to a similar trough carried on pillars across the entire face of the concentrators; a 2½-inch pipe descends to each, and admits the juice, by a brass cock with a graduated dial, into small cast-iron cisterns (fitted with a glass gauge for ascertaining the level of the juice), from which it flows through a brass pipe having 3 branches into the tray. At the opposite end, the syrup flows through a similar pipe into a second cast-iron regulating vessel, also fitted with the glass gauge, and thence through a 2-inch brass bib-cock with graduated dial, into a small open cast-iron cistern, having an overflow keeping the syrup within 2 inches of the top, and fitted with a large gilt Baumé hydrometer floating in a cage, and arranged to point to a small staff fixed to any desired degree of density; so that the illiterate men attending the trays have merely to keep the density such that the upper end of the hydrometer shall float fair with the top of the fixed staff. The syrup overflowing from these cisterns runs into a copper main, by which it is distributed into either of 4 tanks, each holding 2500 gallons, where it is allowed to subside 3 hours before being drawn up into the vacuum-pans.

The suction-pipes of the vacuum-pans dip into the tanks to within about 1 inch from the bottom. The scum that remains is drawn off by suitable plugs, and carried to the scum-presses, where the expressed syrup mixes with the clarified juice, and so passes again through the trays. On watching the working of the concentrators through the peepholes, the surface of the juice, while rising to the boiling-point, appears quite calm for about ⅓th of the length nearest the inlet; it then begins to simmer, and finally to boil violently. If the juice is in good order, it makes very little foam; if not properly tempered, a thick froth soon forms, but appears to condense against the cover, and drop back into the boiling fluid. Each particle of juice takes about 18 minutes to pass through the tray, and although exposed to the temperature due to 3 or 4 lb. pressure of steam on its surface, the syrup gains very little colour, hardly more than would be due to the increased density.

The steam generated from the juice is collected in an 18-inch wrought-iron main, and taken thence by one 12-inch branch to the vacuum-pans, and by another to the vacuum-pumps and centrifugal engines, which it actuates, supplying thus all the power necessary for boiling to grain, curing, and raising the water required throughout the mill. The great drawback to the use of steam from the juice is its low pressure (3 to 6 lb.).

One of these concentrators was set up and tested as to its evaporating powers. The heating surface of the steam generator or boiler amounted to 1276 square feet, composed of 1138 square feet of vertical tube and 138 square feet of horizontal surface. The juice tray contained 325 square feet of surface, composed of 187 square feet of vertical nozzle and

138 square feet of horizontal surface. The mean of two experiments, each of an hour's duration, gave:—

Mean pressure in generator	47 lb. = 146° C. (294° F.)
,, ,, tray	5·8 = 109° C. (228° F.)
Temperature of water fed in	17° C. (62½° F.)
Gallons of water run in per hour	1160
,, ,, run out per hour, at 100° C. (212° F.)	247
Gallons per hour evaporated from 17° C. (62½° F.) ..	913
Coals consumed per hour..	952 lb.

Raising 247 gallons of water from 17° C. (62½° F.) to 109° C. (228° F.), is equivalent to evaporating 42 gallons from the boiling-point; hence the duty done appears to have been equivalent to evaporating 921 gallons of water per hour from 62° F., or nearly 148 H.-P. To raise the water from 62½° F. to 71° C. (160° F.), the temperature at which the juice flows into the concentrator, is equivalent to evaporating 110 gallons from 160° F. at 5·8 lb. pressure; hence the power of the tray appears to have been equal to the evaporation of 1023 gallons from 160° F.

In concentrating juice from 10° B., the volume is reduced to 43 per cent.; hence each tray should be competent to concentrate 2379 gallons of juice per hour at 160° F. from 10° B. to 21° B. In actual work, however, this result is very much modified, partly by the accumulation of soot on the tubes of the generator, partly on account of the increased amount of heating surface in the trays necessary to evaporate syrup, and partly from the thin film of incrustation that soon forms over the surfaces of the trays when the clarification is carelessly done.

In some experiments made to guide in proportioning the trays, it was found that similar surfaces transmitted per difference of 1° F. of temperature per square foot per hour: in heating to the boiling-point, 368 units; and in evaporating, 660 units, or 1·8 times as much. Assuming these relations to hold in the trays, the mean result of the experiments shows that 271 units are transmitted in heating and 491 units in evaporating per difference of 1° F. of temperature per square foot per hour. That 2 square feet of evaporating surface are required in the tray per H.-P.; and also that 55 square feet are occupied in heating, while 270 square feet are occupied in evaporating. In the generator, 8·6 square feet of gross heating surface per H.-P. is required, or nearly 4 times as much as in the tray. It was feared that the vertical water tubes would become coated with soot, and require sweeping from time to time; but at the end of the season's working, they were reported comparatively clean. There is no fear of internal incrustation, as the water in the generators is never changed; for that reason, this form of boiler is very suitable for a concentrator. It will be noticed that the experimental tray gives a much higher duty than the actual concentrator; this is accounted for by the circumstance that the model was supplied with unlimited steam from the factory boilers, while in the actual tray the generator was evidently unequal to the work; but this want of balance was expressly made to provide for the deterioration of the trays from incrustation. The mean weight of fuel consumed was 952 lb., being at the rate of 6·43 lb. per cubic foot of water evaporated in the trays.

The advisability of concentrating syrup under pressure in this manner has been the subject of much discussion. It is usually held that any temperature above 60° C. (140° F.) is prejudicial to sugar solutions, and that above 74° to 77° C. (165° to 170° F.) the proportion of sugar inverted to the uncrystallisable condition is very large. It is found that a perfectly white refined sugar exposed to a temperature of 107° C. (224° F.) for 3 hours becomes quite yellow. The normal boiling-point of syrup at a density of 10° B. is about 101° C. (214° F.). In these Aba pans, the extra pressure of 3 to 6 lb. of steam means an increase of 8° to 16° F. in the temperature in order to arrive at the boiling-point, which would seem to be highly injurious.

As a matter of fact, however, long exposure is quite as mischievous as a high temperature. It is easy to avoid one by incurring the other; the difficulty is to avoid both. Perhaps the chief harm of rapid concentration of a high temperature is the violent ebullition of the mass, whereby portions of the heated surface are momentarily left dry. The Aba pans, working with a steam temperature of 143° C. (290° F.) on the under side, and the juice being at 105½° C. (222° F.), actually made much less molasses (i. e. inverted and charred sugar) than more generally-recognised plans. Still the system cannot be recommended for adoption where there is no necessity for using the water evaporated from the juice.

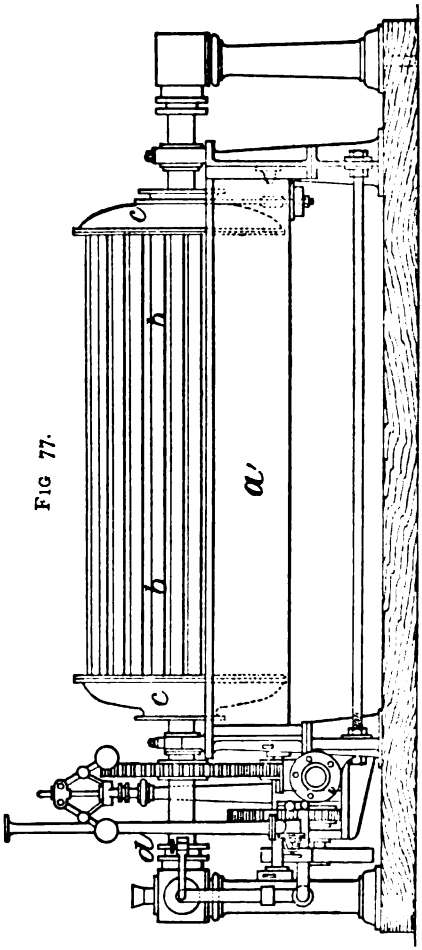
Film Evaporators.—Under this head are particularly included those forms of evaporator which depend upon the principle of exposing thin films of liquid to the action of a heated surface in the open air. They are generically known as "wetzels" among planters, and comprise the "pans" bearing the names of Gadsden, Wetzel, Schroeder, and Bour, and many other modifications, some of which, as Murdoch's, have steam-heated coils.

The original form of this class of evaporator was Aitchison's simple cylinder, revolving with partial immersion in the liquid, and heated internally by steam. In its revolution, the cylinder carries on its surface a film of liquid, whose water is soon evaporated. The objection to this plan was the difficulty of adjusting the cylinder to suit the decreasing volume of liquor.

In the Gadsden pan, the cylinder is replaced by a sort of skeleton cylinder, consisting of two metallic discs at the ends connected by a series of metallic rods fixed at short invervals around the periphery of each disc. Here the objections were the churning of the liquor (except at very low speeds), and the insufficiency of the heat derived from the steam-jacket of the pan.

Wetzel's improvement upon this was the substitution of steam-pipes for the solid rods. This overcame the deficiency of heat, and has been very generally adopted, though the churning is not reduced. Fig. 77 shows the Wetzel pan and its special engine, as made by Fawcett, Preston, & Co., Liverpool. The pan *a* contains the liquor; the pipes *b* are heated by steam passing through them; and the whole cylinder *c* is caused to revolve by the engine *d*. The large heating surface enables steam at very low pressure to be used, exhaust steam from the cane-mill engine being sometimes utilised for the purpose. By fitting the pipes diagonally (instead of horizontally) between the discs, the churning is modified, but not altogether prevented.

FIG. 77.



Wetzel's Pan.

Schroeder aimed at overcoming the churning by having a jacketed pan fitted with a set of revolving solid metallic discs strung upon a square shaft, and fixed at about 6 inches apart. The churning is thus avoided, and the apparatus has the additional advantage of cheapness, but the heat derived from the steam-jacket requires to be

Fig. 1.

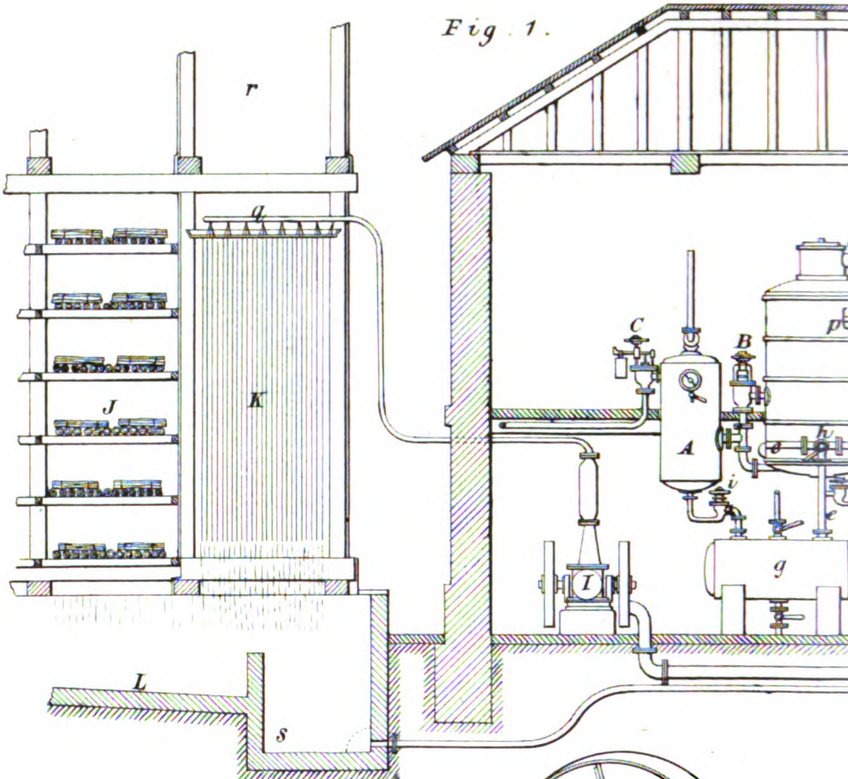
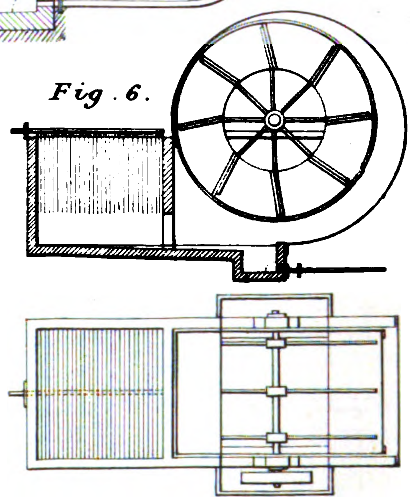


Fig. 6.



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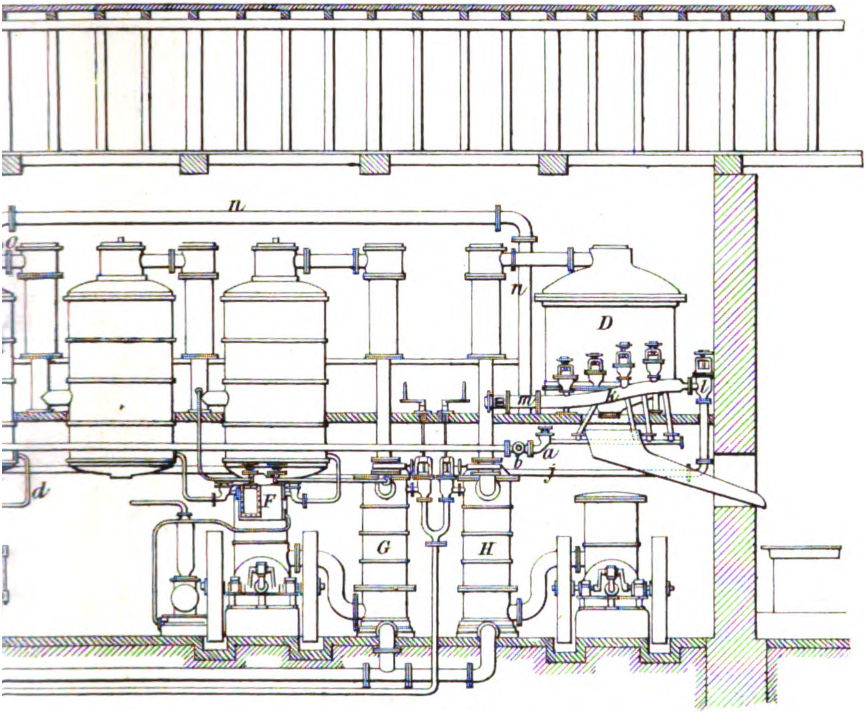


...g. 5.

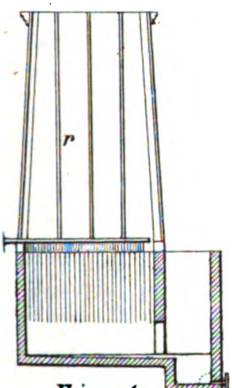


Fig. 4.

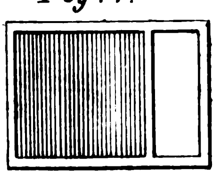


Fig. 2.

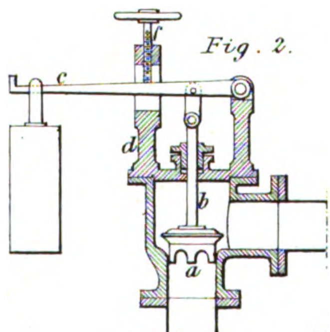
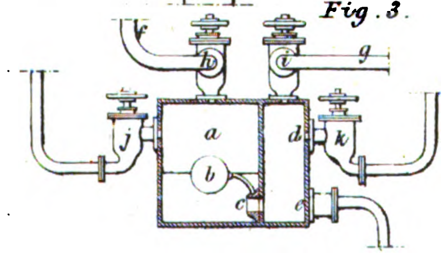


Fig. 3.

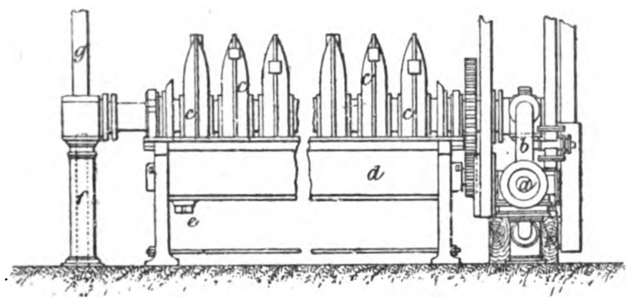


...ndon & New York.

supplemented by a coil of steam-pipe winding between the discs.

Bour observed that larger grains of sugar were produced on the discs in Wetzel's pan than on the pipes, and hence concluded that a series of hollow steam-heated discs would

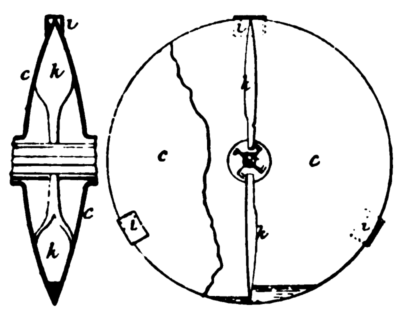
FIG. 78.



Bour's Pan.

increase the evaporating surface, and produce better grain. A front elevation of his pan is shown in Fig. 78; and vertical and transverse sections of the disc on an enlarged scale in Fig. 79. *a*, is the steam-engine; *b*, the exhaust-pipe used to heat the revolver; *c*, the revolver, consisting of 10 copper discs; *d*, a copper pan for holding the liquor under treatment, and which is discharged by the valve *e* at bottom; *f*, a pipe for carrying off the condensed water from pan; *g*, pipe for carrying off air and uncondensed steam; *h*, safety-valve. Thus the pan consists of 10 hollow discs of copper, mounted on an axis of a form which allows the steam to communicate

FIG. 79.

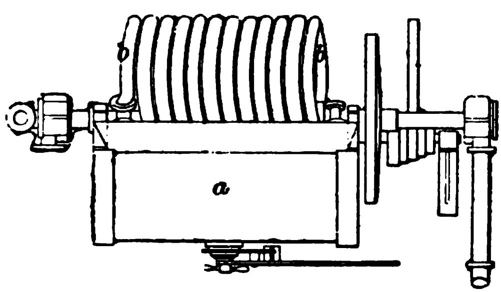


Sections of Disc of Bour's Pan.

freely with all the discs, and, at the same time, collects the water resulting from the condensation, and carries it off at one end. In the inside of each disc, are 2 spoons *k*, running from the extreme diameter of the disc, and terminating in the axis into which the water is delivered. On the outside of the discs *c*, are a number of small buckets *i*, which lift the liquor as the discs move round, and, being open at the sides, allow it to spread itself as a thin film over the surface which is not immersed. The speed of the revolver may be 10 to 20 revolutions per minute. Where steam is plentiful, equally good sugar is produced by the quick speed, and nearly double the work is performed in the same time. On an estate in Penang, one of these pans has cooked 12 cwt. of sugar per hour, from 20° B., as taken from the battery, the temperature never exceeding 77° C. (170° F.). The safety-valve blows off at 2 lb. per square inch; this prevents bursting from over-pressure. This apparatus would be improved by the removal of the distributing-cups *i*, which churn the liquor excessively.

One of the most recent modifications is that invented by Pontifex, and shown in Fig. 80. The pan *a* contains the

FIG. 80.



Pontifex's Pan.

liquor to be evaporated, within which revolves a coil of steam-pipe *b*. Thus a large heating surface is obtained, without the drawback of churning up the liquor.

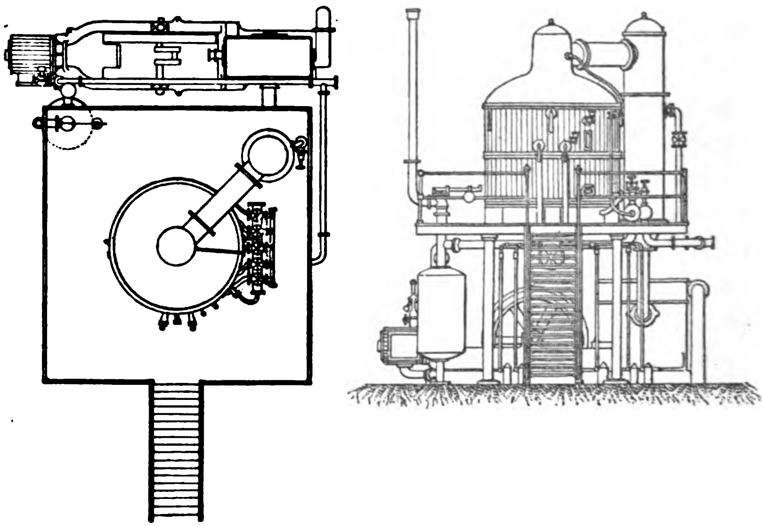
It is to be observed that all these forms of film evaporator are destined only to finish the concentration begun in the battery. The liquor is brought to them at a density of 26° to 27° B.

Vacuum-pans.—The difficulty of boiling dense liquids is too well known to require more than passing mention. The cause of this difficulty is the lessened ability of the vaporised water to overcome the pressure of the atmosphere, normally amounting to about 15 lb. per square inch. By relieving the liquid of this pressure, the "boiling" (that is the driving-off of the watery vapour) can be effected at far lower temperatures, reducing the consumption of fuel, and lessening the danger of burning the liquor. To apply these principles to the concentration of sugar syrups, the various forms of vacuum-pan have been introduced, in all of which the boiling proceeds *in vacuo.*

Fig. 81 shows an arrangement of a vertical cylindrical vacuum pan and pumping engine, by Manlove, Alliott, Fryer & Co., Nottingham.

The pan is of cast iron, with dome cover and conical bottom, having a sharp fall towards the outlet. The heating surface consists of five solid-drawn seamless copper coils, with brass inlet and outlet pipes, stayed to the sides and top of the pan with brass clips and rods. Each coil is supplied with steam by either of two valves—one for low-pressure steam, and the other for high-pressure steam from the boilers. On the top of the pan is fitted a capital with manhole and cover, and a large vapour pipe which leads to a save-all where any watery particles carried over by the vapour are intercepted, and may be returned to the pan or withdrawn as desired. From the save-all the vapour passes downwards into a condenser of extra large capacity, supported from a staging, and fitted with a large injection pipe with valve and perforated copper spray pipe, which can be readily removed or examined by opening a special hand-hole cover. The condenser is connected by means of a conical outlet pipe to the pumping engine. The pan is fitted with two charging cocks for different qualities of syrups or molasses, proof-stick, test-cock, large oblong sight-glasses with wash-cups, steaming cock for cleaning the pan, barometer, thermometer, and air-cock; and

FIG. 81.



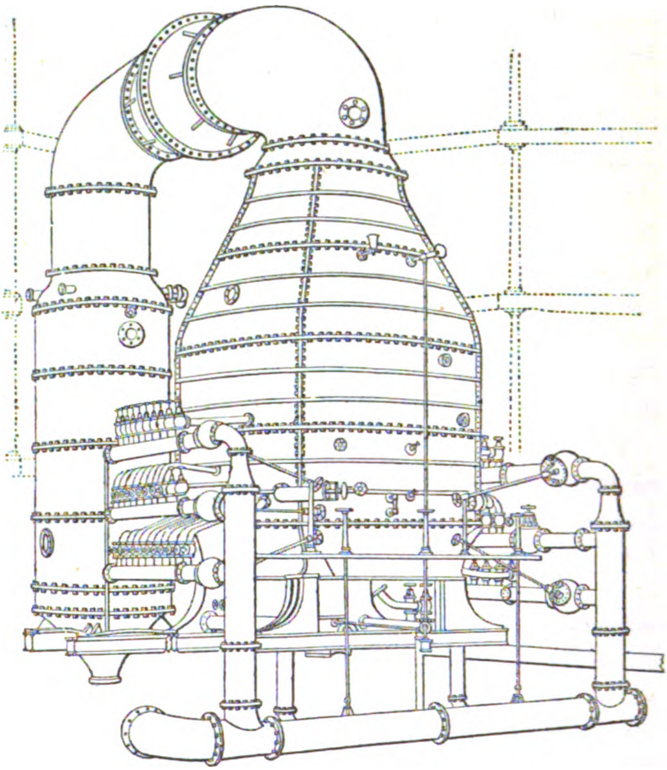
Manlove's Vertical Vacuum Pan.

is lagged with polished mahogany, felt, and polished brass bands. At the bottom of the pan a large outlet sluice-valve is provided, especially arranged to prevent the *masse-cuite* from adhering to the working surface, and arranged for luting with molasses. This valve is worked by a hand-wheel and screw carried from the under side of the staging. The whole is supported on a neat wrought-iron stage with polished hand railing, ornamental iron staircase, and strong cast-iron columns. A steam receiver is provided to collect the exhaust steam from the vacuum pump and other engines in the factory for the supply of the coils, and it is furnished with an escape-valve, pressure-gauge, and steam-trap. The condensation water is withdrawn by means of a separate steam-trap from each pan coil. The vacuum pumping engine is of unusually large capacity, to ensure the maintenance of a very high vacuum and consequent efficiency of the pan. This vacuum pumping engine has been specially designed to avoid several of the disadvantages inherent in some of the well-known types of these engines; the heavy fly-wheel is entirely carried between the bearings and the pump ram, and the steam piston is directly connected without the intervention of link-work; the whole pump occupies much less valuable floor space than is usual, and all the parts are most readily accessible for examination and repairs, and are easily understood by any unskilled mechanic. The pump proper is of the floating ram displacement type, with suction and delivery valves of very large area, and is so arranged that all the valves, gun-metal grids, and guards, can be withdrawn, examined, and replaced in a few minutes.

Fig. 82 shows probably the largest vacuum pan ever built, recently constructed by Robert Deeley & Co., New York, for the California Sugar Refinery, San Francisco. The body of the pan is of iron, 1½ inches thick, there being four perpendicular sections, two dome-like sections at the top, and one bottom section, all accurately and carefully fitted and bolted together. The inside diameter is 17 feet, the height being 31 feet 7 inches, and the height to top of overflow 42 feet 6 inches. The capacity of this pan is about 1000 barrels, or over 100 tons of sugar at each "strike," the time required to make a "strike," or sufficiently exhaust the water from the juice before treatment by the centrifugal, being under ordinary conditions three hours.

The principle on which a vacuum-pan is based, is the fact that the boiling point of water, syrup, or any liquid, is in part dependent upon the pressure of the atmosphere, the temperature at which the liquid boils being higher or lower according as the atmospheric pressure is increased or diminished. In practice, with these pans, the liquor is boiled at a temperature of 110° to 120° F., so there is no danger of burning the sugar, the inversion of sugar is reduced to a minimum, and the rapidity of the operation is greatly increased. A pan of this

FIG. 82.



Deeley's Vacuum-pan.

size must necessarily be of great strength, in order to resist the atmospheric pressure, which increases according as the vacuum is more perfect.

The arrangements for heating will be readily understood by reference to the illustration, the copper coils for this purpose presenting a surface of over 3000 square feet. There are eight of these separate coils, five being of 4-inch diameter, and three of 5-inch diameter, affording 69 inlets and outlets, and connected with eight steam trunks, two of 8-inch and six of 12-inch diameter, the steam being supplied by a 30-inch main. Every facility is given for easy working, all the main valve-stems being carried to convenient positions on the working platform, from which also the "strike," or discharge valve at the bottom of the pan, is operated. This valve is 20-inch diameter.

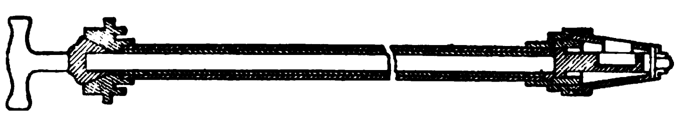
The pan is charged with the liquor through two 6-inch valves, controlled on the working platform, the atmospheric pressure readily forcing the liquor in. The cane-juice with which the pan is charged, usually gauges 25° to 30° Baumé, or about 10 lb. to the gallon, and when discharged it is about the consistency of thick mortar. It is intended, in operation, that this pan will be filled with liquor only to a depth of 18 feet, leaving 8 feet vapour space above within the pan itself, besides the room allowed in the great pipe leading from the top. There is a spray catcher or intercepter in the dome of the pan, and the vapour pipe leading up from its top is 6 feet in diameter. Situated in this vapour pipe, between pan and condenser, is a portion enlarged to 10 feet diameter, forming a trap to catch any overflow, which can be returned to pan or tanks as desired, and thence the 6-feet vapour pipes continue to condenser, which is 8 feet diameter and 28 feet high. The condenser has two 8-inch perforated injection pipes and four scattering plates. The pumps which make and maintain the vacuum are connected with the condenser, forming what is termed a "dry" vacuum.

The pan has two of what are styled lock proof-sticks, for removing and testing from time to time a small quantity of the syrup, but these proof-sticks are in reality tubes with nicely fitted valves and a piston for removing the syrup without destroying the vacuum. There are also eight eye-glasses arranged in different positions to enable the operator to keep a constant watch on the work going on inside the pan. A barometer and thermometer are also connected with the interior of the pan, by which the extent of the vacuum and the temperature of the contents are indicated at a glance. Formerly vacuum pans were built almost exclusively of copper, but of late years cast iron has been the choice, only the heating coils being of copper, the coils being so fixed as to prevent their vibrating during the boiling, and allowing for expansion and contraction without strain.

Besides the amount of fuel saved and the economy of conducting the sugar manufacture with a pan of such device as this, where the work can all be so easily overlooked and the process minutely regulated, probably the greatest advantage of all lies in the largely increased proportion of sugar thus gained, and the comparatively small quantity of molasses which each "strike" affords. By such improved pans the yield of sugar amounts to six or eight hogsheads to one of molasses, while by less improved means only two or three hogsheads of sugar are obtained to one of molasses.

The proof-stick (Fig. 83) is simply a brass or gun-metal tube, which is driven from the upper part of the side of the

FIG. 83.



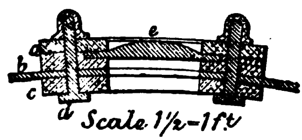
Proof-stick.

vacuum-pan down an aperture made of the same size as the rod. When it reaches the bottom, the tube is twisted half round by the cross handle, and opens a communication between the end of the tube and the syrup. In the end of the tube is a groove into which the syrup enters; the handle is half turned again, the tube is drawn out, and the entrance is closed as before. The liquor can thus be examined without destroying the vacuum in the pan.

The detail of the sight-glass is shown in Fig. 84: *a*, gun-metal rings; *b*, vacuum-pan; *c*, leaden ring; *d*, ⅝-inch bolt; *e*, glass plate.

Fig. 85 shows a side-view, and Fig. 86 a plan underneath of a slide. It consists of a gun-metal cup and slide *a*, and wrought-iron lever bar *b*, fitted with bearings, and of the form and figured dimensions shown.

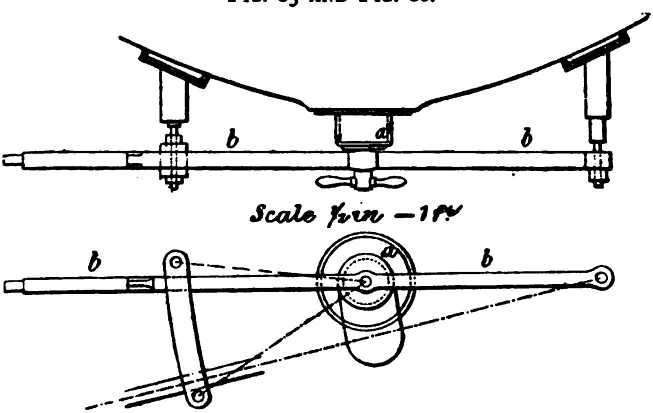
FIG. 84.



Sight-glass.

Figs. 87, 88, 89, and 90 illustrate vacuum-pans as used on nearly all large sugar estates. Figs. 87 and 88 show a section and plan of a vacuum-pan erected lately in Cuba, made of copper, and with 2 breasts instead of 1, so as to give large

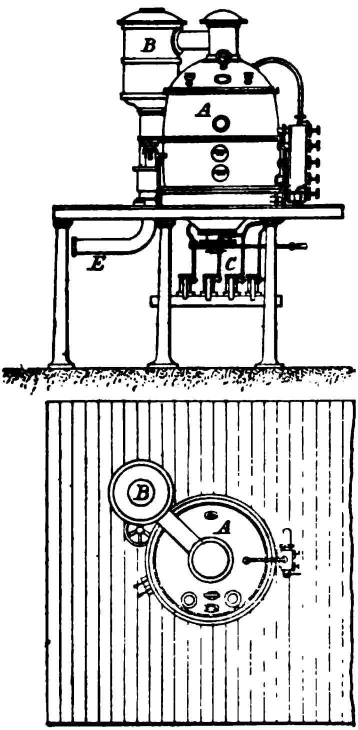
FIG. 85 AND FIG. 86.



Vacuum-pan Slide.

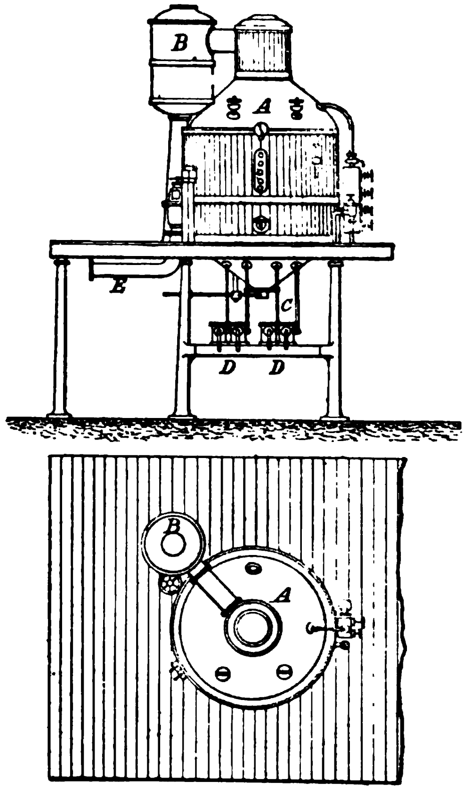
capacity, to enable the planter to concentrate and finish to grain one day's work if he chooses, by slowly concentrating and building up the grain during 10 or 12 hours; in this way is produced a strong brilliant grocery sugar of large grain, giving in the centrifugals from 66 to 70 per cent. of marketable sugar from the *masse-cuite*. The vacuum-pan is shown at A; B is a save-all, E is the charging valve, and on the opposite side are seen the steam valves for charging the different worms, and for regulating the heat inside when molasses alone is being boiled.

FIG. 87 AND FIG. 88.



Copper Vacuum-pan.

FIG. 89 AND FIG. 90.



Cast-iron Vacuum-pan.

Figs. 89 and 90 show a section and plan of a cast-iron vacuum-pan. The dome A is conical in shape and covered with cement. The save-all B is attached in the usual manner; E is the charging pipe, C the discharge valve, and D the boxes for the condensed water, to prevent the emission of live steam from the worms of the pan.

Some years ago, the syrup was boiled in the vacuum-pans simply until it reached such a point of concentration as to crystallise freely in coolers. This operation used to take about 3 to 3½ hours; but it has been found more profitable of late years to elaborate the grain in the pan before discharging the *masse-cuite*, and a charge may now take from 5 to 10 hours to finish: hence very large pans are required to hold one large charge of *masse-cuite* instead of several smaller charges. The grain formed from syrups boiled *in vacuo* is larger and more solid than that from syrups simply concentrated to crystallising-point in open batteries. A Cuban hogshead will contain only 1600 lb. of sugar made in the copper-wall, but 1800 lb. of vacuum-pan sugar. By the use of the vacuum-pan also, the planter is enabled to boil his molasses, and to extract from 1 gallon some 4 to 5 lb. of sugar, still leaving a second molasses for the rum distillery.

Surface Condensation.—In situations where there is not sufficient water to admit of condensation by injection being used, surface condensation is employed to maintain a vacuum in the pan. For this purpose, Pontifex & Wood use condensers, which consist of one or more series of iron or copper pipes, fixed to boxes at each end, with partitions to direct the current of the vapour. Above each series of pipes is fixed a trough, always kept full of water, and so constructed that the water trickles in a gentle shower uniformly spread over the pipes, so as to keep them well covered with a thin film. The lowest pipe is connected with a small pump worked by the engine, which draws the condensed vapour, and any air that may have collected, from the pan. The improvement consists in doing away with solder joints at the junction of the pipes with the case, the solder being liable to crack from the unequal expansion of the pipes (owing to the lower pipes being cooler than the upper ones), and the substitution of an elastic joint, which allows for the irregularity of the expansions without injuring the vacuum. They are also easily replaced, not requiring any mechanical skill, and take up less space for shipment. The superior economy of water in these condensers is owing to the condensing water being evaporated, and carrying away not merely sensible but latent heat. The ordinary method of condensation is similar to that employed in the condensers of steam engines, when the steam is led into a vessel where it is brought into contact with a stream of cold water. In this case, as the condensing water must not be allowed to become vaporised, all the heat it absorbs must be in the form of sensible heat, and it is said practically to require about 30 times the quantity of condensing water. But in these surface condensers, the vapour which passes off from the surface of the pipes not only carries off the sensible heat, but also renders latent a great amount of heat in its conversion into vapour, the quantity of water passing off from the surface being equal, or nearly so, to the quantity condensed inside the pipes. The water which falls into the trough under the condenser is used over again, the heat of it not materially affecting the action of the condensers.

Working the vacuum-pan.—The method of using the vacuum-pan is generally as follows:—

The air-pump is started, and so soon as the vacuum reaches 26 or 27 inches, the feed-cock on the side of the pan is opened, and sufficient liquor is drawn in to completely cover the first coil; steam is next turned in, and the liquor rapidly concentrates; fresh supplies are admitted at short intervals, the feed-cock being opened say for 15 seconds at a time, until the mass commences to show "grain." The grain is fed carefully, the cock being opened frequently, and each time the quantity admitted is increased. As the amount of sugar in the pan continues to augment, steam is turned into the 2nd and 3rd coils, until, at the completion of the charge, the pan is nearly full, or just below the sight-glass. In this way, the grain "grows" in size. On the conclusion of the boiling, the vacuum is destroyed, and the charge is run out into a tank, and allowed to stand for an hour or two, when a further crystallisation takes place.

It is customary to draw in as much syrup as will cover the bottom coil (when reduced by concentration), called "graining low down." Some prefer to grain higher; some when the pan is half-full. An objection to graining high is that the grain has not so much time to grow, but it does not always hold good. A pan taking 7 hours to boil a strike of 8 tons of *masse-cuite* (concentrated juice) grained low, will only take 6 hours if grained higher. The crystals in the second case will not be so large, but, in an 8-ton pan, they will be of fair size, even by the quicker method. The drawing-in is conducted thus:—The charging-cock is opened, and shut off again as soon as the liquid boils up to the "bull's-eye" on the opposite side. The contents quickly boil down; the cock is opened again, and shut off as before when the liquor boils to the same height. This is kept on until the syrup intended to form grain has been taken in: roughly speaking, 2000 gallons of good 18°- to 20°-B. syrup to a 5-ton pan is about the correct amount.

The granulating-point is easily recognised by a practical pan-boiler: a "proof" of the syrup, taken between the thumb and finger, should draw to a thread $\frac{3}{4}$-inch long; but this test is of no value if the syrup is sticky, resulting from under-tempering or sour canes.

In boiling for large grain, it is essential to grain low. The grain commences to form in minute specks; these rapidly increase in number and size, until the whole mass of liquor is filled with them. As each lot of syrup is admitted, it deposits on the grains already formed, causing these to grow larger. During granulation, the temperature should never be more than 71° to 78° C. (160° to 172° F.), though raised later on to harden the crystals; but this must not be done too soon after graining, or the crystals will melt.

Rules for graining syrup in the vacuum-pan are: the thinner the syrup admitted, the bigger will the crystals be; for large-grain sugar, few and heavy charges must be admitted, so as to give the grain time to grow; the larger the crystals are required, the more quietly and slowly must the boiling be carried on; to make regular grain, granulation is brought about very slowly, and on no account must the grain be forced by boiling very high before the first charge.

It is important in pan-boiling to avoid forming "false grain." The two stages when the danger of it is greatest are —(1) The time when the sulphuric acid (for producing "yellow crystals") is admitted into the pan; (2) the "opening" of the sugar when restarting the pan to "double," i. e. when, having struck out half the contents of the pan, fresh portions of syrup are admitted on to the *masse-cuite* left in the pan. If the contents are not sufficiently high when sulphuric acid is admitted, false grain forms whilst working up for striking. Unless the *masse-cuite* be "opened" very slowly, the new lot of syrup, instead of depositing on the already-formed crystals and increasing their size, will form an independent grain, called "false grain," which not only spoils the sugar, but prevents the molasses leaving it in the centrifugals.

When false grain is very bad, the best course is to strike it out immediately, and spin it in the centrifugals, mixing it with warm water if absolutely necessary. When not very bad, and the pan is little more than half-full, the heat and washing of a few heavy charges of new syrup will remove it.

Demerara "yellow crystals."—Sulphuric acid imparts to the sugar the delicate yellow bloom so much admired in "Demerara crystals," instead of the ordinary green-grey colour. If too little is mixed with the *masse-cuite* in the pan, the colour is scarcely improved; if too much, the sugar turns quite red a day or two after curing. It is admitted last of all; pan-boilers should not be allowed to make a charge of syrup on to it immediately previous to striking. The quantity of acid to be used depends on the colour of the *masse-cuite*; as a rule, 3 gallons of acid diluted with 1½ gallons of cold condensed water to 5 tons of sugar is about right. In all cases, the least possible quantity should be used compatible with securing the desired result.

The proper striking-point is of great importance, and arrives when the proof will scarcely run out of the socket of the proof-stick. *Masse-cuite* on leaving the pan should have a light-red colour tinged with gold, and a temperature of 66° C. (150° F.)—never higher. The objects of doubling are to increase the size of the grain, so that the market value of the sugar may be enhanced, and to save time. Some syrup makes sugar that will bear doubling 2 to 5 times; while some gets sticky after the 1st cut of the pan. Great care must be taken while opening the *masse-cuite* left in the pans; for the 3rd or 4th cuts, a temperature of 74° C. (165° F.) may be maintained while opening slowly and carefully, the operation requiring 15 to 25 minutes. The drawing-in of syrup demands more care in subsequent cuts than in the first.

Great loss of sugar is caused by doubling, depending on the amount of acid used, and on the quality of the syrup; it is estimated to amount to 20 to 25 per cent. of the sugar, and some hold that a better return is obtained from the larger quantity of dark sugar at a lower price; but on the other hand the "loss" means sugar converted into a high-class "golden syrup," and the extra market-value of the yellow crystals is affirmed by some of the best authorities to more than atone for the extra cost and increased inversion of crystallisable sugar.

When sour canes are sent to the buildings, the sugar is apt to get sticky in the pan, and occasionally to such a degree as to interfere with the formation of grain, and endanger the whole strike of sugar. If the stickiness is not very bad, 2 to 3 buckets of strong lime-water, taken into the pan through the acid-cock, will put things straight. Besides this, the excess of acidity should be neutralised by lime-water, leaving the syrup only slightly acid before drawing into the pan.

Molasses.—"First molasses" runs from *masse-cuite* which has had no molasses boiled in it; "2nd molasses" drains from *masse-cuite* boiled with molasses in it; "3rd molasses" drains from vacuum-pan molasses-sugar (not muscovado sugar). These are kept distinct. Third molasses is so sticky and impure that it is sent to the rum distillery (see Chapter on Rum), as is also sometimes the case with 2nd molasses, when low quotations do not pay to convert it into sugar. Only 1st molasses should be used for mixing with syrup-sugar in the pan, and 2nd molasses for boiling molasses-sugar ("3rd sugar"); 2nd molasses should never be used for boiling with pure syrup-sugar in lieu of 1st molasses. There is a great difference of opinion about the boiling of molasses; but the plan now to be described is the best, provided arrangements permit the molasses to be boiled within 1 to 2 hours of separation in the centrifugals.

Supposing that the pan has struck out 3 tons, being refilled and cut a second time, leaving it still half-full, for a third time fresh molasses tempered with lime-water, and reduced with water to 30° B., is drawn in. The contents, struck out and "spun" in the centrifugal, should yield 2½ to 3 tons of 2nd sugar, i. e. syrup-sugar with which molasses has been boiled, giving about 1·2 tons of sugar from molasses, much improved in colour, in addition to the 2 tons obtained from the syrup, and upon which the molasses was admitted. To make a very pale sugar, this process will not answer, and the molasses must be made into fine quality 3rd sugar, or into rum.

For tempering molasses, lime-water should be stirred in until most of the acidity is destroyed, and only a faintly acid reaction is shown on litmus-paper. For 2nd and 3rd syrups, or molasses which is to be boiled for grain, the density must be reduced to 30° B., either by blowing in live steam, or, if this be inadmissible, by the addition of condensed water. The boiling is performed in an exactly similar way to 1st syrup, except that it is useless to try for large grain, as the impurities effectually prevent the grain from increasing beyond a certain size. It is not an unusual custom to considerably raise the temperature before striking, by dropping the vacuum 2 to 3 inches; this is readily done by checking the supply of water to the condenser, and keeping the steam full on the coils and jacket. The temperature of the *masse-cuite* is then about 77° C. (170° F.), whereas it has previously been about 68° to 74° C. (155° to 165° F.). The object of this is to harden the grain, in order that it may be washed in the centrifugal. The *masse-cuite* from 2nd and 3rd syrups should always be allowed to stand 2 to 3 days in coolers, to "grow" the crystals before centrifugaling. Molasses from 3rd sugar of about 34° to 36° B., is always "jellied" or "boiled smooth," and it is not then necessary to reduce the density. If very acid, it should be nearly neutralised, and boiled until a proof will draw out in a thread 1 to 1½ inches long between the finger and thumb. At this stage, and before any sign of granulation has commenced, the contents of the pan are discharged into a cooler, and allowed to stand for 1 to 2 weeks, until the sugar has properly granulated, before centrifugaling.

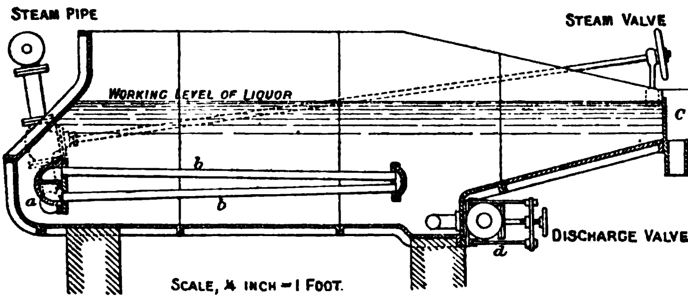
Novelties in Vacuum-pans.—A process has recently been introduced by Conrad W. Finzel and Edward Beanes for the use of water at the boiling-point, or of very low-pressure steam, for boiling sugar in vacuum-pans. Hitherto, for this purpose steam has been used at temperatures of 170° C. (225° F.) and upwards, equal to a pressure of 4⅓ lb. and upwards, whereby there has been more or less carbonisation, and consequent colouring of the sugar; it was deemed necessary to use steam of such high temperatures, in order that sufficient heat might be obtained throughout, and at the end of the worm used in the vacuum-pans, to cause the proper evaporation of the syrup. By the use of water continuously kept at the boiling-point, or steam at a temperature not exceeding 102° C. (215° F.), or at a pressure not exceeding 1½ lb. to the square inch, the syrup is boiled without carbonisation. To effect this object, it is convenient to employ a tubular vacuum-pan, reducing the length of the tubes, and increasing at the same time the number of tubes according to the evaporating surface required, so that it will only be necessary to use hot water or steam at a temperature below the carbonising point of saccharine syrups; while, from the shortness of the tubes in the pan, the water or steam will continue sufficiently hot during its passage through them, as to be perfectly effective for the purpose of boiling, and creating the proper evaporation throughout the pan, without causing any carbonisation and colouring of the sugar.

At Aba-el-Wakf, the vacuum-pans derive their steam from the concentrating-trays, as already mentioned. The pressure is thus very low, generally not more than 3 lb. per square inch, yet, with a vacuum of 27 inches, they work very satisfactorily.

Eliminating Pans.—On all well-appointed sugar estates on which the "Double," "Triple," or "Quadruple" effect is in use, eliminating pans for finally clearing the sugar liquor of all impurities before passing it into the effect are found to be a necessary adjunct. The latest and most improved form of this apparatus is the patent eliminator constructed by M'Onie, Harvey, & Co., colonial engineers, Glasgow. It has the great advantage of thoroughly cleansing the liquor, and the further advantage of being almost wholly automatic in its skimming action.

This eliminator is shown in sectional elevation in Fig. 91. It consists of a rectangular tank, built of cast-iron plates, fitted with a trunnion pipe *a*, having two rows of heating tubes *b*, and a skimming gutter *c*, fixed on end of tank farthest from trunnion. The trunnion *a* is fitted with packing boxes at each end, where it passes through sides of tank, and thus the whole heating part can be turned up out of the way so that the pan can be thoroughly cleaned. The trunnion *a* is divided by a longitudinal arch into two divisions, and is fitted

FIG. 91.



Eliminator.

with a tube-plate having the two rows of tubes fixed therein, these tubes being connected at their farther end by a similar tube-plate and cast-iron return pipe of D section. In working, the steam is turned on to trunnion, and is admitted into top section of same, from whence it travels along the top row of tubes, is returned at end of tubes by return pipe, through under row of tubes, and escapes at reverse end of trunnion, where a connection is made to steam-trap, said trap being capable of working under a pressure of at least 50 lb. per square inch. By the peculiar form of construction of the tank the end next steam trunnion is much the hottest part of the vessel, and as the liquor when heated rises there is a constant flow of colder liquor from the far end of tank, which causes a surface-current towards skimming gutter. The mode of working the automatic skimming eliminator is as follows :—

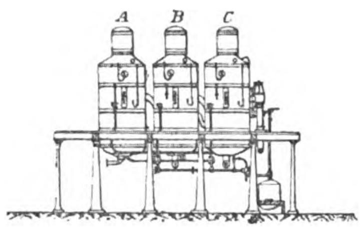
Steam is turned on to tubes soon enough to cause contents to simmer, say 210° F., by the time vessel is charged. Scum thus formed (a thin sticky film) is gently swept into the end skimming gutter. Steam is then turned nearly full open and the whole is violently boiled; as soon as active boiling takes place, the proper dose of phosphoric acid is thrown in, and boiling continues for about ten minutes. During this time a swift current (about 3 feet per second) is maintained towards the skimming lip, over the whole surface between the ends of heating tubes and skimming lip. A thin film of froth is maintained constantly flowing over the lip, and on the surface of the froth bubbles the impurities remaining in the liquor are carried away until the whole charge is clean. It is important to leave no obstruction to prevent the free circulation of the juice or liquor, hence a peculiar form of draw-off pipe attached to run off valve *d*, has been adopted.

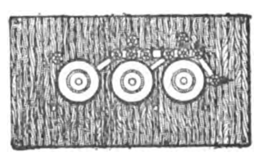
The size of eliminator shown, which is that most generally in use, is for a charge of 1000 gallons.

Multiple Effects.—It is not long since the French house of Cail et Cie. introduced a great improvement in the economy of vacuum-pans by working them in sets of 2 or 3, known as "double-effect" and "triple-effect" respectively. The triple-effect apparatus consists of 3 vertical cylinders of copper, each containing 2 tubes, of half the internal height of the cylinders, in which the steam circulates. The cylinders are 6 feet high and 3 feet in diameter, and are surrounded by a wooden casing, which materially retards the loss of heat; they communicate with the outside by pipes. The first cylinder receives the waste steam from the defecators and other machines used in the factory. The steam which rises from the boiling liquid in the first warms the liquid contained in the second cylinder, and the steam from the second in its turn warms the third; a successive diminution of atmospheric pressure in each cylinder takes place, and this reduction allows an active ebullition to go on, notwithstanding the diminution in heat. Two men suffice to look after the apparatus, and if the vacuum-pan be conveniently placed, those who are occupied with it can also attend to the cylindrical generators. By this arrangement all the men employed in looking after the coppers, and the furnace which warms them, are rendered unnecessary, and the sugar is prepared at a temperature which minimises the formation of molasses. The quantity of crystallisable sugar given by the juice thus becomes considerably greater, and at the same time its quality is said to be superior. The juice crystallises in 2 to 2½ hours. The saving of fuel by this system is said to amount to one-third.

Figs. 92 and 93 show an elevation and plan of a set of vertical triple-effect apparatus by Fawcett, Preston, & Co. The exhaust steam enters the heating-space of the pan C, and is condensed by the juice contained in the tubes. The first pan C is therefore a surface-condenser, and requires no injection-water; and the condensed water runs away to a receptacle, to be used again in the boilers. The vapour from the juice in C passes into the interior of B, producing a second ebullition, and is condensed here again by surface condensation. The condensed water from this pan is water of vegetation, as it comes from the cane-juice; it is taken for washing the animal black. Finally, the vapour from B enters A, and the vapour formed in A is condensed by direct injection. As, therefore, injection-water is only used for condensing the vapour formed in the pan A, great economy is obtained. Triple-effects can be constructed either of vertical or of horizontal vacuum-pans. Each system has its advantages; but when equally well constructed and worked, there is little or no difference in their results. On the whole, it may be said that the horizontal system does not require

FIGS. 92 AND 93.





Vertical Triple-effect.

such expensive machinery and such good execution as the vertical.

The saving in labour secured by the employment of triple-effect apparatus may be conveniently illustrated by some actual figures obtained on two similar estates, with syrup and sugar of identical quality and value, and under equally able management. On the estate using open batteries and a single vacuum-pan, the labour (negro) was as follows:—17 hands at centrifugals, 25 at batteries, 4 at vacuum-pan and engine, 8 collecting fuel, 4 at steam boiler: total, 58, working 18 hours a day = 1044 hours of labour. The second used a juice-heater, defecating- and subsiding-tanks, a triple-effect, and a vacuum-pan, and employed the following labour:—12 hands at centrifugals, 3 at triple-effect, 2 at vacuum-pan, 4 collecting fuel, 6 at steam-boilers, 3 engineers, 4 at defecators, 2 at scum-tanks, 2 at syrup-tanks, 2 at molasses-tanks: total, 40, working 13 hours a day = 520 hours of labour. Each factory turned out 13 tons of 1st and 2nd sugars per diem.

Fig. 94 shows a triple-effect by Manlove, Alliott, Fryer, & Co. In this apparatus, the evaporation of the juice is carried out in three successive stages. In the first of the three vessels, in which a vacuum is maintained of about 8 inches of mercury, the juice is heated directly by steam at a pressure of a few lb. above the atmosphere. The vapour from the juice in this first vessel is used to evaporate the juice in the second vessel, in which a vacuum of about 14 inches is maintained; and the vapour from the juice in this second vessel is in like manner utilised to evaporate the juice contained in the third vessel, in which a vacuum is maintained of about 28 inches, or the best obtainable. By this system of evaporation the latent heat of the vapour from the juice in the first and second vessels is utilised in evaporating the juice in the second and third vessels; thus theoretically one pound of steam used in this apparatus will evaporate nearly three

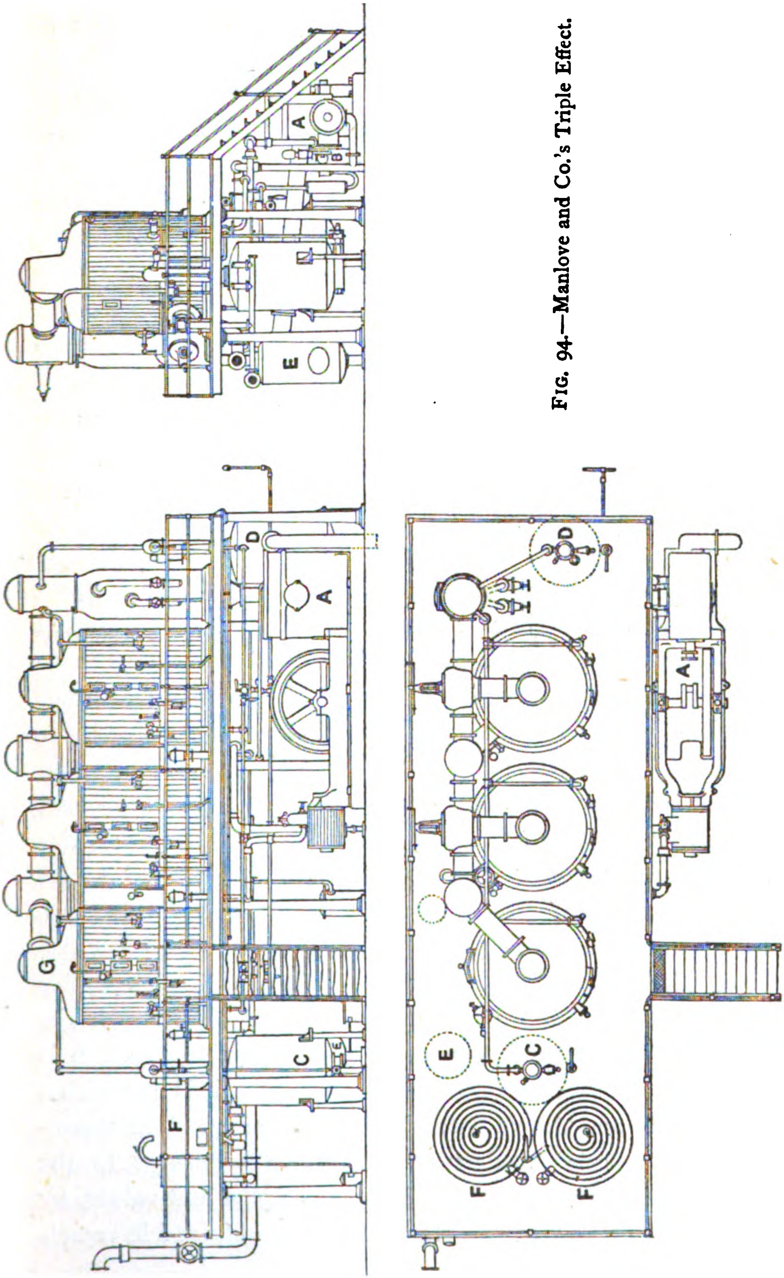


FIG. 94.—Manlove and Co.'s Triple Effect.

times as much water from the juice as would one pound of steam used in an ordinary vacuum pan; added to which the low temperatures corresponding to the vacuum obtained in the different vessels prevent any damage to the juice through over-heating.

The reference letters indicate as follows:—A, vacuum pumping-engine; B, draining-pump for steam chests; C, filling *monte-jus;* D, emptying *vide-jus;* E, low-pressure steam recipient; F, syrup eliminators; G, first vessel.

The three vessels of this apparatus are made of cast-iron, cylindrical in form, with dome covers and specially shaped conical bottoms. Each vessel contains a copper steam-chest, in which are fixed a large number of brass tubes about 2 inches in diameter, thus exposing on the exterior of the chest and the interior of the tubes a large area of heating surface in contact with the juice. A space of about 6 inches in width is left between the drum and the side of the vessel all round for circulation of the juice. Low-pressure steam is admitted by means of a valve and special steel connection into the interior of the steam chest of the first or No. 1 vessel, which has previously been filled to a depth of about 1 ft. above the surface of the chest with clarified cane-juice. The vapour which arises from the juice passes out of the top of the vessel into a cast-iron save-all, which intercepts any watery particles and returns them to the vessel, while the vapour passes down through a vertical pipe and through a large valve into the steam-chest of the second or No. 2 vessel which has also been filled with juice. The vapour from the juice in this second vessel in like manner enters the steam-chest of the third or No. 3 vessel, the vapour from the juice in which is carried past a save-all into a condenser, where it is met with a water-spray and drawn into the vacuum pump. The steam-chests of vessels Nos. 2 and 3 are also connected to the condenser by means of a small copper pipe and valves, by which at starting a partial vacuum can be obtained in vessels

Nos. 1 and 2, and the ammoniacal vapours be withdrawn. By a simple but not easily described arrangement of pipes and valves below the platform, the partially concentrated juice from the first vessel can be passed over into the second vessel, from which the still more concentrated juice can be drawn over into vessel No. 3; or a further supply of cane-juice can be drawn from the supply tanks into either of the three vessels; or the partially concentrated syrup can be passed direct from the first to the third vessel. A further system of pipes is provided for washing out the vessels. The condensation water from the steam-chest of the first vessel is withdrawn by means of a special form of steam-trap, that from the steam-chests of vessels Nos. 2 and 3 is withdrawn by means of pumps worked off the vacuum pumping engine; and pipes and valves are fitted for the purpose of supplying high pressure steam to either of the three steam-chests when desired. The clarified cane-juice is supplied to the first vessel by means of a *monte-jus* connected with the condenser, and can thus be drawn from tanks at some distance below the level of the staging. Concentrated syrup is removed from the third vessel by means of a *vide-jus*, which is also connected to the condenser, and delivers into either of two circular eliminating pans. In these pans the syrup can be heated by means of steam coils to nearly the boiling point, so as to coagulate, and thus facilitate the removal of any albuminous matter or other impurities which may have escaped previous clarification; it is then usually fit to be sent to the vacuum pan supply tanks. The supply of juice and the removal of syrup are sometimes effected by means of pumps, which can be adjusted to run continuously and maintain the juice at a constant level in the vessels. Sight-glasses, barometers, thermometers, and test apparatus are fitted to each vessel to admit of the process of evaporation being easily observed and tested. Air cocks and steaming cocks are also fitted for emptying or cleaning purposes. The condenser is of specially large capacity, and fitted with large injection pipes and roses, and the vacuum pumping engine is extra powerful, to ensure the maintenance of a very high vacuum in the third pan, since upon this directly depends the efficiency of the whole apparatus, nothing being more detrimental to the proper working of a triple-effect than any insufficiency of vacuum-producing power. A large receiver with the necessary escape-valve and other fittings is provided for collecting the exhaust steam from the vacuum pump and various engines of the factory. The whole apparatus is carried by a neat wrought-iron staging, with polished hand-railing and ornamental iron staircase having strong cast-iron pillars. Large two-way change valves of special design are fitted to the vapour pipes between the vessels, so that any one or two of the latter may be isolated and the apparatus worked as a single- or double-effect when desired. Messrs. Manlove also arrange a closed tubular juice-heater, through which the vapours from the juice in the third pan pass to the condenser. This is used for heating the raw juice from the mill on its way to the clarifiers, and has been found to effect a considerable saving in steam.

An excellent arrangement of multiple-effect apparatus, with a specially designed vacuum-pump, is made by J. Fletcher & Co., Poplar, to whom application should be made for further information.

Rillieux, of Paris, recently introduced some improvements in triple-action apparatus used in the manufacture of sugar. The improvements will be readily understood from Plate V., in which Fig. 1 shows a general elevation of the combined apparatus, while Figs. 2 to 6 show separate details.

In multiple action apparatus, direct steam is required; this is introduced into the recipient for discharged steam A, whence the first evaporating pan is fed through the valve B. If too much steam is introduced, the action of the apparatus is retarded or stopped. In order to prevent this, the recipient A is provided with an equilibrium valve C (shown in enlarged detail in Fig. 2), which regulates the maximum quantity of steam that can be used. It prevents the difference between the pressure upon the one face of the piston of the engines, and the counterpressure on the other side, from sinking below a certain point. For this purpose, the valve is arranged as follows:—The valve *a* (Fig. 2) has a stem *b* passing through a stuffing-box, and connected to a loaded lever *c*; this lever cannot be raised until the pressure in the generators exceeds the limit adapted for the proper working of the apparatus. It works inside a loop *d*, in the top of which is a screw *f*, so screwed down as to allow of only a small amount of motion in the lever and its valve; by means of this screw, the supply of steam is regulated. Instead of arranging this valve C to the left of the recipient A, it may be placed at B, on the pipe leading to the first evaporating pan.

The first recipient being the steam generator of the entire apparatus, and being heated by the discharge steam of all the engines, it is also connected with the discharge water from the coils of the boiling-pan as follows:—The steam-coils, being provided at their extremities with check-valves *a* (Fig. 1), are connected to a common collecting pipe *b*, of which the other end *c* is connected to a branch pipe at the bottom of the tubular part of the first evaporating pan. By this means, the small excess of steam that escapes with the water from the coils is made to assist in heating the first pan, while the combined water of condensation from the coils and from the said pan pass off through another pipe *d e*, provided with a check-valve *f*, into a recipient (*g*) or reservoir for the feed-pump to the generators. When the boiling-pan is employed without using the triple action, the passage of the condensing water and steam from the worms to the first pan is prevented by turning a three-way cock *h* into such a position that the steam worms of the boiling-pan communicate directly with the reservoir *g* of the feed-pump.

The cock *h* is arranged in the length of the collecting pipe *b c*, and allows this to communicate either with the bottom of the first pan, or with the reservoir *g*. The water of condensation from the first pan, as also the water contained in the vessel A, flows directly into the reservoir of the feed-pump through pipes in which are the check-valves *f* already mentioned, and the valve *i* on the pipe leading from the vessel A to the reservoir *g*. The several check-valves *a* to the worms of the boiling-pan, as also those (*f i*) of the first pan and recipient, have the extent of their opening regulated by a screw passing through the top of the valve chamber, so that they shall only allow the exact quantity of steam and water to pass that is necessary for the proper action of the apparatus. The boiling-pan D (Fig. 1) is also heated by the steam (from the discharge steam recipient A), which is conducted into it through the pipe *j* and distributing pipe *k*, the admission being regulated by a valve *l*. From the distributor *k*, it is led into one or other of the three or four coils of the pan. Steam could, however, also be taken from the first evaporating pan. For this purpose, the distributor *k* has a branch provided with a valve at *m*, connected to a pipe *n*, leading to the branch connecting the first evaporating pan with its condensing column. The boiling pans with steam coils have only a small amount of heating surface in proportion to their charge.

In order to effect boiling with double action with these pans, a considerable pressure is required in the first pan, namely, from ½ to ¾ atmosphere, and even more, according to the size of the coils. Under these conditions, the vacuum is very small, or even nothing in the second pan. Experiment has shown that no deterioration of the sugar takes place at the temperature indicated by this pressure. The pressure is regulated by introducing into the feed vessel for the triple action a sufficient quantity of direct steam, so that it does not interfere with the action of the apparatus. The pressure in this vessel may be one atmosphere or more. Up to the present time, operations have never been conducted under these conditions; the use of direct steam, therefore, has in this case quite a different object from that which ordinarily regulates its employment.

In order to maintain the normal pressure in the first pan, it is necessary in large machines to regulate the pressure by means of special apparatus. For this purpose, there is provided in the steam exhaust pipe of the first evaporating pan a throttle-valve *o*, which is automatically regulated so as to intercept the passage of the steam to the second pan as long as the pressure is not equal to that which it is desired to maintain. For this purpose, the axis of the throttle-valve *o* is provided with an external lever connected to a piston in a small cylinder *p*, on one side of which acts the steam pressure in the first evaporating pan, while the other side is open to the atmosphere. The piston is loaded so that it only rises when the pressure in the first pan is equal to that desired to be maintained. Thus, when the pressure is low, the piston closes the throttle-valve; while when the pressure rises so as to be equal to that desired to be maintained, the throttle-valve is full open; and at any intermediate pressure, the valve is held in a corresponding intermediate position, thus maintaining the pressure approximately constant. The regulating apparatus may either be a cylinder and piston or plunger, or a flexible diaphragm, provided it be sensitive.

If the boiling pan is heated by direct steam at high pressure, the discharge (condensed water and steam) is conveyed to the first evaporating pan. If steam from the expansion chamber be used, or the escape steam from the engines, the discharge from the boiling pan will be conveyed to the second evaporating pan. If steam from the first evaporating pan be used for boiling, the discharge passes to the third evaporating pan, and thence to the condenser. A pipe passes for this purpose along the evaporating apparatus, and a branch provided with a valve or cock extends from this pipe to the tubular part of each pan.

In triple-action apparatus, the first evaporating pan is, according to Rillieux's system, provided with two small auxiliary pans (shown at E, in Fig. 5) one serving to evaporate the syrups that have been subjected to the osmose action, and the other for evaporating the saline liquors, both being connected to the same condensing column.

For drawing off the water of condensation from the second and third evaporating pans, a double-acting pump is generally employed, each suction-valve of which is in communication with only one of the pans. In order to enable these pumps, which are generally too small for the work, to be employed with more effect, the following arrangement is employed:—The waters of condensation from the second and third pans pass into a small receptacle (Fig. 3), having two compartments; one (*a*) of these, which receives the water from the second pan, has a float *b* actuating a throttle-valve *c* which opens or closes a communication between the first and second compartment *d*, of which the latter receives the water from the third pan, while at bottom it is connected to the suction *e* of the exhaust-pump. The first compartment *a* also communicates by a pipe *f* with the safety-valve of the second pan, and the second compartment *d* communicates with the condenser by the pipe *g*, both communications being regulated by check-valves *h i*. The admission of water into the two compartments is also regulated by check-valves *j k*. When the water-level in the first compartment *a* has sunk to a certain depth, the float closes the communication with the second one, and only opens it again when the water has accumulated to a certain extent. As the float is so arranged as not to allow the water-level to uncover the communicating opening of the two compartments, no steam can pass from the one to the other, although a single pump is employed for drawing off the water from both pans. The back of the receptacle is removable, and can be made of glass for inspection.

To obtain a maximum effect from the apparatus modified as above described, it is necessary to maintain a considerable vacuum in the last pan. As it is much more difficult to obtain an effective vacuum by condensation of the steam by means of a water jet in this apparatus, than it is to obtain it in the condenser of an ordinary steam engine (probably on account of the presence of a large quantity of air and other uncondensable gases in the steam in the former case), the condensation is effected by bringing the steam into contact with very extended surfaces, over which the water flows in thin films, thus obtaining a very complete contact of the steam with the particles of water. The steam from the safety chamber is, as usual, subjected to a water jet.

To render the air-pumps for the exhaust more effective, the water is removed from the bottom of the condensers G H, by separate pumps I, so that the air-pumps, in only pumping air or gases, can work much more rapidly than in the usual arrangement where they have to pump both air and water. The pumps are, however, kept moistened to prevent heating. The pumps that draw off the water from the condensers deliver it to the refrigerating apparatus.

In this apparatus, instead of causing the water to trickle over layers of faggots J, as usual, a series of vertical canvas screens K are placed close together, and descend to a certain distance above the water-level in a trough L below; these are surrounded by tarpauling, woodwork, or brick walls, and a strong current of air is directed by a fan, as shown in Fig. 6, into the bottom of the enclosure, so as to ascend in the narrow spaces between the canvas screens, while the water discharged by the pump I is made to flow down them in a very divided state from perforated pipes or channels *q* above, in the reverse direction to the air currents, whereby the water will be cooled several degrees below the atmosphere. The air currents may also be produced by forming a ventilating shaft *r*, extending some height above the screens, as indicated in Fig. 4. The lower part of the apparatus would in that case be enclosed by movable doors or panels, which would be opened on the side whence the wind proceeds.

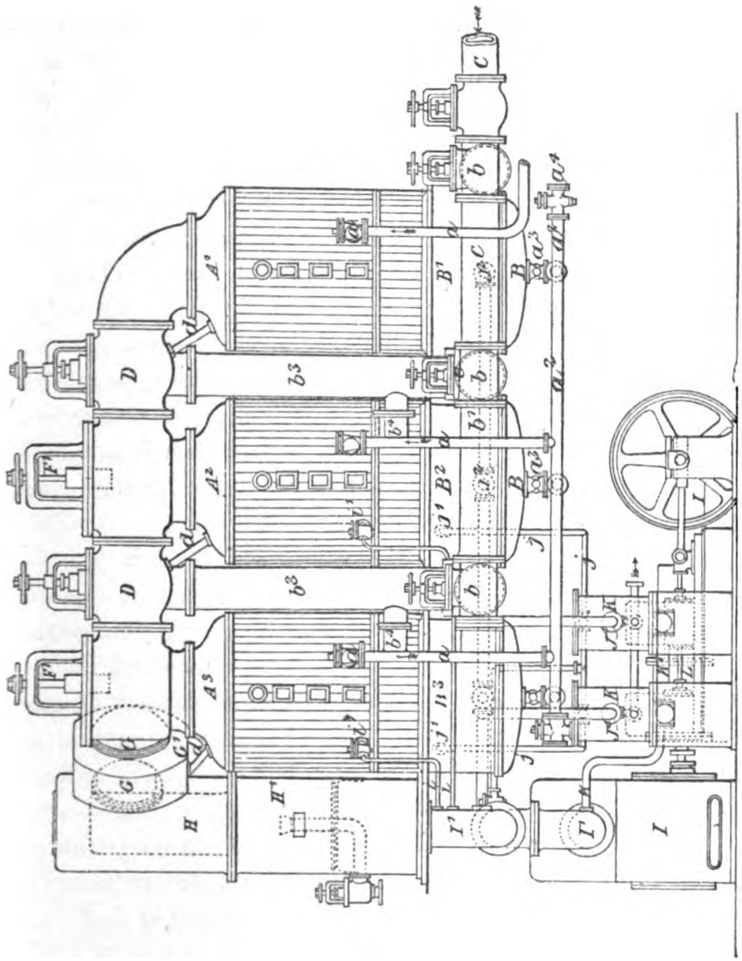
The water descending from the refrigerator is collected in a tank *s*, where the excess of air passes off from it, and whence it is then led by a pipe to the tops of the condensers. The canvas screens may conveniently be made out of old filter-press cloths or sacks sewn together. The apparatus does not require the large dimensions of the faggot house, and this may therefore readily be converted into the former.

This modification introduced by Rillieux is receiving considerable attention among the beet-sugar makers in France, though it was originally devised more especially for cane sugar. Reports which have appeared on its working are loud in its favour. One large manufacturer of beet sugar, in whose case the employment of the diffusion process gives a very low juice (sometimes only 2½° B., and generally not more than 3¼° B.), states that with the ordinary arrangement of the triple effect he evaporated 1800 hectolitres of juice at 3·2° B., with 150 hectolitres of milk of lime, making a total of 1950 hectolitres (each hectolitre = 22 gallons), to 18° B. per 24 hours; with Rillieux's modification, he evaporated down to a density of 25° B., which, with the increased quantity worked off, is equal to a total evaporation of 5158 hectolitres per 24 hours, or a gain of 3208 hectolitres. This gain is said to be effected at the cost of only a little (the quantity is not stated) additional steam.

Fig. 95 illustrates Foster & Campbell's patent evaporating apparatus, as applied to sugar-cane juice, of which Messrs. M'Onie, Harvey, & Co., colonial engineers, Glasgow, are the makers. The advantages claimed by this patent arrangement are complete and rapid circulation of the juice, combined with proper distribution of the steam in the most effective manner for the heating of the juice. This is arrived at by placing the various vapour inlets at such an angle in relation to the lines of heating tubes, that the steam comes in contact with all the tubes farthest away from the centre of large return tube.

The first vessel (A^1) has two inlets *b*, the top of this vessel

FIG. 95.



Foster and Campbell's Multiple Effect.

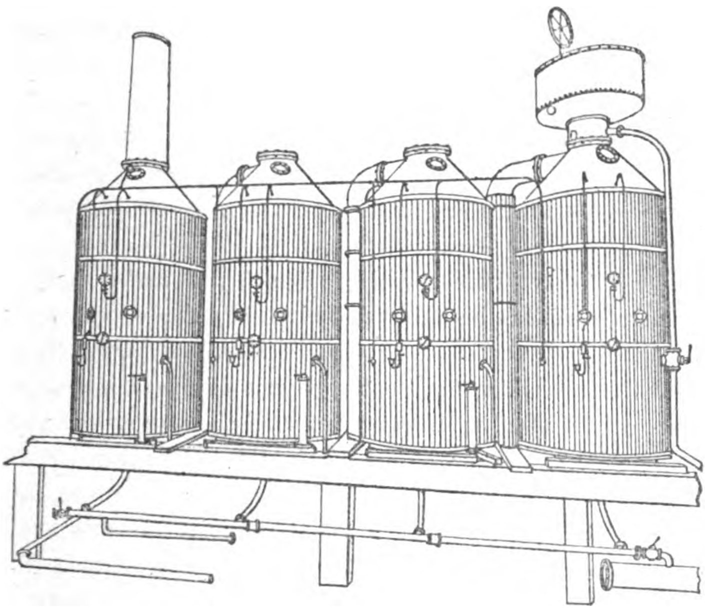
(A^1) has large outlet to chamber D, which has large size downcast pipes b^3 communicating with the four inlets b^4 to calandria or heating chamber B^2 of second vessel (A^2). The top of this second vessel has also large outlet chamber D^2 with downcast pipes b^3 to calandria B^3 of third vessel having also four inlets b^4. The top of this third vessel (A^3) is connected to large size condenser, which is again connected to a displacement vacuum pumping engine of corresponding size. This pumping engine has calandria pumps (L), which are used for drawing off the condensed water from the three calandrias B^1, B^2, and B^3. Calandria B^1 is also provided with a large size steam water trap, and the apparatus is in addition fitted with two special large and patent water traps K K between calandrias B^2 and B^3, which make it impossible for the calandria pumps above mentioned to draw anything but water. All the vapour arising from the water contained in these special receivers or traps can be returned to the calandrias. There is a special arrangement of pipes and cocks connected to main condenser, by means of which gases of any density lodging in any part of the calandrias can immediately be drawn off, the accumulation of such gases being one of the sources of interruption to the free distribution and circulation of the vapour or steam in the calandrias.

The drawing shows isolating valves with connecting valves and pipes, so that any one vessel can be shut off at any time for repairs, and the other two kept working. In general practice this is found unnecessary, and the makers recommend simple direct uninterrupted communication between all three vessels, which makes a very much simpler apparatus, and reduces the first cost considerably. The usual back pressure or exhaust steam of 2½ to 5 lb. on the square inch is ample to work this apparatus, which is automatic in its action, and has given great satisfaction to sugar planters—reducing the cost of labour, and effecting a very great saving in fuel.

Fig. 96, taken from a photograph, shows a patent multiple-effect evaporating apparatus in which several novel features have been introduced; it is constructed by Fawcett, Preston, & Co., Limited, for a plantation in Demerara.

In the first place, the quantity of juice passing through the apparatus is entirely controlled and regulated by the feed valve or cock seen to the right of the right-hand pan, the passage of the juice from this pan to the next one, and thence from pan to pan, being automatic and self-regulating. The

FIG. 96.



Fawcett and Preston's Quadruple Effect.

concentrated syrup is extracted from the last pan by a special steam pump, which can be stopped and started and regulated in speed by a valve attached in convenient position to the last pan.

Secondly, the condensations in the drum of the first pan are carried to the drum of the second pan, and then to that of the third pan, and so on. Though the idea of thus carrying the condensations from one drum to another, until they finally issue from the last drum at the temperature corresponding to the pressure therein, having parted with all the heat possible, is not novel, it has hitherto been unacceptable, because of the complications required in the connections between the pans, on account of the differences in pressure in the different drums. These difficulties have now been overcome by a simple system of syphons, which are entirely self-acting, and require no steam traps of any description.

The same firm have in hand as we go to press another apparatus of similar design, but capable of treating upwards of 5000 gallons of juice per hour.

Varyan System.—Multiple effect evaporation is based on the well-known law that the boiling point of a liquid varies with the pressure. Thus, the greater the pressure, the higher the boiling point; the less the pressure, or the higher the vacuum, the lower the boiling point.

The different boiling points of a liquid under different pressures can thus be utilised, by making the vapour given off in boiling the contents of the first vessel (or "effect") at a certain pressure, form the heating agent of the liquid boiling in the second effect at a lower pressure, the vapour from this second effect forming the heating agent in the third effect, and so on.

In liquids liable to injury by heat, the total variation of temperature available under ordinary conditions, is that between the temperature of steam at 5 lb. pressure per square inch (227° Fahr.), and the temperature of a solution at 30° B. boiling under a vacuum of 26 inches (131° Fahr.)—a total of 96° Fahr.

With a triple effect (or three vessels), there is steam at 5 lb. pressure in the drum or shell of the first effect, and the liquid in the tubes—at atmospheric pressure—boils at 227° Fahr., giving off vapour at 212° Fahr. This vapour at 212° Fahr. passes into the shell of the next effect, and boils the liquid in the tubes of this effect under 14 inches vacuum, giving off vapour at 161° Fahr. This, again, passes to the shell of the third effect and boils the liquid in the tubes under a vacuum of 26 inches, the boiling point of this liquid (supposing it to be a concentrated solution of 30° B.) being 131° Fahr.

It is a point worth noting that where the liquid is a solution of solids in water, the vapour will always be at the temperature of boiling water at the pressure to which the liquid at the time being is subjected, while the liquid itself will be warmer.

The total difference in temperature in evaporating liquids liable to injury by heat being, as mentioned above, 96° Fahr., while the amount of heat transmitted through the tubes (and therefore the work done), is practically proportional to the difference in temperature, it is evident that the same work is done whether the whole of this difference is in one vessel, or subdivided among several vessels.

In other words, a double, triple, or quadruple effect can only do the work of a single effect the size of the first vessel of the multiple effect; but it does it with $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ the quantity of steam or fuel respectively.

These principles apply equally to all multiple effect evaporators. We now come to the methods by which they are carried out in the Yaryan system, as illustrated in Fig. 97.

On a light iron framing, supported by columns about 6 feet high, are placed the "effects," so that the various cocks and valves can be operated by a man standing on the floor. Each effect consists of tubes surrounded by a shell (like a multitubular boiler), terminating in a separating chamber which contains a series of specially constructed baffle plates. Accompanying the above apparatus are the necessary feed, tail and vacuum pumps, and the condenser.

The method of operation is as follows:—

The liquid is pumped through the tubes of the first effect, the entrance to which is partially closed, so that only about one-tenth the area of the tube is filled with liquid, the openings being so arranged that there is an equal feed to each tube. Steam being let into the shell of the first effect causes the

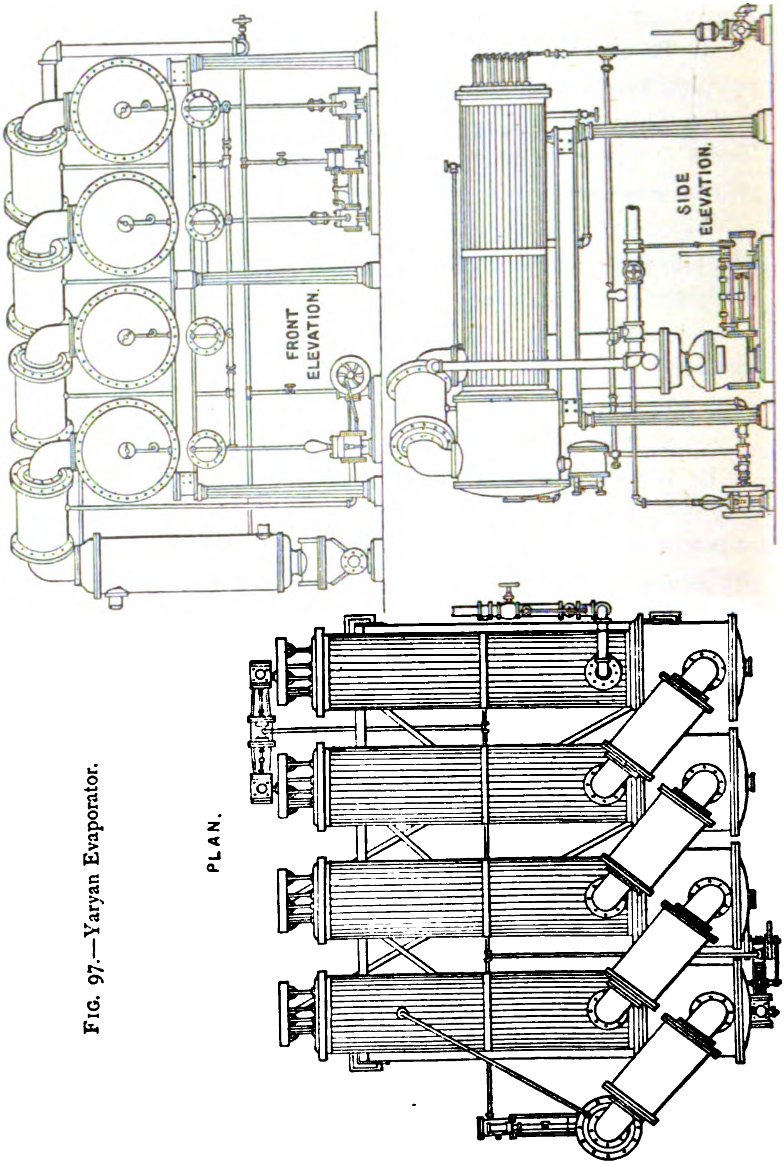


FIG. 97.—Yaryan Evaporator.

liquid fed into the tubes to boil, and the ebullition bathes the whole interior surface of the tube with a film of liquid.

When the liquid reaches the other end of the tube it is completely separated from the vapour by impingement on the baffle plates in the separating chamber. The vapour now passes into the drum of the next effect to form the heating agent there, while the liquid is drawn through the tubes of that effect by the lower pressure or partial vacuum maintained therein. The same process is repeated according to the number of effects.

The vacuum is maintained in the last effect by means of the vacuum pump and condenser, while the concentrated liquid is withdrawn by the tail pump.

The liquid being evaporated as a thin film, is only under treatment about a minute and a quarter in each effect.

The condensed vapour is drawn from each shell by the superior vacuum in the shell of the next effect; and from the shell of the last effect either by the vacuum in the condenser or by a small drip pump, if it is desired to utilise the drip water.

The various pumps can be worked, if desired, by one engine.

The advantages of this system in its application to sugar solutions are:—

(1) Short Exposure to Heat.—The liquid is exposed to heat for only 1¼ minute in each effect, instead of three-quarters of an hour as formerly. Thus in a "quadruple effect" it is only under treatment for five minutes altogether, from the time it enters into the apparatus as weak liquor till it is removed as a concentrated solution by the tail pump.

(2) Saving in Fuel.—The multiple effect system of using the steam several times can be carried further in the Yaryan than in any other system, on account of the less *difference* of temperature between the outside and inside of the tube necessary to evaporate a film as compared with a large body of liquid.

A well proportioned boiler, fired with good coals, should evaporate 8½ lb. of water per pound of coal, and supposing the liquid is at the boiling point when it reaches the apparatus, every pound of steam condensed in the first effect evaporates 1 lb. of water, and in turn the vapour thus produced evaporates 1 lb. of water in the next effect, and so on. There is of course some loss by radiation of heat, but as the vessels are small and easily lagged, this is reduced to a minimum. 16 lb. of water will therefore be evaporated in a double effect Yaryan apparatus, 23½ in a triple effect, 30½ in a quadruple effect, and 37 in a quintuple effect, for each pound of coal burned under such a boiler.

With ordinary vacuum pan—or steam pan—boiling, only 8½ lb. of water will be evaporated per pound of coal used, while with direct firing not more than 5 lb. of water per pound of coal can be evaporated.

Ease in Cleaning.—When there is no more liquor, hot water is run into the feed box, and this follows the juice through the apparatus, there not being more than a few gallons which come in contact with and can be diluted by the water. As this is done every day, the scour of the hot water through the tubes removes any deposit which may take place, while it is still soft, and once a month, if necessary, dilute hydrochloric acid is used after the hot water, and a further use of hot water removes all trace of acid from the tubes. The cover can also be removed and the tubes brushed out if desired.

(4) Rapidity in getting to Work.—The apparatus is in full work in a few minutes, giving off liquor of required density, and therefore the vacuum pans can start at once, instead of waiting two hours, as is not infrequent in other systems.

(5) Waste of Sugar by Priming.—This is impossible in the Yaryan system, liquors being boiled without any attention which in an open vacuum pan would be one mass of bubbles,

though the pan were 60 feet high. In fact, in this system, priming, instead of being the great evil to be avoided, is in a way the normal condition, all the vapours being given off mixed with the juice; but after passing through the separating chamber, the vapour is absolutely freed from sugar, so that the water from all the effects can be used for boilers—a thing that has hitherto been out of the question. In fact careful experiments three times a day have demonstrated that the condensed vapour did not contain one ten thousandth part of sugar.

(6) Automatic Working.—After having been started, the apparatus is automatic, as each vessel draws away by its superior vacuum all the liquor that is in the separating chamber of the previous vessel, the tail pump doing the same for the last vessel.

(7) Brass Contact under Heat.—During the time that the heat is applied to the liquor, it is in contact with brass alone, and the same effect is produced as in a vacuum pan made entirely of copper, which, though acknowledged to be the right mode of construction, has not been adopted on account of its prohibitive cost.

(8) Economy in First Cost.—Though the price is similar to that of other systems doing the same work, the much smaller cost for freight and foundation make it really cheaper.

Intending purchasers in asking for estimates would do well to give the following information:—

(1) Number of imperial gallons to be treated per hour.

(2) The density and temperature of the thin liquor, and the density to which it is desired to concentrate it.

(3) The steam pressure which can be provided to the pumps.

(4) The back pressure, if any, carried in the exhaust steam pipe.

(5) The treatment of the liquor before evaporation.

(6) If required for a refinery, whether the sweet water contains gypsum or other impurities.

The "Lillie" evaporator marks an important step in the right direction, inasmuch as the evaporation takes place as the liquid flows through the apparatus, and the liquid being only for a moment under treatment, the liability to injury by heating or long-continued churning is reduced to a minimum.

The apparatus is vertical, and may consist of any number of effects. Each effect is a cylindrical vessel filled with tubes opening into a common chamber above and below.

The liquid is continuously fed into the first effect, and passes on to a plate, from which it quietly overflows the tubes and runs down their inner surfaces in thin films; it passes from them in a shower into a chamber, from which it is taken by a rotary pump and delivered to the second effect, or may be partly returned to the first effect, if desired, and so on through the whole system. The concentrated liquid is taken continuously from the lower chamber of the last effect by a tail pump at any desired density. After use, the chambers and tubes may be readily steamed out and cleaned.

The steam enters the first effect by an annular space from which it is supplied to the steam cylinder, and surrounds the tubes in the space from the plate to the tube-sheet; by this device, the tubes are equally surrounded by steam and are uniformly effective.

The vapours coming off the liquid in the first effect are carried through the 20-in. vapour pipe, and enter the second effect through the annular space, into the steam chamber; they concentrate the liquid passing through the tubes in the second effect, which operation is repeated in as many effects as the apparatus may contain, and so on out through the condenser attached to the vacuum pump.

The water of condensation is taken off from the steam cylinder by a suitable steam trap, and may be utilised in the boilers or otherwise. The "Lillie" apparatus is operated with either live or exhaust steam, which in a triple effect is usually maintained at a pressure of about 5 lb. in the steam cylinder of the first effect, with a vacuum in this effect of 5 in.,—a vacuum of 15 in. in the second effect, and a vacuum of 26 in. to 27 in. in the third effect; but these conditions are not necessary. Excellent results are obtained with less steam and lower vacuum, and the apparatus can be worked with satisfaction under varying conditions.

The good features of the "Lillie" system of evaporation are:—Adaptability to concentration of solutions for refiners, chemists, and manufacturers. The novel feed by overflow of tubes and unrestricted passages. Little liability to incrustation of tubes. Remarkable simplicity of the apparatus in construction and operation, not requiring an expert to manage. Greater power of evaporation per square foot of heating surface than in any other system. Greatest possible economy. Least possible injury to liquids on account of heat. Ability to readily clean the apparatus without injury, and maintain its efficiency. The small stock of liquid and few storage tanks required. Exhaust steam used for evaporation. The small floor-space required for the apparatus. The smallness of the parts and ease of transportation. The apparatus is made of any size, from one tube to hundreds, and in any number of effects. The comparatively low cost of evaporators.

The liquid in transit can be seen and its action observed, and in case of need the tubes and every interior part of the apparatus may be examined by entrance at the manholes, without breaking any joints. Every inch of the interior of the tubes through which the liquid passes may be examined and cleaned by hand daily if necessary; but, the tubes being vertical, clean themselves with every operation.

By passing the liquid over the entire inner surface of the tubes in a thin film they are completely utilised, and yield results per square foot of heating surface greater than can be obtained in any other process under similar conditions.

This evaporator is made in iron, copper, &c., according to needs, and those interested in the subject of the concentration of thin solutions should apply to the makers for further information.

Fryer's Concretor.—In principle, Fryer's concretor differs essentially from all preceding systems, inasmuch as no attempt is made to produce a crystalline article, but only to evaporate the liquor to such a point that when cold it will assume a solid or concrete state. The mass is removed as fast as formed, and being plastic while warm, it can be cast into blocks of any convenient shape and size, hardening as it cools. In this state, it can be shipped in bags or matting wrappers, suffering neither deliquescence nor drainage. The cost of an apparatus capable of making 10 cwt. per hour is about 1000*l*. It is the invention of Alfred Fryer, of Manchester and Antigua, and is made by Manlove, Alliott, Fryer, & Co., Nottingham and Rouen.

The most recent and improved form of the concretor is shown in side elevation and plan in Figs. 98 and 99. It consists of a series of shallow trays A, placed end to end, and divided transversely by ribs running almost from side to side. At one end of these trays is a furnace B, the flue of which runs beneath them ; and at the other end, are a boiler C and an air-heater D, which utilise the waste heat from the flue, employing it both to generate steam and to heat air for the revolving cylinder.

The whole series of trays A is placed on a slight incline, the upper end being next the furnace. The topmost 3 trays are made of wrought iron, since the intense heat here would render cast iron liable to fracture. The clarified juice from the pipe M flows first upon the tray nearest the furnace; it cannot run straight down the incline towards the air-heater D, because of the transverse ribs already alluded to, which oblige it to meander from side to side of the tray in a shallow stream. Thus it has to traverse a channel some 400 feet long, before it can leave the trays at the end adjacent to the air-heater, although the distance between the furnace and the air-heater

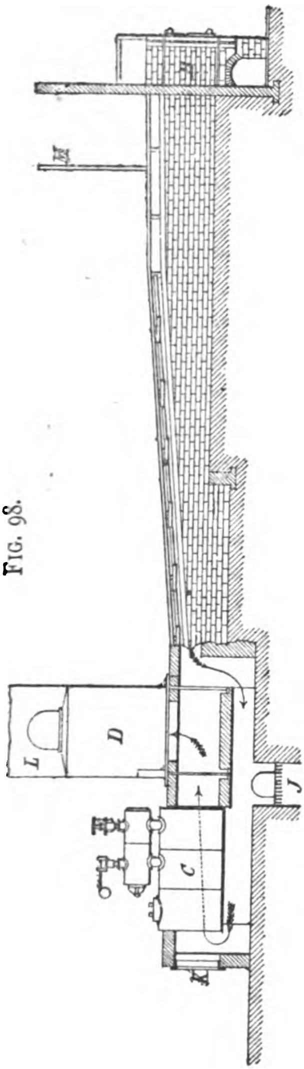


FIG. 98.

Side Elevation of Fryer's Concretor.

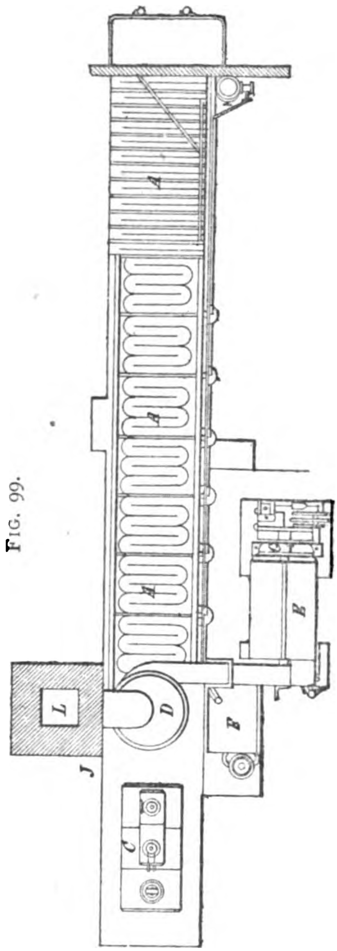


FIG. 99.

Plan of Fryer's Concretor.

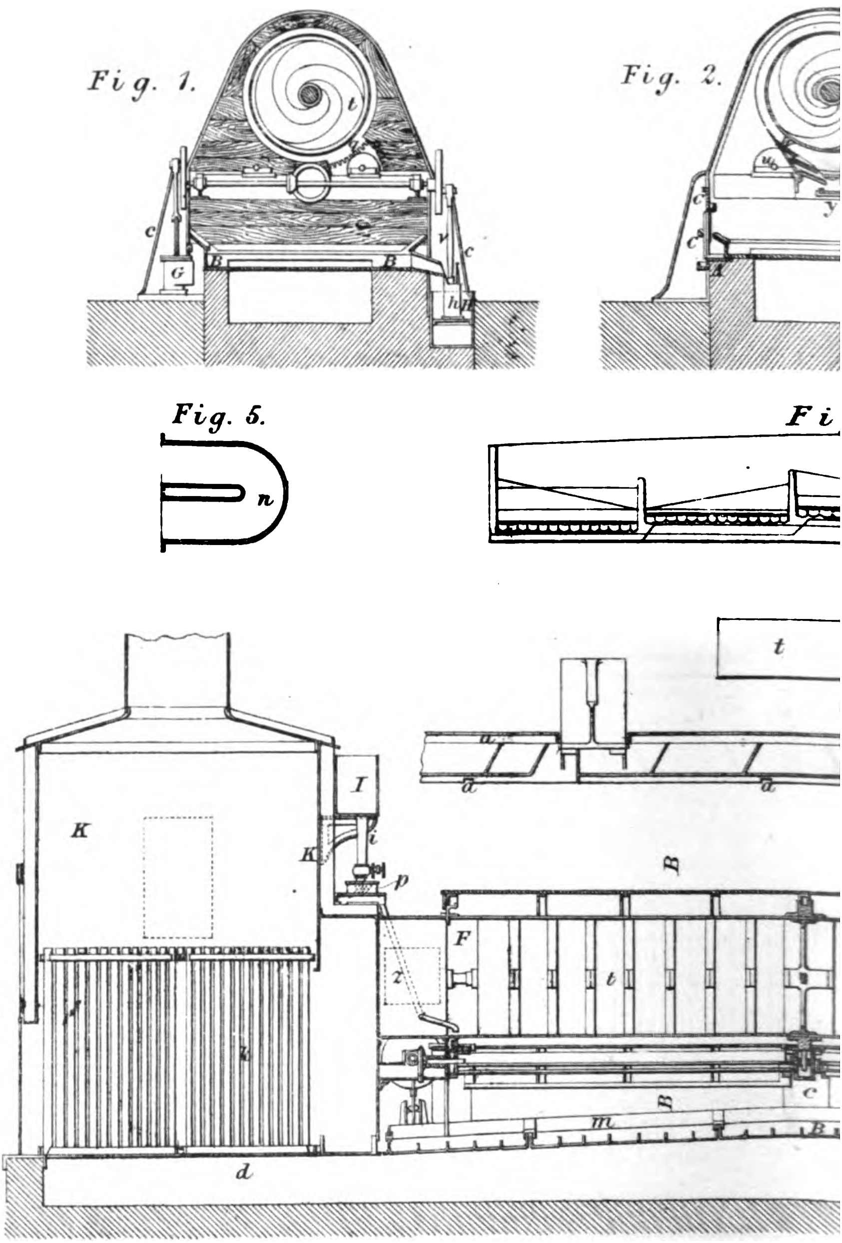
in a direct line is not quite 50 feet. While flowing over these trays, the juice is kept rapidly boiling by means of the heat from the furnace; and although it only takes some 8 to 10 minutes to traverse, its density is, during this short time, raised from about 10° B. to about 30° B.

From the trays, the thickened syrup flows into the tank F, and thence passes out into the revolving cylinder E. The cylinder is full of scroll-shaped plates of iron, over both sides of which the thickened syrup flows as the cylinder revolves, and thus exposes a very large surface to the action of hot air, which is drawn through it by means of a fan G. Motion is given to the whole apparatus by means of a small engine H. In this cylinder, the syrup remains for about 20 minutes, and at the end of that time, flows from it at a temperature of about 91° to 94° C. (195° to 200° F.), and of such a consistency that it sets quite hard on cooling.

By the use of dampers, the hot gases from the flue may be directed either under the boiler, returning through it to the heater, or direct to the heater. At J, is an auxiliary furnace for raising steam, when the heat from the concretor flue is insufficient or not forthcoming—as, for instance, when beginning to crush canes, and before the juice has covered the trays. K is a smoke-door for cleaning out the boiler-tubes. L is a chimney, either of brick or iron, for the last escape of the gases.

The details of construction of the older and more common form will be seen on reference to Plate VI., in which Fig. 8 is a longitudinal view, chiefly in section; Fig. 1 is a cross section on the line A A; Fig. 2 is a cross section on the line B B; and Fig. 3 is a cross section on the line C C, all of Fig. 8; Fig. 6 is a plan showing the connecting channels between the trays; and Fig. 4 is a section of one of the trays. The plates A rest on brickwork; B are the trays; C, cast-iron brackets which carry the beams and cylinder; D, the furnace constructed to burn coal. Where begass or other fuel is intended to be used, it must be modified. *d* is the flue. The plates A lie on the brickwork, are fastened to the brackets C, and support the trays B, allowing them to expand and contract without injuring the brickwork; they also bind and protect the brickwork, and, by their construction, form channels *a* for taking away the water arising from the condensed steam in working. The plates are recessed on their inner edge, to receive projections cast on the bottom corners of the trays. Each of the trays B has a series of curved corrugated channels. Ribs *b* extend from one side to near the opposite side, and make the channels continuous from end to end of each tray. An incline is made from one series of channels to the next, as shown in the sectional view Fig. 4. At the turns of the channels, the corners are filled up by a sloping corner-piece; saddle pieces *l* are dropped over the ends of the adjoining trays. The ends of these saddle-pieces are sloped upwards to support plates *m*, fixed on the sides of the trays. The trays are connected to form one continuous vessel, by open elbow channels *n*. *o* is a gauge-vessel, through which the juice is introduced into the top end of the trays; this vessel is made similar to one which will be further described in reference to *p*, Fig. 8. E are beams fastened to the brackets C, and carrying the cylinder F, made of copper or iron, which has for a central support a belt of double-angle iron *f* fixed upon it; a concentric ring is fastened on the inlet end of the cylinder, which it serves to strengthen, support, and drive. The external periphery of the ring is a toothed-wheel *q*; the central part of each tooth is cut away so as to leave two rows of teeth and a plane intermediate portion, which rests upon two anti-friction rollers *e*, while a toothed pinion works into the double row of teeth and drives the cylinder. *r* is a concentric ring fastened on the outlet end of the cylinder; this ring rests upon two similar rollers *s*. The outlet end of the cylinder has a flat delivery pipe, made wide and sloping outwards, so that each time it passes the bottom centre it will discharge a portion of the contents of the cylinder. The cylinder is slightly inclined downwards at the outlet end to assist the flow of the material. *t* are sets of spiral blades placed in the cylinder F. Instead of these blades, reticulated metal drums concentric with the cylinder, the lower edges of which are immersed in the juice, may be used. Each of the sets of spiral blades is composed of thin metal plates pierced with holes, as shown in plan at Fig. 6; these vary in number from three upwards, are fixed at their inner ends to a central tube, while by their spring-like action the outer ends press against the cylinder; the tubes carrying the blades are fastened upon a shaft carried by bearings. In some cases, when the reticulated metal drums are used, scoops are fixed to the hollow shaft carrying them, and at the outlet end of the cylinder, formed so as to take up, when required, the juice from that end, and deliver it into the hollow shaft, whence it is returned through an aperture in the hollow shaft into the cylinder at the inlet end. In such case, the cylinder is placed on a level instead of being inclined; or the diameter of the hollow shaft is made such that the inclination shall not prevent the juice running out of the end at the inlet end of the cylinder. The set with the smallest number of blades is fixed nearest the inlet end, and the number of blades in each set is gradually increased towards the outlet end. Stays are used for part of the extent of the blades, to keep them in their determined spiral form. *e s u* are rollers for supporting the cylinder F; these rollers are fixed on spindles which run in bearings carried on flanges cast on the beam E. A shaft driven by a steam-engine communicates rotary motion to the cylinder F, and drives the pump-rod *v*. *c* are upper tie-beams which support the covering of the cylinder, and, beyond the cylinder, the covering of so much of the trays as extends beyond the cylinder. Doors allow access to the trays. A flanged bracket is formed with flanges projecting from the beams E, for supporting guards or catch-boards *w*. These boards are set under the cylinder to catch the water condensed on its surface, and which drops on to the

FRYER'S



E & F.N. Spon, L

CONCRETOR.

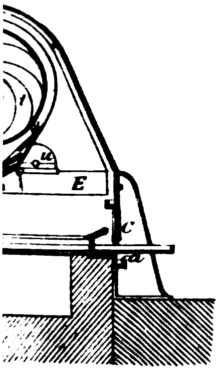
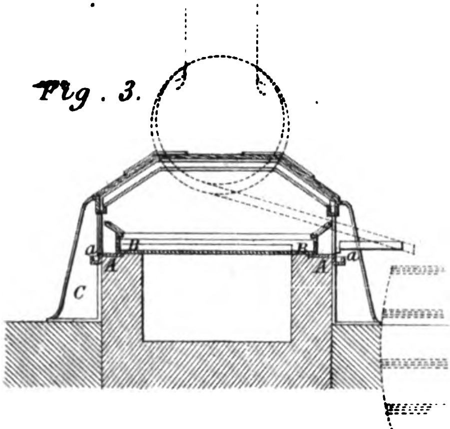
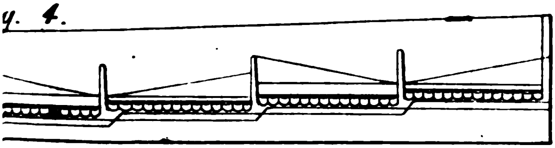


Fig. 3.



g. 4.



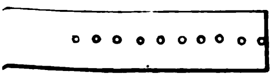


Fig. 6.

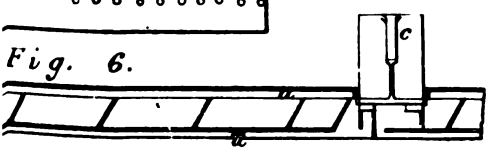


Fig. 7.

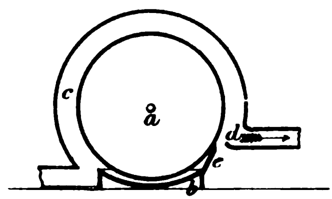
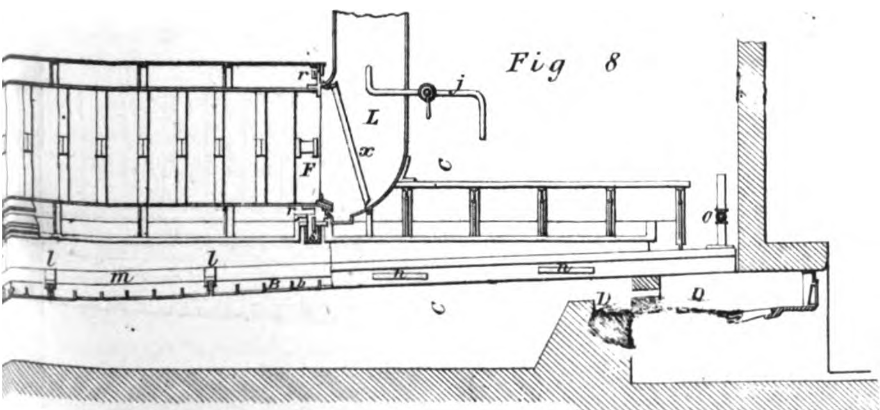


Fig 8



channel *y*, along which it flows into the hollow beam E, and away through an outlet. H is a cistern for receiving the juice from the trays B. The juice in falling into the cistern first passes through a vessel *h* containing a saccharometer, so that its density is under constant inspection. A pump stands in the cistern H, worked by the pump-rod *v*, and sends the juice up to the cistern I. The juice flows through the pipe *i* into a gauge-vessel standing in a saucer. The gauge-vessel has holes pierced in its side, commencing from the lower edge. The second hole is pierced, say, at half its diameter above the first in a diagonal direction. The third and succeeding holes are pierced in the same manner, but for convenience they are pierced in groups. The flow of the juice can be regulated by the tap to run through the desired number of holes into the saucer, then through the pipe *z* into the cylinder F. K is an air-heating apparatus, formed of a casing containing a series of tubes, *k*, situated to give passage to the products of combustion from the furnace after passing through the flue under the trays, and before entering the chimney. Air is admitted to circulate between and among the pipes, and thus becomes heated before entering the cylinder F. L is an elbow-pipe at the exit end of the cylinder F, into which a steam-jet *j* is introduced for the purpose of creating a draught to draw the heated air and vapours through the cylinder. When a steam-jet is objectionable, a fan is used, and heated air is either exhausted from or forced through the cylinder; *x* is a gutter for preventing any condensed water running down the chimney from mixing with the concentrated juice. If the saccharine mass is to be more highly concentrated than when it issues from the cylinder F, it is caused, while sufficiently fluid, to flow into a trough in which a heated drum slowly revolves. Fig. 7 is a transverse section of the drum and trough: *a* is the revolving drum heated inside by steam; *b* is the trough in which the concentrated juice is placed; *c* is the casing round the drum into which heated air is admitted;

d is the outlet for the heated air and vapours; *e* is a knife or scraper for removing the hardened concrete from the surface of the drum. In revolving, the drum takes up a thin film of the concentrated juice, which, by the time it reaches the knife or scraper, has, by contact with the heated drum, and by the action of the heated air, become dry. On meeting the knife, it removes the concreted or dried sugar from the drum.

According to Minchin, the following are the results of using Fryer's concretor with diffusion juice. It was in work just 2 months, day and night, stopping every Sunday to clean.

During that period there ran over it ..	1,030,680	gallons juice.
And were delivered from it	500,225	"
Hence it evaporated	530,455	"

This gives per day of 24 hours as below:—

Ran over concretor	18,570	gallons.
Ran off	9,013	"
Evaporated	9,557	"

For this, wood fuel was used at the rate of about 15 tons per diem, for which it will be seen that nearly 400 gallons an hour were evaporated. The concretor here used was incomplete, consisting only of 3 wrought-iron and 6 cast-iron trays, hence much of this fuel was wasted. The juice ran on at about 6° to 6½° B. cold, and it ran off at about 11° to 12° B. cold. The concretor was used as an auxiliary to double-effect. The juice was sent direct from the diffusors, after simply passing through the bag-filters, on to the concretor; it scarcely darkened at all by transit over the trays, and was moreover decidedly brighter, although 24 to 36 oz. of slaked lime were used per clarifier of 600 gallons. The juice throughout was golden-coloured.

The deposit from the trays, which was removed once a week, was, on drying, found to weigh about 80 lb., i. e. not ¾ lb. per 1000 gallons run over the concretor, the quantity run weekly being on an average 18,370 × 6 = 111,420 gallons.

The quantity of scum removed from the juice while in transit over the concretor was 2½ gallons per hour = 2 gallons per clarifier of 600 gallons. The greatest deposit took place on the first and second cast-iron trays. Analyses of these deposits are appended :—

No. 1. Sample of deposit from concretor on wrought-iron trays, March 11, 1879.
No. 2. Sample of deposit from concretor in January.
No. 3. Sample of deposit from concretor on cast-iron trays, March 11, 1879.

	No. 1.	No. 2.	No. 3.
Moisture	5·437	5·754	4·913
Loss on ignition	21·007	18·479	14·718
Insoluble	24·711	14·844	2·999
Sulphuric Acid (SO_3) ..	0·704	0·951	1·215
Phosphoric Acid	2·981	14·988	7·335
Lime	37·265	37·272	39·456
Iron	2·393	3·254	2·201
Alkalies, &c.	5·502	4·458	27·163
	100·000	100·000	100·000

The preceding figures may be compared with those on pp. 356–7, relating to the use of the concretor by the Umhloti [Natal] Sugar Co.

The 1877–1878 crop had suffered much from drought, and the yield per acre is estimated to have been 35 per cent. less than the 1876–1877 crop, which was not a heavy one, having also felt the want of rain, but not to the same extent. The yield of sugar from the juice was also less.

From the prices realised in the London market, have to be deducted the charges for dock-dues, sorting and lotting, rent, marine insurance, advertising and catalogues, brokerage and commission, amounting to about 34*s.* per ton ; also charges in Natal for railway carriage, transport from estate, bags, shipping, &c., about 2*l.* per ton, and loss in weight, freights varying from 17*s.* 6*d.* to 30*s.*—in round numbers, say 5*l.* per ton.

CROP, 1876 AND 1877.

No.	Month in which Cane was Crushed.	Description of Cane.	Weight of Sugar Bagged.				No. of Clarifiers (400 galls.).	Average Density from Mill.	Total No. of Gallons of Juice.	Lb. of Sugar per Gall. of Juice.	No. of Waggon Loads of Cane Delivered at Mill.	No. of Waggon Loads per Ton of Sugar Bagged.	Highest Price realised in London Market per Cwt.	Lowest Price realised in London Market per Cwt.	Average Prices.
			tons.	cwt.	qrs.	lb.		° B.					s. d.	s. d.	s. d.
1	November 1876 ..	Green Natal plant cane ..	78	14	1	26	216	9 to 10	86,400	2·04	522	6½	29 0	19 0	24 9½
2	December 1876 ..	First ratoon China cane ..	12	11	3	20	33¾	9	13,500	2·07	126	10	23 0	22 6	22 9
3	December 1876 ..	First ratoon China cane ..	23	10	1	4	..	..	..	..	..	..	22 0	19 6	20 0
4	Dec. '76 and Jan '77	Green Natal plant cane ..	86	16	3	26	262½	10½	105,000	1·86	734	8½	26 6	23 0	24 0
5	Jan. and Feb. 1877	First ratoon green Natal	35	5	0	19	99½	12	39,800	1·98	307	8½	26 0	25 0	25 7
6	February 1877 ..	Green Natal plant cane ..	40	4	0	8	117½	10	46,900	1·92	205	7	24 0	20 6	21 7
7	February and March	Green Natal plant cane, small quantity of China mixed	44	7	2	18	134	10	53,600	1·85	369	8	22 0	19 0	21 4
8	March	Natal and China mixed ..	17	2	2	9	56	9	22,400	1·71	..	..	18 0	18 0	18 0
9	March	China cane plant crop ..	3	18	2	14	14½	9	5,700	1·57	..	..	18 0	18 0	18 0
10	March	First ratoon green Natal ..	17	1	2	20	55	9½	22,000	1·73	..	..	21 0	19 0	20 9
11	March and April ..	Natal and China mixed ..	110	6	2	14	354	10	141,600	1·74	..	..	21 0	17 6	18 6
12	May	First ratoon Natal cane ..	13	4	0	15	36	10	14,400	2·05	97	7½	21 0	15 3	15 4
13	May	Natal and China mixed ..	12	10	1	20	..	..	..	..	..	..	15 3	15 3	15 3
14	May and June ..	Natal and China mixed ..	47	13	2	14	149	9	59,600	1·79	..	..	..	..	..
	Total crop		543	7	2	3									
	Deducting the two lots Nos. 3 and 13, where the number of clarifiers are unknown		36	0	2	24									
	Leaves		507	6	3	7			610,900	1·86					

610,900 gallons of juice gave 507 tons 6 cwt. 3 qrs. 7 lb., being at the rate of 1·86 lb. of sugar to the gallon of juice.

CROP, 1877 AND 1878.

No.	Month in which Cane was Crushed.	Description of Cane.	Weight of Sugar Bagged.				No. of Clarifiers (400 galls.).	Average Density from Mill.	Total No. of Gallons of Juice.	Lb. of Sugar per Gall. of Juice.	No. of Waggon Loads of Cane Delivered at Mill.	No. of Waggon Loads per Ton of Sugar Bagged.	Highest Price realised in London Market per Cwt.	Lowest Price realised in London Market per Cwt.	Average Prices.
			tons.	cwt.	qrs.	lb.		° B.					s. d.	s. d.	s. d.
1	August 13, 1877 ..	China cane, burnt	50	1	0	6	..	..	..	..	..	..	17 0	17 0	..
2	September	China cane ratoons	7	0	2	16	29½	7	11,800	1·33	98	14	17 0	15 3	16 5
3	September	Natal plant cane, flowering heavily	9	4	2	25	26	9½	10,400	1·98	60	6⅓	18 0	17 6	17 8
4	Sept. and Oct. ..	Natal plant cane ratoons	112	9	2	27	314	10	125,600	2·00	899	8	18 0	14 6	15 11
5	November	Very old and poor China cane	10	15	2	14	44½	6½	17,700	1·38	..	..	16 6	15 6	16 2
6	November	China and Natal	52	15	1	9	160	9	64,000	1·84	..	..	..	..	..
7	December	Green Natal plant cane with some China	43	1	0	25	144	9	57,600	1·66	391	9	17 6	15 6	16 6
8	Dec. and Jan. 1878	Green Natal plant and part young ratoons, with little China	62	5	3	25	208	7 to 2½	83,200	1·67	394	6⅓	18 6	17 0	17 4
9	Jan., Feb., and March	Green Natal plant and China	142	19	3	27	509	8 to 9	203,606	1·57	..	..	17 6	15 5	..
10	April	Natal cane, old ratoons ..	10	2	0	14	31	10	12,400	1·82	100	10	..	..	..
	Total crop		500	16	1	20									
	Deducting the lot No. 1, where the number of clarifiers are unknown		50	1	0	6									
	Total		450	15	1	14			586,303	1·72					

586,300 gallons of juice gave 450 tons 15 cwt. 1 qr. 14 lb., or at the rate of 1·72 lb. of sugar per gallon of juice.

By Cold.—More than 30 years ago, Kneller proposed to concentrate syrups by forcing cold air through them, and his plan was much improved by Brame Chevallier. The latter provided his vessel with a steam-jacket, a coil of piping inside, and a set of tubes ; through these last, dry air is forced to the bottom of the pan, and, rising through the body of the liquid, carries off a large amount of watery vapour, at the same time keeping the liquid at an extremely low temperature. Sugar made in these pans completely rivalled that of the vacuum-pan in every respect. A pan capable of holding 200 gallons of syrup (comprised of 3 parts of sugar to 1 of water) is estimated by Wray to turn out 12 tons of sugar daily. The cost of the apparatus is small ; the power required is trifling ; the ordinary air of the estate could be used at once in dry weather, and would entail an insignificant expense for drying in damp weather ; and the quality of the sugar is unsurpassed.

In 1865, Alvaro Reynoso proposed to rapidly cool the syrup in suitable machines, and thus form a confused mass of particles of frozen water (ice) and dense syrup. The mixture is afterwards separated by being passed through centrifugals, and the syrup deprived of ice is evaporated *in vacuo* ready for crystallisation.

It certainly seems a most singular circumstance, that, in the face of the many drawbacks and great cost incurred by concentration by means of heat, and in presence of the many improvements introduced of late years into refrigerating and cold-producing apparatus, so little effort is made by sugar-growers to adapt such a convenient system to their needs. A similar crystalline product, namely common salt, is obtained by hundreds of tons from sea-water, by the effect of natural cold, in favourable localities; and there would appear to be no valid reason why a modification of the plan should not succeed on an extensive scale with sugar solutions. Experience would soon show to what point it was most convenient to carry the freezing,—whether the water should be entirely removed, or whether sufficient should be left, as in Reynoso's plan, to form a dense syrup with the sugar, leaving only a very small proportion to be evaporated off. There are now many cheap and efficient forms of refrigerating apparatus in the market, so that trials could be made on the large scale at no great expense. Even if the method effected no considerable saving in cost, which is hardly probable, it would possess a great advantage in lowering the temperature of tropical "boiling houses," entailing comfort to the workmen and consequent increased care and attention in carrying on the operations.

CHAPTER VI.

CURING THE SUGAR.

IT will be readily understood that the products of the various operations described in the preceding chapters, differ widely in character, and demand separate treatment in their preparation for the market. This treatment is generally known as "curing," and embraces the whitening or bleaching of the sugar. The several plans will be discussed in succession.

Simple Drainage.—This is the oldest and crudest method, and is on a par with the dirty-looking mass of sugar and impurities produced by the wasteful and slovenly copper wall. In order to remove a certain amount of the molasses and other impurities, the semi-liquid mass, dug out of the coolers as soon as it is sufficiently cold, is placed in casks with perforated bottoms; the holes in the casks are loosely filled with twisted leaves or rushes (the latter long enough to reach above the contents of the casks), in such a manner as to form the roughest imaginable kind of strainer. The casks stand meantime on rafters over an immense tank. Here the draining process slowly and imperfectly goes on, a portion of the molasses escaping into the tank below, but much still remaining imprisoned in the mass of sugar. The separation of the molasses is so incomplete, that very great leakage and waste continue while the sugar is on its way to European markets. Sugar which has been cured in this way is termed "muscovado," and is the most impure form of "raw" ("grocery," "moist," or "brown") sugar. It is still produced in some backward countries, but it is pretty well obsolete in the English and French colonies, and its manufacture is decreasing rapidly in Louisiana.

Claying.—The first improvement upon this barbarous system was introduced by the Spaniards and Portuguese in Cuba, and is based upon the fact that the impurities present in muscavado sugar are much more soluble in water than the crystalline sugar itself. Thus washing with water will effect considerable purification. The earliest manner of carrying this out was by placing the sugar in inverted cones with a minute aperture in the apex, which is stopped up during the filling and for about 12 hours afterwards; upon the mass of sugar in the cone, was placed a batter of clay and water (hence the term "claying"), the object being to ensure a very gradual percolation of the water through the mass. This water carries with it the uncrystallisable sugar and colouring matters imbedded between the crystals of the sugar. The resulting sugar is much lighter-coloured than muscovado, but the grain is very soft, and the operation is most wasteful. In Bengal, a wet rag is sometimes substituted for the clay batter.

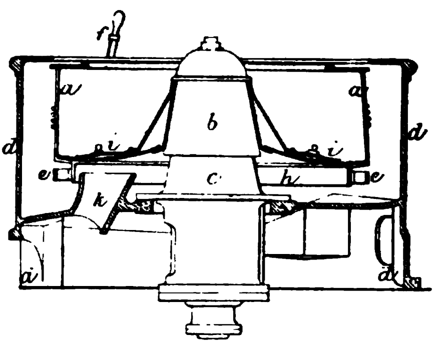
Spirit-washing.—The very slight solubility of sugar in alcohol, coupled with the ready solubility in that medium of many of its impurities, suggested the practice called "spirit washing." This consists in substituting cold alcohol or alcohol and water for the simple water used in claying. The results are not perfect, however, and the costliness of the method soon caused its abandonment. It was principally employed in the East Indies.

Vacuum-chest.—The vacuum-chest consists of an iron box with a tray of wire gauze above, and connected with air-pump suction below. The sugar is spread on the tray, and the downward suction produced by working the air-pump creates a tendency in the fluid portion of the mass to separate itself. Effectual separation, however, can only be attained when the grain or crystal of the sugar dealt with is large, hard, and well formed: with small or soft grain, the process is utterly inapplicable. This fault has restricted its use.

Centrifugals.—The preceding modes have been practically superseded by centrifugal machines or hydro-extractors, so called from their being first used for drying textile goods. There are many varieties, but all consist essentially of a cylindrical basket revolving on a vertical shaft, its sides formed of wire gauze or perforated metal, for holding the sugar. The basket is surrounded by a casing at a distance of about 4 inches, the annular space thus left being for the reception of the molasses, which is expelled by centrifugal force through the sides of the basket when the latter revolves at a high speed. A spout conducts the molasses from the annular space to a receiver.

An example of a simple centrifugal is shown in Fig. 100; more complicated forms are used in refineries, and will be

FIG. 100.

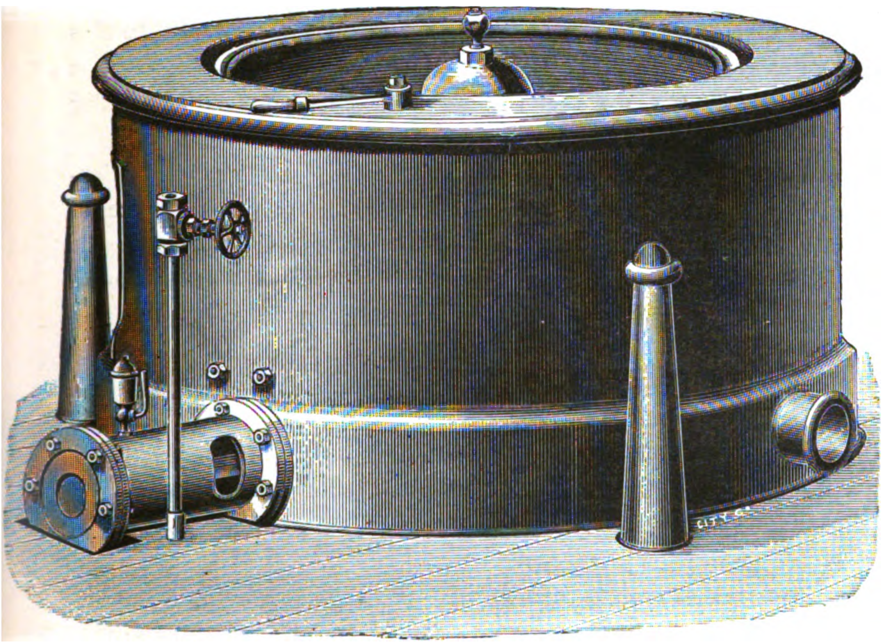


Simple Centrifugal.

described in Chapter XIX. The machine in the figure comprises a revolving basket *a*, carried by a cast-iron dome *b* upon a central shaft, arranged with driving pulley, footstep, and neck-bearing, on the central bracket *c*, the whole being supported by the outer cast-iron casing *d*, which collects the liquid thrown off from the material in the basket, and conveys it away through a discharge-pipe. The brake *e*, for stopping the motion of the basket, is applied by the lever-handle *f* acting upon the angle-iron ring *h* riveted to the cylinder bottom. The sugar is discharged through two copper doors *i* covering openings in the cylinder bottom, and passes down the shoot *k* cast in the outer casing, into a receptacle below.

The hydro-extractor has become such an important factor in many industrial processes, that some large engineering firms devote themselves specially to it. Foremost among

Fig. 101.



Broadbent's Hydro-extractor.

them are Thomas Broadbent & Sons, Chapel Hill, Huddersfield, one of whose apparatus is shown in Fig. 101.

These hydro-extractors are driven direct by a small steam engine, which, from its peculiar construction and accuracy of balance, can be run at a very high velocity without any liability to get out of order. The reciprocating parts are made very light, and of carefully selected material; all the wear can easily be taken up, and the nuts or cotton taking up such wear can be firmly locked. The spindle is made of steel, with a balance crank (patent) forged on. It is provided with two long conical bearings, firmly fixed in the centre casting of machine, the wear of which bearings can easily be taken up (patent) without there being any liability to shake loose. The lubricating of the machine is all done from the outside, that of the crank-pin and eccentric being automatic in its action; by a simple contrivance, every time the machine is started these parts take up a few drops of oil, and to this the remarkable durability of these machines is in a great measure due, the necks being kept cool, and no oil being wasted.

Messrs. Broadbent have made a specialty of hydro-extractors driven on this principle for the last twelve or thirteen years; and have, during that time, gained great experience, which could not have been arrived at otherwise than by careful and minute examination of the machines, after working for some years. This has enabled them from time to time to correct and improve the various parts, until now they claim that they are the most simple, durable, and efficient hydro-extractors that are made. The wear and tear, and cost of repairs are very slight, and much less than the cost of maintaining belts alone where strap-driven hydro-extractors are used.

The machine being suspended requires no holding-down bolts or special foundation, and can be placed on any good ordinary floor without fear of causing the slightest vibration. No power is wasted in shaking the ground, nor are the bearings heated and worn, and the machine strained, by the effort to vibrate when unevenly loaded and fixed to massive foundations.

It has long been evident that direct steam-driving is the only proper means of working hydro-extractors, especially the larger sizes, and that this method will eventually take precedence of all others. There are several reasons why this should be so. It is the only method by which slip and friction in starting are totally avoided, and as it is necessary for all hydro-extractors to be stopped and started once for every load or operation, this assumes a very important aspect; especially when it is borne in mind that the weight of a large sized basket, when fully loaded with damp material, approaches half a ton, and that this has to be rapidly raised from a state of rest to 900 or 1000 revolutions per minute. The slip of belts and of any friction arrangement in such cases is enormous, and is the most serious objection to their use, as there is a great loss of time and power in getting on full speed, and excessive wear and tear, which makes it necessary for the belts to be frequently renewed, thus causing annoyance and great expense.

When centrifugal friction pulleys are employed as the method of driving, the loss of time caused by slip is even greater, as the friction arms must be so constructed as to slip easier than the belts, or they fail in their first object of preventing the belts from slipping; and thus by the attempt to remedy one evil, another is increased.

Another objection to belts is the usually damp nature of the position in which these machines are fixed, where steam and moisture have a very injurious effect upon them, and greatly accelerate their decay. Broadbent's steam-driven machines in this respect are very much superior, as they are quite impervious to wet, and work equally well when fixed in the dampest place, or even in the open air.

The great difficulty hitherto in regard to direct steam-driven hydro-extractors, has been to construct an engine that should maintain the machines at a speed of something like 1000 revolutions per minute, and yet be quite free from danger of breaking down or shaking loose; this Messrs. Broadbent have thoroughly and effectually succeeded in doing, and their machines have been in constant work for upwards of ten years; with only ordinary attention have cost nothing in repairs, and are still working as smoothly as ever.

Experience of the working of these machines teaches that even under the most favourable circumstances of belt-driven hydro-extractors, the method of driving direct by steam has many advantages; so that these machines are coming to be preferred to any other design, and give general satisfaction.

The treatment of the molasses separated from the sugar in the curing and bleaching operations has been already described under the use of the vacuum-pan (see p. 320).

CHAPTER VII.

COMPLETE FACTORIES.

IT has been quite impossible in the preceding chapters to combine detailed descriptions of the many forms of apparatus used to effect the same purpose, with a connected account of the operations through which the material passes. It will therefore be interesting to follow the processes in general, by the aid of a few representations of complete factories on different systems.

Plate VII., Fig. 1, shows an elevation of a factory recently erected in Cuba, by Cail et Cie., Paris. The cane is crushed in the 3-roller mill *a*, worked by a 30-H.P. beam-engine *b*, connected by the gearing *c*. The expressed juice flows into a tank, and thence to the *monte-jus* *d*, by which it is raised to the 6 purifiers *e* (one shown) provided with supply and discharge-pipes, and heated by steam coils, and where it undergoes defecation with lime. Hence it flows through 10 animal-charcoal filters *f* (one shown), and through their perforated false bottoms into a pipe leading to the tank *g*, whence it is transferred by another *monte-jus* to the receptacle *h*, for delivery to the vessel *i* which regulates the supply to the concentrating-pans *j*. Leaving the pans, the syrup is pumped into the vacuum-pan *k*, when the concentration is completed. The separators *l* collect any water that may pass with steam from the vacuum-pan to the pipes in the concentrating-pans. The concentrated syrup is next treated with blood in the clarifiers *m*, re-filtered through *f*, re-concentrated in *k*, and run into moulds to crystallise. The crude crystallised sugar is crushed in a mill *n*, and passed through the centrifugals *o*, the molasses being collected in a tank *p* for further treatment.

The whole plant costs about 32,000*l.*, and is capable of dealing with 100 tons of canes per 24 hours, employing engines of 150 H.P., and producing 8 tons of sugar daily.

Plate VII., Fig. 2, represents a plan of the Khedive's factory at Aba-el-Wakf:—A, 4 coal-burning boilers (two shown); B, cane-mills; C, high and low pressure engines; D, raw-juice tank; E, sulphur-pumps; F, sulphur-furnace; G, raw-juice pumps; H, lime-mixing tank; I, permanganate-mixing tank; J, clarifiers; K, subsiders; L, scum-presses; M, donkey-engine; N, concentrating-pans; O, begass-burning boilers; P, syrup-tank; Q, vacuum-pans; R, crystallising tanks in coolers; S, mixing-mills and syrup-tanks; T, centrifugal curing-machines; U, syrup-waggons; V, molasses-waggons; W, molasses crystallising-tanks; X, engines for working centrifugals; Y, vacuum-engines; Z, mechanics' shop; A', forge; B', carpenters' shop; C', air flue to boilers; D', water tower; E', well; F', chimneys (one omitted); G', warehouse; H', tramway leading to molasses-tanks (not shown). This factory cost a total of 70,000*l.*, in addition to 20,000*l.* worth of charcoal filters and revivifying kilns which were not erected. It was designed to work up 1000 tons of cane per 24 hours. The H.P. employed, assuming each cubic foot of water at 17° C. (62° F.) evaporated to represent 1 H.P. of boiler duty, is:—

	H.P.
The four cane-mill engines take 68 I.H.P. each. Allowing 25 lb. of steam per H.P. per hour, which will cover loss by steam-pipes, &c., they will require of boiler power	112·0
The clarifiers have to heat 6000 gallons of juice per hour, from 72° F. to 212° F., and to boil for five minutes, and will absorb ..	163·5
The concentrators having to raise 5473 gallons of juice from 160° F. to 230° F., and to evaporate 3118 gallons under 3 lb. pressure, will take	519·0
Steam under 60 lb. pressure used in steaming centrifugals, calculated	11·2
Sulphurous acid pumps, calculated	1·5
Donkey feed pumps	2·3
Total	809·5

Or nearly 11 H.P. per ton of sugar per 24 hours.

The yield of 164,345 gallons of raw juice, at 9¾° B. and 22° C. (72° F.), was:—

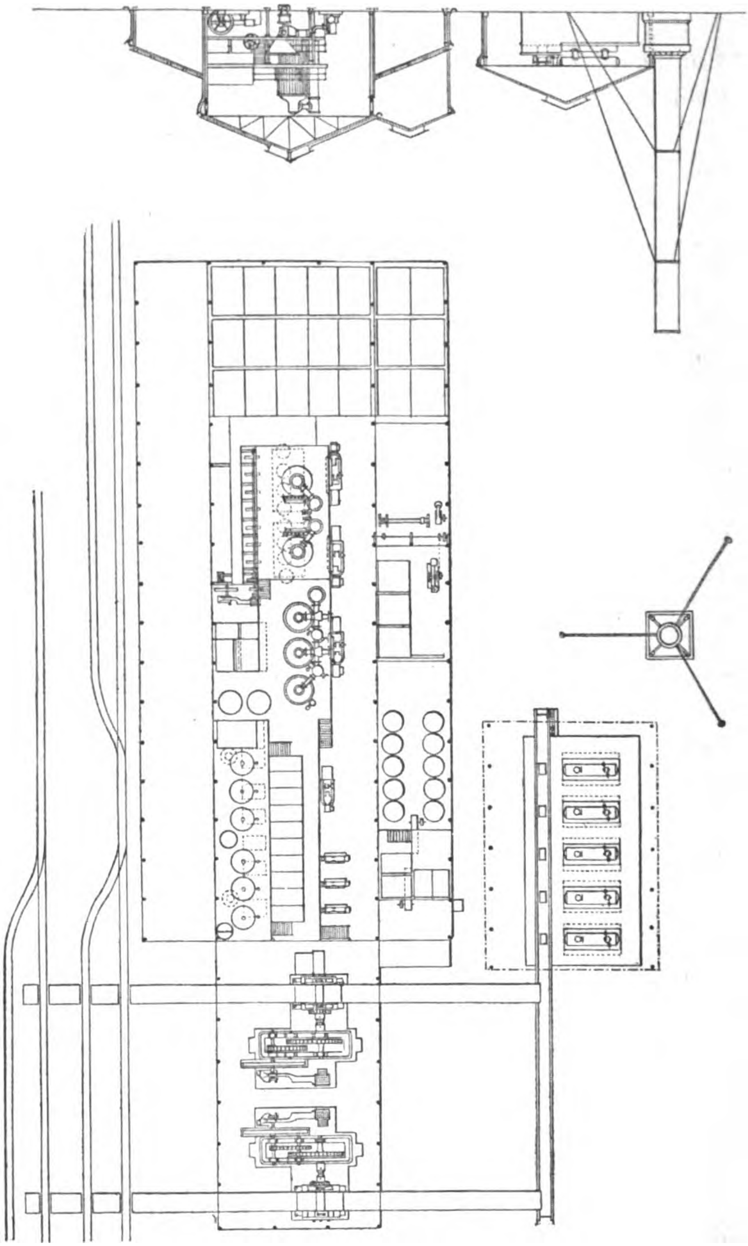
	tons.	cwt.	qrs.	lb.
First white sugar..	54	18	2	18
Second boiling, brown	18	6	3	1
Third „ estimated	9	3	1	14
All sugar—total	82	8	3	5
Molasses after second sugars	24	12	2	25

Or, at the rate of 1·124 lb. per gallon, the white sugar alone being 0·75 lb. per gallon. The second boiling forms only 33 per cent. of the first, and it is not likely that the sugar derived from the third boiling would make the aggregate amount greater than 50 per cent. Taking the quantity of molasses remaining after the first boiling as indicating the degree of degradation suffered by the juice during manufacture, it would seem that the sulphurous acid gas process, combined with rapid concentration, gives a larger percentage of marketable sugar than any other system, to judge by the annexed comparative table:—

Yield.	Egypt.		Demerara.	New South Wales.	
	Aba-el-Wakf.	Bene Mazar.	Colonial Company.	Chatsworth.	Southgate.
First sugar, white ..	56·1	43·6	43·6	..	..
Ditto, ditto, yellow	..	..	..	50·8	62·5
Second ditto	18·7	20·8	23·6	16·5	8·4
Molasses and third sugar	25·2	35·6	32·8	32·7	29·1
	100·0	100·0	100·0	100·0	100·0
Percentage of molasses on first and second sugars ..	33·7	55·3	47·6	48·6	41·4

The total yield of all sugars and molasses, in pounds per gallon, was 1·325 at Aba, 1·62 and 1·75 in the Australian factories, and 2·19 in Demerara, showing the bad condition of the Egyptian canes. The Australian factories used Fryer's concretor, and Bene Mazar was worked with animal-charcoal filters.

FIG. 102.



Manlove & Alliott's Complete Cane-sugar Factory.

Fig. 102 illustrates an arrangement of a cane-sugar factory, with the most improved appliances, as designed by Messrs. Manlove, Alliott, Fryer, & Co.

The canes are brought to the factory in specially designed waggons drawn by small locomotives on the railway shown on the plan. The endless cane carriers or travelling bands are in this instance arranged below the ground level, so that the train of trucks can be run directly over them, and the contents tipped on the moving band, thus dispensing with the usual large number of hands required for this purpose. Near the mill the carrier emerges from below the ground level and carries the canes forward and upward, delivering them on the feeding tables of the mills. The crushed cane or megass leaving the rolls is delivered on an inclined table leading downward to the foot of the elevator by which it is again carried forward and upward, and delivered into the megass feeding trough in which a carrier is arranged to convey it to the feed hoppers over the boiler furnaces. This carrier is driven by a pair of small engines on the platform over the boilers. The mills which crush the canes are of the ordinary three-roller type of the heaviest possible construction, or the five-roller type now sometimes used. With Messrs. Manlove, Alliott, Fryer, & Co.'s ordinary three-roller mills, reports extending over several successive seasons by the owners of the estates to which they have been supplied, have shown an efficiency of 73 to 75 per cent. in ordinary work, and a larger percentage has been occasionally obtained under special conditions for experiment. This is equal to any results usually obtained by the adoption of the five-roller mill. The mills are driven by powerful horizontal engines running at a high velocity, and with very heavy compound spur gearing, thus utilising to the best advantage the accumulated work in the very heavy fly-wheels which are used, and giving a very steady speed of crushing. Link-motion reversing gear fitted to the engines enables the mills to be rapidly and easily controlled. The exhaust steam from the engines is conveyed to the juice heater and exhaust steam receivers at a pressure of a few pounds above the atmosphere, and is utilised for heating the juice at various stages. The raw cane juice from the mills is raised by an independent steam pump to the juice heater, which is fully described on p. 263. From the heater the juice passes to the clarifiers at a temperature of about 180° F. The clarifiers are of the hemispherical double-bottom type heated by high pressure steam, and are described on p. 264. The necessary supply of milk of lime for clarification is obtained from a lime tank on the clarifier platform at the centre of the group. The clarified juice is led down into a series of rectangular settling tanks fitted with ball floats and decanting cocks for drawing off the clear juice, which is then run into the triple-effect supply tank. The sediment, scum, and sweet washings from the clarifiers and settling tanks, &c., are led down into a scum blow-up tank, where they are treated with steam and forced through a series of filter-presses by means of a *monte-jus*. The clear effluent from the presses is collected in another tank, and raised by means of a second *monte-jus* to the clarifiers or triple-effect supply tank. The triple-effect apparatus (described on p. 326) is arranged on the same staging with the settling tanks, with its vacuum pumping engine on the ground floor in line with those of the vacuum pans, the whole arrangement being exceedingly open, accessible, and well lighted. The syrup eliminators, into which the syrup from the triple effect is discharged, are described on p. 323. These are arranged on the same staging, and from them the clarified syrup is delivered either direct into the vacuum pan supply tanks, or if filtration is desired, is conveyed to the hot syrup tank over the bag filters in the adjoining building. The vacuum pans, two in number, are arranged on a staging continuous with, but at a higher level than, that of the triple effect. These pans are of the vertical cylindrical type as described on p. 307. The *masse-*

cuite from the pans is led down into either of two large iron hoppers under which the centrifugals are arranged. A valve attached to the hopper over each centrifugal admits of the contents being worked off either hot or after standing for further crystallisation as may be desired, and with the least possible amount of manual labour.

The centrifugal machines are of the well-known Hepworth patent suspended type, of which Messrs. Manlove, Alliott, Fryer, & Co. control the English and colonial patents, and are run at a speed of about 1500 revolutions per minute. The *masse-cuite* is delivered into a perforated steel basket lined internally with fine perforated copper or brass gauze; the high speed of rotation forces the *masse-cuite* against the sides of the basket, and separates the adherent molasses and syrup from the crystals, which latter are left in a dry state, and are at once discharged through a door in the bottom of the basket on a travelling band which conveys them direct to the sugar store. The separated molasses or syrup passes through the perforations in the basket into the outer casing of the machine, from which it is run off through spouts and gutters into the syrup and molasses tanks, which in this case are arranged below the floor level immediately behind the centrifugals.

These machines are driven by a horizontal high-speed engine, countershaft, and friction clutches of special design, admitting of the machines being stopped or started without any shock or severe strain on the belts. The low sugar or *masse-cuite*, which it may be necessary to leave for granulation before being centrifugaled, is run off from the vacuum pans through inclined shoots into a series of iron granulating tanks or coolers, arranged on a staging at such a height as to permit of an overhead railway with small waggons being arranged beneath to receive the contents through a door in the bottom of each tank, and convey the *masse-cuite* to the centrifugals with the minimum of manual labour. The syrup or molasses from the underground tanks is raised by means of a special pump of the rotary type, and delivered into either of two rectangular blow-up tanks, from which, after treatment with steam, the diluted molasses can be drawn into either of the vacuum pans for re-boiling.

Injection water is supplied to the factory by means of one of Manlove, Alliott, Fryer, & Co.'s improved horizontal water pumping engines drawing from any adjacent stream or creek and delivering into the injection-water tank arranged at a convenient height for supplying the pan and triple effect condensers. A further supply of cold water for washing purposes is raised by means of a small independent steam pump into a tank on the clarifier staging at the highest point in the factory, from which the water may be drawn for washing down, fire extinguishing, and other purposes. The condensation water from the various coils and steam-heated vessels is collected in a tank from which it is drawn by an independent steam pump, and fed into the boilers. The steam boilers are arranged in a building to leeward of the factory, and at some distance therefrom. They are usually of the well-known multitubular type, with Manlove, Alliott, Fryer, & Co.'s special improvements, admitting of the tubes being readily withdrawn for cleaning, and easily replaced, and have large horizontal steam receivers, double safety valves (one to lock up for preventing over-pressure), smoke-box doors for giving access to the tubes for cleaning, and Manlove, Alliott, Fryer, & Co.'s patent automatic feeding gear for burning green megass direct from the mill, admitting of the least possible number of boiler attendants. The boilers are connected with a wrought-iron chimney by underground flues. The chimney is of special design, arranged to occupy the least possible space in shipment, and can be erected by specially designed appliances without scaffolding or the usual ponderous shear legs. A sugar store is arranged, extending along the windward side of the building, and the system of railway from the cane carriers is led close alongside the store, and continued to the shipping wharf. The buildings are entirely of iron covered with heavy corrugated galvanised iron sheeting, and have lattice girders under the eaves, ridge ventilators, gutters and down-pipes to collect the rain water from the extensive roof surface.

The machines are carried throughout on wrought-iron staging of special design, with timber floors; chequered iron flooring is sometimes supplied to meet customers' requirements. Polished brass hand railings and balusters, and convenient iron stair-ways are provided throughout.

When the syrup is to be subjected to filtration before entering the vacuum pans, it is raised from the syrup eliminators into a hot syrup tank at the top of the char house, where it is heated, and then run into the bag filters. These are of the usual type, consisting of a series of specially woven filter bags suspended from brass nozzles in a cast-iron casing to which steam can be admitted. The syrup in passing through the bags leaves behind it most of its solid impurities and issues bright and clear; it is then run into char filters, on leaving which, it is run by means of cocks, pipes, and gutters into one of a series of filtered liquor tanks. It is now quite colourless and translucent, and is conveyed to the vacuum pan supply tanks. Hot and cold water tanks are fixed on the same level as the hot syrup tank, and bag washing tanks are provided in connection with the bag filters.

The charcoal used in the filters is removed from them when dirty, and conveyed in barrows to a char washer, where most of its solid impurities are removed, and is then elevated to the top of the char kiln where it is partially dried and then fed into the kiln pipes for re-burning. The charcoal kiln is of the usual vertical pipe type, standing on iron pillars independent of the building, with external firing stage and flue leading to the main chimney. The re-burnt char from the coolers under the kiln is conveyed to a dry char elevator, which raises it to the level of the char cisterns for refilling them. Hot and cold water pipe systems with the necessary valves are provided in connection with the char cisterns, also iron staging, wooden flooring, stairways, and hand rails.

A small workshop is arranged at one end of the char house, with one or two machine tools arranged to be driven

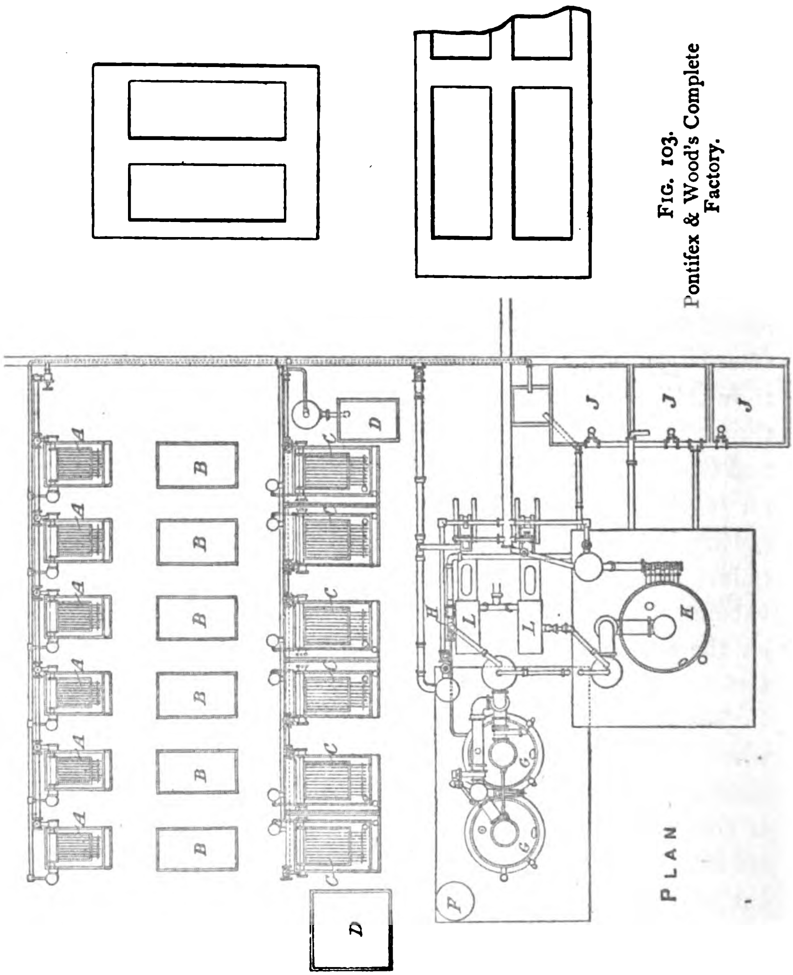


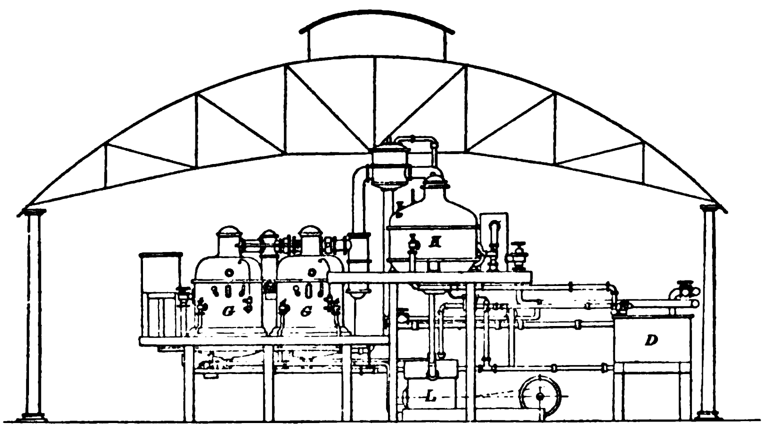
FIG. 103. Pontifex & Wood's Complete Factory.

by a small engine or from the fly-wheel of a steam pump which is engaged during the season in raising filtered syrup to the vacuum pan supply tanks.

Plate XII. illustrates the arrangement of a smaller factory by the same firm.

Figs. 103 and 104 show a plan and elevation of a cane-sugar factory as made by Pontifex & Wood, Limited, London, and erected by them in Honolulu, Sandwich Islands, for the Honourable H. A. P. Carter. The cane is crushed by a 3-roller mill, 3 feet in diameter by 6½ feet long, worked by a pair of coupled horizontal engines 20 inches diameter and

FIG. 104.



ELEVATION

Pontifex & Wood's Complete Factory.

2 feet stroke. The juice runs from the mill into a receiving tank fitted with a perforated false bottom, to prevent bits of megass, &c., going into the pump, where it is elevated to the clarifiers A. These are made of wrought iron, with copper heating coil, made to lift up for cleaning purposes. The juice, after being properly defecated, runs by gravitation into the precipitating vessels B, where it is allowed to remain until the lime falls to the bottom, leaving the clear juice at the top, which is run off into the cleaning vessels C, made similar to the clarifiers, where it is again subjected to heat and boiled. The scum rising is carefully removed, and together with that

from the clarifiers, and the precipitate from the precipitators, is pressed to extract any remaining juice, thus reducing to a minimum that loss of juice, which would otherwise be a serious item in a large factory.

The tanks D receive the clarified and cleaned juice, which is forced thence by *monte-jus* E into cistern F. This feeds the juice into the double-effect apparatus G. After being evaporated here from 9° to 26° Baumé, the syrup is pumped by means of a force-pump H to syrup tanks J, which feed the cast-iron vacuum pan K, where the syrup is concentrated and crystallised. The mass of sugar and molasses is then run out of the pan into a mixer, where the lumps are broken up and a homogeneous mass is formed; it is then cooled in the cooler and drained to form moist sugar. L are the vacuum pumps for the vacuum-pan and double-effect apparatus.

The following is an approximate estimate for a set of apparatus to work with a 16-H.P. sugar-mill, and sufficient to take the full produce of juice from that sized mill when working at its best. The prices are for the goods packed and delivered at the works:—

	£	*s.*	*d.*
1 16-H.P. cane mill, pump for raising liquor, 3 spur-pinions to connect rolls, intermediate gearing, 1 high-pressure 16-H.P. horizontal engine and fly-wheel, 1 Cornish boiler 20 ft. long, 6 ft. diameter, and 3 ft. flue, fitted and mounted complete, the whole including all necessary bolts, &c., complete for fixing	1450	0	0
1 7-ft. inside diameter strong and highly finished copper vacuum-pan, with large copper worm, steam branch direct into jacket, gun metal steam- and air-valves, copper measure, copper safety-receiver with arm pipe, cast-iron condenser with gun-metal dial, cock, and copper injection-pipes, 2 condense-water boxes, glass gauges, barometer, thermometer, proof-stick, &c., &c., complete. A cast-iron staging, supported on columns, to receive the vacuum-pan, with flooring-plates, hand-rail, and stairs, and with air-pumps, engine, &c.	1913	0	0
6 strong copper steam clarifiers, 5 ft. diameter, with cast-iron steam jackets, gun-metal steam-valves, and two-way cocks, 2 copper channels and copper pipes from discharge cocks	895	0	0

	£	s.	d.
4 wrought-iron bag filters of 60 bags each, with gun-metal draw-off cocks, steam cocks, copper main, &c., and one set of bags to each	380	0	0
1 wrought-iron evaporating or clear-liquor heating cistern, with copper steam-coils, gun-metal valve discharge-cocks, &c., &c.	65	0	0
1 wrought-iron *monte-jus*, with gun-metal cocks, copper-pipes, &c.	80	0	0
8 wrought-iron charcoal filters, stop-cocks, &c., copper mains, cocks, &c.	410	0	0
10 wrought-iron store water-tanks, pipes, cocks, &c., steam pipes to all vessels and sundries	470	0	0
2 30-ft. Cornish boilers, mounted complete	500	0	0
2 open copper clarifiers of 600 imperial gallons, each with discharge-cocks, &c., and 4 open copper pans, or teaches, of 200, 300, 400, and 600 gallons contents respectively..	598	0	0
Total cost	£6761	0	0

Cost of manufacture is to a great degree regulated by the relative positions of various parts of the buildings: compact factories are always cheaper to work than those which are scattered. Suppose a building turning out 50 hogsheads of sugar and 15 puncheons of rum per week. The field expenses, that is, cutting and transporting the canes and incidental expenses, should be covered by 16*s.* 8*d.* a hhd. when the land is yielding 2 hhds. to the acre ; a smaller yield will cost a trifle more for cutting. In the buildings, the day's expenses will be :—

	£	s.	d.
9 men throwing canes at 1*s.* 6*d.* per day	0	13	6
1 driver at 2*s.*	0	2	0
2 men unloading canes..	0	2	0
2 men picking sour canes from carrier	0	2	0
2 men feeding mill at 2*s.*	0	4	0
3 boys at mill bed and liquor pump at 1*s.*..	0	3	0
2 boys throwing back begass at 1*s.*	0	2	0
6 men working trucks at 1*s.* 8*d.*	0	10	0
2 men packing begass at 1*s.* 4*d.*	0	2	8
1 engine driver and boy at 5*s.* a day, but as the factory only works 6 months in the year probably, and the engine-driver is permanently employed, say	0	10	0
10 begass carriers at 1*s.* 8*d.*	0	16	8
2 begass diggers at 1*s.* 4*d.*	0	2	8
1 man and boy to feed boilers	0	5	0
1 man to clear away ashes, &c.	0	1	4
2 stokers at independent boilers at 3*s.* 4*d.*..	0	6	8

	£	s.	d.
1 head man at clarifiers	0	3	4
1 second man at clarifiers	0	2	0
3 boys working at clarifiers at 1*s*.	0	3	0
1 man to attend to sulphur	0	1	8
1 head boiler on copper wall	0	3	4
8 boiler men at 2*s*.	0	16	0
1 head man at subsider boxes	0	2	8
3 boys working at subsider boxes at 1*s*.	0	3	0
Washing filter bags	0	1	4
Pan boiler at 4*s*. 2*d*. and assistant at 3*s*.; the same remark applies to them as to the cane engine driver, their wages are therefore calculated at double the actual	0	14	4
Vacuum-pan engine driver	0	3	0
Curing sugar	1	6	8
Cleaning buildings, 4 women at 1*s*.	0	4	0
Cleaning tubes of 2 boilers on copper wall	0	1	4
1 boy attending *monte-jus*	0	1	0
Cost per diem	8	10	2
			6
Cost per week for making 50 hhds.	51	1	0
Cost per hhd. in buildings	1	0	6
Cost per hhd. in field	0	16	8
Total cost per hhd.	£1	17	2

Therefore 37*s*. 6*d*. should cover every cost from the cutting to the sugar-store; no allowance has been made for cost of transportation of coal or stores, nor for cooperage of packages.

The distillery day's expenses will be:—

	£	s.	d.
1 head distiller	0	3	4
2 men at 1*s*. 8*d*.	0	3	4
1 distillery engine driver	0	1	8
2 boys to attend to lees boxes, &c., at 1*s*.	0	2	0
1 man to attend to molasses	0	1	8
Cost per diem	0	12	0
In case of fire stills, an extra fireman for the distillery alone at 3*s*. a day will be required	0	3	0
	0	15	0
			6
Cost per week for 1500 gallons	£4	10	0

These figures show only the expenses belonging to cutting and transporting the cane, and manufacturing the produce;

in addition, there is the cost of packages, small stores, &c. The lowest calculation of coal required is about 9 cwt. of coal to 18 cwt. of sugar; the supposed 50 hhds. of sugar would therefore consume about 450 cwt. of coal. Taking all these items into consideration, the cost of cutting and transporting canes, and making them into sugar and rum, would be for the supposed 50 hhds. sugar and 15 puncheons rum :—

	£	s.	d.
Field expenses	4	3	4
Building expenses for sugar	51	1	0
,, for rum	4	10	0
22½ tons of coal for sugar at 35*s*. 6*d*.	39	18	9
5 ,, for rum	8	17	6
450 lb. of roll sulphur (including waste) at 2½*d*. ..	4	13	9
750 lb. of temper lime (including waste) at ¾*d*. ..	2	6	9
10 gallons of engine oil at 7*s*. 6*d*.	3	15	0
30 lb. of tallow at 7¾*d*.	0	19	9
7 gallons of sulphuric acid at 3*s*. 8*d*.	1	5	8
50 hhds. at 1*s*. 8*d*.	4	3	4
15 rum puncheons at 31*s*. 3*d*.	23	8	9
Coopers' expenses	2	1	8
Sundries: lining paper, wood hoops, nails, kerosine oil, lumber, &c., &c.	6	5	0
	£157	10	3

This is about the weekly expenditure on the manufacturing, not including the transportation of stores, coal, or sugar. The cost of transport is very various for different estates; some can give a berth alongside the buildings to a vessel that will carry their produce direct to the market; others have to convey to the railway, a distance of perhaps two miles, pay railway fees, lighter the produce to a store, and perhaps have again to lighter it alongside the vessel in the stream. It is well worth while to pay rather high for rapid transportation of sugar. Sugar very quickly loses its bloom, and the sooner it is in the market the better. One lot may realise 6*d*. per cwt. more than another, solely because it is a month newer.

CHAPTER VIII.

THE CENTRAL FACTORY SYSTEM.

As a general rule in the cane sugar industry, each cane-grower also works up his own sugar and rum; but there are important exceptions to this rule, where the planters of a district send their canes to a central factory to be dealt with. This system seems to have originated among the French beet farmers, and has been thus introduced extensively into the cane-raising French colonies. It has been adopted on a much smaller scale by British colonists in Natal and elsewhere, and appears to succeed pretty well in Brazil. Nevertheless it must be confessed that the system has been brought to greatest perfection under French management in Martinique and Guadeloupe.

The largest central factory or *usine* in the French West Indies is the Usine d'Arboussier, situated in the suburbs of the seaport of Point-à-Pitre. It is constructed upon the grandest scale. The cost was 216,000*l.*, and the *usine* is equal to an out-turn in the first 6 months of the year of 8000 to 10,000 tons of sugar. The supply of canes is derived from both divisions of Guadeloupe, the volcanic and calcareous. From the former, they are conveyed in large lighters towed by steam-tugs; from the latter, by the tramway, several miles in length. The canes are carted by the planter to his nearest point on the railway or shore, and thence by the *usine* to their destination, where they are weighed by a sworn agent in the presence, if required, of a representative of the estate. The planter receives 5½ per cent. of the weight of his canes of *conne quatrième*, equal to No. 12 "Dutch Standard," the price being regulated by the market at Point-à-Pitre at the time the canes are delivered.

The process of sugar manufacture at this *usine* is as follows. The canes are brought by the planter to a siding of the main tramway on his estate. The waggon generally carries 2 tons of canes, and a mule on a good level ordinary tramway can draw easily 2 waggons. The waggon, when brought to the mill itself, conveys the canes to the rollers, the begass being elevated by power to a platform over the boilers. The juice on leaving the mill-bed falls through 3 strainers into a tank which has a double bottom heated by steam. It is treated here with a little bisulphite of lime, and is then run into a *monte-jus*, which sends the juice up to the clarifiers, where it is heated in the ordinary way, and tempered with lime. From this, it is passed to the charcoal filters, through which it gravitates, and thence by a gutter into a receiver, to be forced up into a cistern over the triple-effect. From this cistern, it flows into the triple-effect, passing from the first to the second and from the second to the third boiler, as the attendant wishes.

When it leaves the third boiler, it is, generally speaking, at 25° B.; it is immediately passed through new charcoal, and falls into another receiver, whence it goes to the vacuum-pan. The first quality sugar is generally crystallised in the pan, and is then dropped into sugar-boxes which stand 7 feet from the ground; under these boxes, a little charging vessel runs on a railway that is hung from the bottom of the boxes, and this vessel conveys the sugar over the centrifugals, where it is cured; the molasses from this is boiled up, when found in good condition, with the syrup of the following day. When these molasses are thick and clammy, they are boiled by themselves and dropped into sugar-boxes, where they are allowed to granulate for a number of days. This makes the second quality of sugar; the molasses from this, along with the skimmings and subsidings of clarifiers, goes to make rum.

The juice that leaves the clarifiers does not pass over fresh charcoal, but follows the syrup from the triple-effect, thus assisting to wash out the sweets which may have been left by the syrup.

The following figures show the weight of canes delivered to the factory in the 4 years commencing 1869 :—

1869	..	17,808,217	kilogrammes (about 1000 kilo. equal 1 ton)		
1870	..	42,808,079	,,	,,	,,
1871	..	68,745,493	,,	,,	,,
1872	..	75,000,000	,,	,,	,,

This factory pays 5½ per cent. for its canes, and the figures following show the financial results for the 3 years ending 1871 :—

	Profit.		Loss.
1869	4,385		
1870	—	.. ..	440
1871	28,899		
	33,284		
Deduct ..	440	Loss in 1870.	
Leaving ..	£32,844	Balance of profit.	

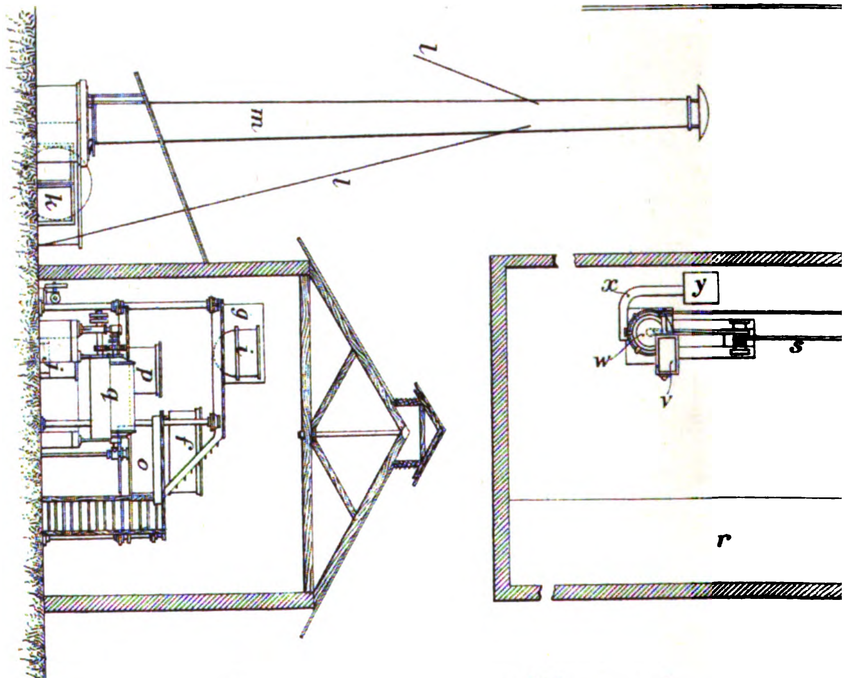
A profit of 7000*l.* was expected in 1870. Severe losses sustained on produce shipped, owing to failures during the Franco-German War, are assigned as the reason for the failure of profits at the *usine* in 1870.

In 1870, 6096 boucauts of sugar of 500 kilos. each, equal in round numbers to 3000 tons, were obtained from the 42,808 tons of canes received, or 7·12 per cent. of sugar; 3 per cent. of syrup was also obtained, which was converted into 470,486 litres, equal to 117,620 gallons of rum, of an average centigrade strength of 60°, equal to 39⅗ gallons per ton of sugar.

In 1871, 19,651 boucauts of sugar, or 5325 tons, were obtained from the 68,745 tons of cane received, or 7·74 per cent., composed as follows :—First quality sugar, 6·24 per cent. ; second and third quality, 1·50 per cent. A minimum

ARRANGEMENT OF

Suitable for turning out 30

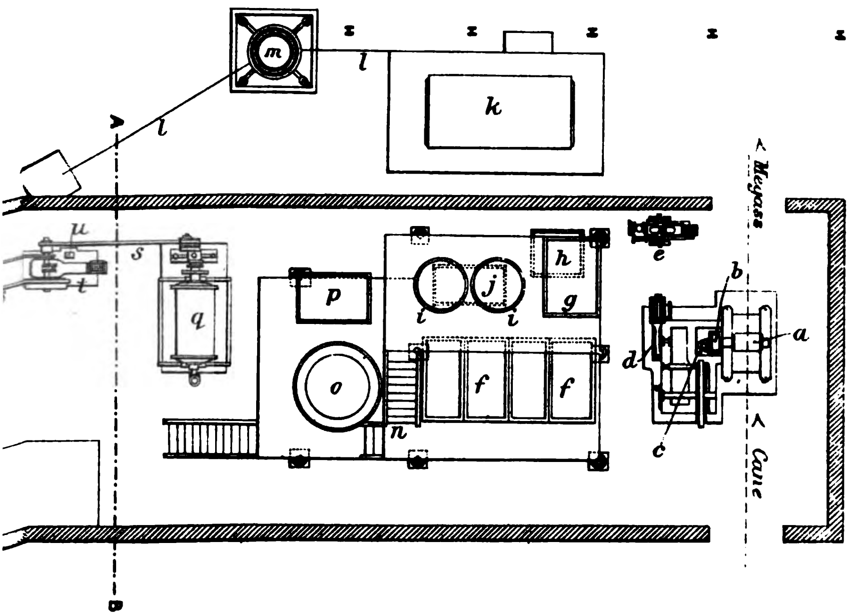


a Cane mill.
b Raw juice tank.
c Juice pump.
d Engine.
e Cold water boiler feed pump.
f Clear juice subsider tanks.
g Cold water tank.
h Condensed water tank.
i Clarifiers.
j Scum Subsider tank.
k Boiler.
l Guys.

E & F. N. Spon, Lond

SUGAR FACTORY.

cwt. to 2 tons of Sugar daily.



m Chimney.
n Stairs.
o Evaporator.
p Molasses blow up.
q Wetzel pan.
r Space for Cooling tanks.
s Driving belts.
t Engine.
u Molasses pump.
v Mixer.
w Centrifugal
x Gutter.
y Molasses tank.

...on & New York.

average return of 8 per cent. is confidently expected when not less than 25 per cent. of plant canes are regularly forwarded from the contributory estates to the factory.

This *usine* in April 1872, the third year of its existence, declared a first dividend of 24 per cent., exclusive of 4 per cent. carried to the "Sinking Fund Account." The general manufacturing and working expenses in 1871 amounted to 2,394,298 francs, or 117,732*l.* The sugar realised 3,543,867 francs, or 141,754*l.*; the proceeds of rum were 306,894 francs, or 12,275*l.*; equal together to 154,029*l.*, showing a profit upon a simple debit and credit account (without charging interest upon capital, wear and tear of stock, &c.) of 36,297*l.* upon a manufacture of 68,745 tons of sugar and 182,798 gallons of rum.

The processes of manufacture both of sugar and rum in all the *usines*, both in Martinique and Guadeloupe, are more or less identical, the only perceptible difference being the adoption in new factories of modern and improved appliances. The clarification of the juice, its reduction to syrup at a low temperature, the perfect crystallisation and good colour of the sugar, and a maximum return, are obtained by repeated filtration through animal charcoal, the triple-effect and vacuum-pan processes and centrifugal machines.

A small private *usine* called Beauport, not far from Point-à-Pitre, purchases canes from the neighbouring estates, paying 6 per cent. for them, and upon a manufacture of 2000 tons of sugar per annum the clearances are very handsome. The books show a return of 19,400*l.* upon 59,963,371 lb. canes purchased (1868). These figures indicate a profit of about 14*s.* 6*d.* per ton of canes purchased. The quantity of sugar made in 1868 was 2600 tons, and 62,700 gallons of rum, or a return of about 210 lb. of sugar and 1½ gallon of rum per ton of canes manufactured.

The Usine Cluny is in general respects similar to that of Beauport, and canes are brought by water in punts from a distance of 20 miles, and afterwards conveyed some miles farther by tramway, to the *usine.*

At short distances from the small port of Le Moule are several *usines,* constructed on a smaller scale than that of D'Arboussier. The water is derived from ponds, wells, and cisterns, there being no running water of any consequence.

The method of manufacture at the Usine Zevalloz is generally the same as D'Arboussier,—charcoal filters, triple-effect, vacuum-pan, and turbines. There is, however, a novel feature in the employment of refrigerators for economising the water supply. These consist of high sheds open on all sides, in which are placed strata of fascines. Over these is conducted the waste water which has served for condensation in the vacuum-pans, &c., and, percolating through them, it falls into a cistern underneath, its temperature reduced to that of the atmosphere; thus reduced, it is again available for condensing purposes. Zevalloz makes 2000 tons of sugar. It works night and day, and employs 140 hands by day, and the same number by night. The greatest distance from which it brings its canes by rail is 3½ miles; they are carted by the planter to his nearest point on the railway, and thence at the expense of the *usine.* This railway, with material, cost between 1600*l.* and 3200*l.* per mile. The breadth between the rails is 1½ yard, and the speed attained is 6 to 10 miles an hour. The Usine Duchassaing is on the same principle and scale as that of Zevalloz. They both pay 6 per cent. of the weight of the canes.

The labouring population in this district has not increased since the establishment of central factories; about 50 per cent. of the hands of the separate sugar-works, when these were abolished, were required to work the *usines,* the planters thus gaining 50 per cent. of the hands employed about the works. After crop, many of the *usine* labourers assist in the cultivation of the estates; others till their own plots, being generally small land-holders. In 10 years, the price of labour has augmented by $\frac{3}{8}$. Here, again, estates within easy distances of the central factory, which formerly were in a chronic state of indebtedness, are now clear, prosperous, and well cultivated.

In Martinique, the *usines* are situated principally on the north-east of the island; there is only one on the south-west side, close to St. Pierre, called La Rivière Blanche. It has the latest improvements in machinery and apparatus, is capable of making 2500 tons, and its cost, everything included, was 48,000*l.* It consumes 400 to 650 kilogrammes of coals to the 1000 kilogrammes of sugar made. The process includes the usual charcoal filters, triple-effect, vacuum-pan, and centrifugals. This *usine* gives 6 per cent. for its canes.

Near Fort de France is the first factory established in Martinique, by an Englishman, 35 years ago, Pointe Simon. It did not succeed well at first, in consequence of want of experience, defective machinery, &c., but is now paying well; it gives, however, only 5 per cent. of the weight of canes.

The Dillovi factory is situated about 3 miles from St. Pierre. The works are well constructed and very compact, with all the latest appliances. The machinery is by Lecointe et Villette, and the cost of the *usine* alone amounted to 44,000*l.* The railway, which is 12 miles in length, has been very expensive, in consequence of some mistakes in its construction, as well as the marshy and unfavourable condition of the soil. The scum is pressed and the cake is used as manure. The specific gravity of the juice is 9° to 10° B.; 1100 tons of sugar are made, and $\frac{1}{4}$ ton of coal is consumed per ton of sugar. This *usine* made a profit in 1872 of 250 tons of sugar and 1000 casks of rum of 250 litres each, selling at 90 francs (3*l.* 12*s.*) per cask. The sugar sold at 40*l.* per ton. The mean weight of canes is found to be equal to 28 tons per acre.

The Usine Robert is calculated to make 2000 tons, and the cost of the plant was 60,000. The percentage of sugar got is 6½ to 7 per cent.; of juice, 68 to 72 per cent. In 1871, the quantity of canes ground was 22,300 tons; in 1872, 19,500 tons. The quantity of sugar made was nevertheless the same, so that in 1871 the percentage extracted was 6·29; in 1872, 7·09, the total quantity of sugar made being 1400 tons. Coals used, including steam-tugs, 1117 tons. The cinders and press-residues are given to planters. The average of rum obtained from molasses is 70 per cent.

As an investment, *usines* both in Guadeloupe and Martinique are in high favour. Capital is freely subscribed to establish new factories upon a large and extensive scale. This is evidence that they return a very handsome profit; yet, in passing through the country, the difference between the tillage of estates selling their canes, and those manufacturing at home, is most marked. In the one case, the canes are no sooner out of the fields than the men and cattle are at work preparing the land for the next crop, and all the fields are tidy and clean. In the other case, fields are left to take care of themselves until crop season is over. Over a crop of 300 tons, it is estimated that the *usine* would clear 200 francs per ton, after paying the planter 6 per cent. Bearing this in mind, planters have themselves to blame if they allow the capital of such concerns to be mostly subscribed by outsiders, instead of investing their own capital in them.

In most *usines*, hydraulic or other presses are employed for extracting the last traces of juice from the skimmings. The former are carefully returned to the clarifiers, the residue being a hard cake which is used for fodder and manure.

Clarification is mainly effected with common lime only, the use of the bisulphite of lime being rare.

The filters are filled with animal charcoal, which is covered with the best and softest fresh water procurable. Syrup is first passed through them for 24 hours; afterwards the juice from the clarifiers is sent through them for a like period. The spent charcoal is revivified by washing in pure fresh water, and subsequent re-burning in furnaces especially constructed for that purpose. The absolute loss of charcoal is estimated at 12 lb. to 14 lb. per ton of sugar. The cost of charcoal per ton of sugar, including cost of labour engaged in washing and other work, and expenses for passing juice and syrup through the charcoal, and other contingencies, is about *6d.* per cwt. The use of bisulphite of lime is estimated in Demerara to cost about the same sum per cwt. An almost inexhaustible supply of pure fresh water is indispensable for washing the charcoal.

The distillery process and apparatus, and the quality of the rum manufactured at the *usine*, are superior. The stills are worked by steam, with continuous action, and a very pure spirit, proof strength, without any flavour of acetic ether, is obtained, more resembling common *eau de vie* than rum in appearance and flavour. The average return is 1 puncheon per ton of sugar.

The first experiment made upon a large scale has fully proved the soundness of the principle of separating agriculture from manufacture. What the isolated planter, bare of resources, is unable to do, the association of capital and concentration of labour fully realised, without injury to the chief functions of the planter, which, on the contrary, are greatly facilitated.

It has been stated that the Central Factory System must ultimately conduce to the exhaustion of the soil on these estates supplying canes to the *usines*. That, whereas, in the ordinary system of manufacture, little, if any, of the mineral elements of the cane are finally extracted from the soil, these being restored in the form of begass-ash, distillery-refuse, &c., in the case of central factories they are absolutely lost. This is provided against by the increased employment of chemical manures, these being composed so as to return to the land the principal mineral matters of which the cane has been, by analysis of its ash, found to deprive it. The most successful of these manures have been alluded to on p. 38.

In the principal sugar-works in the vicinity of George Town, Demerara, the process employed is the following:— The canes are brought to the main line of tramway by the planter. The factory takes them to the mill, where the waggon is tilted by a similar method to that employed in the French *usines.* The begass is elevated, and is put, by boxes running upon an elevated railway, into "logies," or the yard, to dry. The juice flows from the mill through the strainers into a pump, getting treated with bisulphite of lime *in transitu.* The pump elevates it to the clarifiers, where it is cracked, racked, and treated with lime. From thence it flows on to the copper wall, where it is cleaned thoroughly, and is raised by *monte-jus* into subsiders, where it is allowed to rest 9 or 10 hours. From these vessels the vacuum-pan draws the juice, and boils it to sugar, the first quality being crystallised and cured as soon as possible. The molasses, where good, are worked into syrup on the following day, until they get so thick as to darken the first quality. They are then boiled alone, and form second-quality sugar, being allowed several days to granulate in the coolers; the skimmings from clarifiers and copper wall, the subsidings from syrup-boxes, and the molasses from second-quality sugar, go to make rum.

It will be seen that the essential difference between this and the French process is the entire elimination of the char filters and triple-effect, and with them the necessity for a large supply of pure water—a matter of much importance where this cannot easily be procured. This process is certainly simpler and less expensive, but that it extracts the same amount of sugar from the juice is impossible.

PALM SUGAR.

CHAPTER IX.

PALM sugar, often called date-tree sugar, is a product of the juices of many kinds of palm, the most important being the wild date palm (*Phœnix sylvestris*), which thus gives a name to the whole class. Other species are the palmyra (*Borassus flabelliformis*), the coconut (*Cocos nucifera*), the gomuti (*Saguerus* [*Arenga*] *saccharifera*), the nipa (*Nipa fruticans*), and the kittool (*Caryota urens*). All these are essentially natives of the East Indies, including India, Ceylon, Siam, the Malay Peninsula, and the Eastern Archipelago.

The production of palm sugar is a branch of industry which, with reference to the usually slow progress of native exertion in any new channel, has increased wonderfully since the impulse given to sugar production in India, through the modification of the sugar duties in 1837, and through the encouragement thereby afforded for the embarkation of British capital and the application of British machinery in sugar production.

The portion of British India more particularly occupied by this cultivation extends nearly due east and west, from Kissengunge in Kishnagur, to a little beyond Nollchit in the Backergunge district; and north and south, from the vicinity of Comercolly in the Pubna district, to the borders of the Sunderbunds, thus occupying on the map a surface of about 130 miles long, east and west, by about 80 broad, north and south. Its principal districts are Jessore, Furreedpore, and Backergunge, with portions of Nuddeah, Baraset, and Pubna; beyond this tract, little or no date-tree sugar is manufactured, although the tree is often cultivated in other districts, and may be occasionally met with in most parts of India.

Here one species only, *Phœnix sylvestris*, is availed of for the production of sugar, though many others might be profitably utilised. From *Cocos nucifera* good goor is commonly made in Province Wellesley; and from *Borassus flabelliformis*, throughout Bengal, a saccharine juice is obtained and used for intoxicating purposes, frequently as a substitute for yeast in making bread, and which is said by the natives to yield a sugar of good grain and greyish complexion.

The sugar obtained by the natives of Bengal and Siam from the various species of palm is, on account of the crude way in which it is manufactured, of very inferior quality, and is mainly consumed in the countries where it is grown. The juice of the nipa palm (*Nipa fruticans*) is almost equal in saccharine richness to that extracted from the cane, with the advantage that it is much cleaner, and contains no colouring matter nor chlorophyll, the vegetable matter being easily precipitated, giving a liquor as clear as spring water. This species of palm flourishes near the sea, or on the edges of brackish pools, and takes up a large quantity of salt, which makes its appearance in the juice in varying quantities, sufficient, in some cases, to give the liquor a decidedly saline taste. Were it not for this drawback, a large quantity of excellent sugar would be obtained from this source.

The date palm requires a humid soil and climate, and flourishes best in the vicinity of water; though it must be above the reach of the annual inundations from the rivers. Like most of the palm tribe, it seems to prefer the vicinity of the sea-shore, and is less often found on the high grounds of the Western Provinces; though on the southern bank of the

Ganges, extending from Rajmahal to Monghyr, a great many trees are met with: their valuable juice is here misused by being fermented and drunk as an intoxicating beverage, and its conversion into sugar is unknown.

The trees are never planted with much regularity by the natives, many of them being set in the hedges surrounding the fields appropriated to rice and other grain. Nevertheless, since the cultivation has so greatly increased of late years, plantations have been formed to no small extent, and some attempts have appeared at planting the trees in rows and at regular distances; yet it is evident that the aid of the measuring rod or line is never considered at all requisite in the work. In such plantations, the trees are placed 10 to 15 feet apart, so that sufficient space is left for cultivating an oil-seed or other dry crop between them, without its being injured by the shade of their leaves; indeed, one never hears of any crop so grown being less productive than in the open field, except that of indigo, which is said to suffer through not obtaining the full benefit of the sun's rays. As the modes of planting, extracting the juice, and boiling the same into goor, differ but in trifling details throughout the date-tree tract, a detailed description of the routine as practised in the principal district, Jessore, will be a fair example of the whole.

The trees attain a height of 15 to 25 feet when full grown, according to the nature of the soil they are in. The annual abstraction of their sap evidently stunts their growth very much. A very plain proof of this is occasionally afforded in the date districts by the owner of a plantation leaving one tree untouched by the knife; he is prompted to this by a superstitious notion, that by so devoting one tree to his *Deb* or favourite deity, a greater productiveness will attend the rest of the plantation, and it consequently may be seen towering above its companions to twice their height, or more.

Planting.—The trees are always raised from seed. The fruit ripening in June or July, the seeds are collected and sown shortly afterwards a few inches apart, in a moist spot selected for a nursery, near the cultivator's house. They soon vegetate, become strong plants, are weeded and watered occasionally during the following dry season, and are ready for being planted out in the field in the succeeding April or May, after the first showers of the season. The ground destined for their reception is well ploughed, and without any assistance from manure, the plants are then placed in the ground, each in an extempore hole made with the hoe or *kodaul.* By the time the rainy season closes, about the following October, they are strong young trees, the leaves 3 to 4 feet high; any accidental vacancy, occasioned by any of them having been destroyed by cattle or other cause, is then filled up.

The roots are occasionally cleared of weeds; and should the ground not be in yearly crop, a ploughing is sometimes given for the benefit of the trees, as this improves them by loosening the earth around them and allowing more scope for the roots. With these exceptions, no other expense or trouble is incurred in their cultivation. The trees arrive at full growth at about their seventh year; but the cupidity of the native cultivator seldom allows them to reach beyond 5 years, before he commences extracting the juice. Should the growth of the young trees be forward, he frequently commences at 2 or 3 years old; though this early exhaustion no doubt injures the after-productiveness of the plant, and probably shortens its term of life. Frequently the trees are tapped when the stem is less than a foot in height from the ground, a hole being dug in which to suspend the earthen pot that collects the juice. When not weakened by too early tapping, the average age the trees arrive at is about 30 years, being 25 years for sugar production after allowing the first 5 for their undisturbed development. On the borders of the Sunderbunds, however, where the trees grow in strong marshy soils impregnated with salt, it is said that their excessive vegetation causes the trees to exhaust their strength sooner; and that their age in such places does not exceed the average of 17 or 18 years.

The quantity of juice obtained before the trees have reached their 5th year is small and uncertain; if allowed their full 5 years for growth, and first cut in their 6th year, the juice for that year is found to be yielded in the proportion of about one-half the yield of a tree of full maturity; in the 7th year, three-fourths of the full quantity; and it is not until the 8th year that the tree is found to give its full average yield of juice.

The expense of planting one beegah of ground is estimated as follows. The natives reckon a beegah to contain 160 trees, or two puns of 80 each, which allows of their being planted, about 10 feet apart, then—

		R. A. P.	
Cost of 160 plant-trees in sowing, watering, &c., say		1 0 0	
Carrying to field, planting, and replanting deficiencies		1 0 0	
Half-yearly* rent of one beegah of ground, at 2 Rs.	1 0 0		
Ploughing twice per annum, at 2 annas ..	0 4 0		
Weeding ditto ditto, at 4 annas	0 8 0		
Yearly expense	1 12 0		
Which for 5 years, is		8 12 0	
		10 12 0	(21*s.* 6*d.*)
Add compound interest on the above yearly account at the rate of 25 per cent. per annum, is		10 7 2	
Net expenses on the beegah of trees when ready for producing goor		R. 21 3 2	(42*s.* 4¾*d.*)

Cutting the Trees and Collecting the Juice.—The trees are first cut about the 20th of October. This is done by stripping

* The other half being chargeable on the oil-seed or other crop grown between the trees.

off the lower leaves of the branching head of the tree on one side, so as to leave a denuded space of about a foot long; from this, a piece of the bark is removed in the shape of a triangle, each side of which is about 8 inches long, and having one angle pointed downwards. For the next 8 or 10 days after the above operation, the cut part is left to harden, and what little sap exudes from it is allowed to run to waste, as not being sufficient for use. Collecting the juice, therefore, does not commence before about the 1st of November, a few days earlier or later, according to the season, the first cold nights causing the sap to run freely. As soon as this is observed by the *Gauchea*, or date-tree labourer, he ascends the tree in the evening, and slices away a further portion of the tree, cutting deeper this time, so as to divide the sap-vessels, and from the centre of the triangle towards its sides, in such a way that along the latter a sort of channel is formed, which conducts the juice to the lower point of the triangle; here in a notch is inserted one end of a piece of reed or grooved stick, about 6 inches long, its other end hanging over the earthen pot which is suspended by a string close under it, and into which the juice trickles as it flows from the tree.

The instrument used for cutting the trees is a *daw* or bill-hook, of peculiar shape. The *Gauchea* ascends the tree by the aid of a thick rope, which he fastens loosely encircling the tree and his waist, before ascending; then, by pressing his feet against the trunk, leaning back against the rope, alternately raising the latter with his hands, and stepping upward, he quickly gains the summit, where, supporting himself against the rope, he leans with his arms free for work. The *daw* is used by pressing the wooden handle tight under his arm, and grasping the back of the blade with both hands, which enables him to cut firmly into the wood.

A man having less than 80 trees does not himself convert their produce into goor, but lets them out, at a yearly rent for their use, to any neighbour who has more, for the reason that a less number than this would not yield a sufficient quantity to compensate for the expense of the necessary arrangements for managing the work, such as the construction of the furnace for boiling the goor, &c. The number worked by any one ryot or family varies from 80 to 300 or 400; but for the greater facility of calculating the expense attending this department, a farm of 160 may be assumed, as about to be worked upon, and that these are all full-grown, and capable of yielding the full average quantity of juice.

Whatever number of trees the plantation or farm may comprise, they are lotted off into 7 distinct divisions, all containing as nearly as possible an equal number of trees. The trees of one of these divisions are cut by the ryot every evening in succession, so that the whole number is cut regularly once in 7 days. The first division may be taken as containing 23 trees, on which the work proceeds as follows. The *Gauchea* having cut or pared this number in the manner above described, and suspended the pots to them on the previous evening, obtains in the morning, as their first day's produce, an average of 10 seers (the seer is about 2 lb. 1 oz.) of juice from each tree; on the second morning, an average of 4 seers of juice; and on the third morning, an average of 2 seers of juice; after this, the reed and pot are removed, and for the 4th, 5th, 6th, and 7th days, the trees are left to recover themselves, the little juice that still exudes during that time being allowed to run to waste, as not worth the labour of collecting. On the evening of the 7th day, it again comes to the turn of these 23 trees to be cut; this is done by peeling off a further portion from the already open cutting, which again divides the sap-vessels, and the juice recommences flowing; the reed and pot are placed as before, and the same process is repeated, and so on regularly throughout the season. It will be seen from this description, that the ryot by newly cutting a one-seventh division of his trees every evening in succession, will have every succeeding morning to gather the juice from three such divisions, yielding respectively 10 seers, 4 seers, and 2 seers of juice from each tree; and that by this system, a uniform quantity of juice is daily procured, and the labour is equally distributed over the time given for it.

1st division	..	23
2nd ,,	..	23
3rd ,,	..	23
4th ,,	..	23
5th ,,	..	23
6th ,,	..	23
7th ,,	..	22
		160

The ryot, therefore, having 160 trees would divide them as per margin, and would collect daily the juice of 68 or 69 trees, yielding juice as follows, for trees of full growth and bearing:—

	M.	S.
23 trees first day's runnings, at 10 seers each	5	30
23 ,, second ,, ,, 4 ,, ...	2	12
23 ,, third ,, ,, 2 ,, ...	1	6
Total juice per diem from 69 trees	9	8 (758 lb.)

The above refers to the juice exuding during the night only, and collected early in the morning, from which alone sugar is made. It is sometimes customary likewise, with trees which bear well, to collect in the same manner what may run from them during the day; but as rapid fermentation takes place immediately the air is warmed, that is, soon after sunrise, the day juice is thereby unfitted for crystallisation into goor, and is boiled up only for sale as molasses. As this practice, however, is far from general, and at the ordinary market rate for molasses barely repays the labour required to produce it, it is not included in the calculation of yield and cost about to be given.

The *Gauchea* commences collecting the juice a little before daybreak; he ascends each tree in succession, having the empty pot for collecting the day juice slung at his back, if it is his intention to collect it also, to be exchanged for that containing the night's produce. With the latter, he carefully descends, and places it near the foot of the tree, proceeding in this way regularly through the trees that may be yielding. A second man collects the juice by merely filling as many spare pots as the quantity obtained may require, and these he places together in some central spot of the plantation ; as soon as a sufficient number are collected to commence a boiling, a third carries them away to the boiling-hut. The emptied pots from the trees are then ranged on the ground in rows of about 20 each, with their mouths downwards over a layer of straw or dry leaves ; the latter is then set fire to, and gives the pots a thorough smoking, covering their inner surface with an even black coat. The object of this is to prevent the acidity, which would no doubt set up a fermentation in the fresh juice, were any of that from the previous night allowed to taint the vessel through being absorbed by it, but which is neutralised by the alkaline salts contained in the smoke.

As an additional slice is pared from the face of the incisions in the trees once every 7th day, this forms towards the end of the season a very deep notch, reaching sometimes nearly half through the trunk. Each succeeding year the trees are cut on opposite sides of the bark, so that they have, when a few years old, a deformed zig-zag appearance. It follows that numbering these notches will, in ordinary cases, tell at once the age of the trees. In some localities, however, the ryots are accustomed to newly tap the trees *twice* in each season, once on each side of the bark, in preference to cutting so deeply on one side ; in this case, of course, half the total number of notches will give the number of years the tree has been tapped, and, adding in all cases 3 to 5 years for its growth previous to tapping, will give the age of the tree.

Boiling the Juice.—This is conducted in a mode characteristically simple. Four shallow earthen pans, about 2 feet in diameter and 1 foot deep, are set in a square furnace, formed by digging a hole in the ground, and raising a mud structure over it, about 6 feet square, in the dome of which are cut the 4 holes in which the pans are set. A hole cut at each side, one for feeding the fire and the other for the escape of the smoke, completes the arrangement of the furnace ; over this, a light roof is usually thrown, supported by bamboos, and thatched with the dried leaves of the date tree, as a partial shelter from the sun and rain, though the latter is unusual during the season when the work is in progress.

The fuel used is the *soondry* wood, with which the date districts are all more or less easily supplied from the neighbouring Sunderbunds, assisted by the dried leaves of the date tree itself.

The four pans are kept about half-full of date juice, and as the contents diminish by evaporation, fresh juice is supplied until each is sufficiently filled to complete the boiling into goor without further addition. Up to this point, skimming goes on ; and about a foot in length, cut from the small end of a date-tree leaf, is kept floating in each pan, which is believed to assist the clarification, though it is difficult to see the rationale of this practice. No lime nor alkali in any shape is used in the process : the juice is simply boiled until it arrives at its proper granulating consisteney, which is known to the natives by long practice, from the appearance of its tenacity when allowed to drop from the end of a stick, and from its colour and appearance while boiling. The juice, as brought from the trees, is clean, white, and transparent, resembling the juice of the coconut, both in appearance and taste, though with an evidently sweeter taste to the palate. These qualities give it a decided advantage over the juice of the sugar-cane, it being quite uncontaminated with feculencies, chlorophyll, and other deleterious substances, the separation of which from the cane-juice causes so much trouble to the planter. The skimmings from the boiling of date goor are in consequence very trifling, and probably consist principally of albumen, coagulated and thrown to the surface during the process. They are turned to no useful purpose.

The boiling occupies 5 to 6 hours with each pan, and as soon as it is complete, the goor is ladled into a vessel set ready near the furnace. If it is intended for immediate sale to the *Moyrah* or sugar-maker, this vessel is a long jar-shaped earthen pot, holding 2 seers to ½ maund weight, the size and form varying much according to local custom. If the pots are large, they are not filled at once, but the boilings of several days are poured in successively, so that 3, 4, or more pots are filled simultaneously, and contain layers slightly varying in quantity, though the average in all is the same. A great deal of goor is, however, converted by the ryots themselves into a description of sugar called *naund dulloah*, in which case the boiling is not carried to so high a point; and this allows it to form a larger crystal, and to part with its molasses more freely. In such a case, it is ladled at once from the boiling-pans into a large *naund* or conical-shaped vessel, holding 2 to 3 maunds, and in this it is cured and drained.

Yield.—Weather that is at once dry and cold is most favourable for the date-juice, both as to its quality and yield; and this is the prevailing character of the climate throughout Bengal for the greater part of the time occupied by the goor manufacturing season, which extends on the average over 3½ months, that is, from the first November to the 15th February. But little is ever made earlier than the former date, and such is generally of small grain, and inferior; on the other hand, any that is made later than the middle of February is of soft grain, and containing an undue proportion of molasses. Occasionally the warm weather sets in a week or two earlier, and effectually cuts short further goor making.; though if the atmosphere be relieved by a good fall of rain in this month, as is not unusual, this is always followed by a temporary return of cold nights: the goor season may be said to commence anew, and very fair produce is obtained for another week or two, extending frequently into the first days of March. But the finest produce is yielded in December and January, that is, during the coldest part of the season; and on the whole, the above estimate of 3½ months, or 107 days, may be considered the time occupied by an average productive season.

In this period, however, are included all the days in which the yield is diminished by rain, or by fogs, which are frequent in Jessore, and are very inimical to the production of good goor, though they do not diminish its quantity. In estimating the yield of good goor for a season, therefore, one-fifth of the total quantity should be deducted from what would have formed the result of an uninterrupted full yield throughout, to compensate for the diminution caused by unpropitious weather. Thus, on the estimate of production given in a former page, 160 trees were reckoned to yield when in full bearing an average of 9 maunds 8 seers of juice per diem throughout the season; this, multiplied by 107, the total number of days, and allowing one-fifth deduction for loss by variations of the weather, leaves bazar mds. 787–20–13 (56,964 lb.) as the nett produce in the juice for the season, and this, being divided over the 160 trees, gives mds. 4–36–4 (356 lb.) as the average total produce of juice from each tree.

The proportion of goor obtained from date-juice averages one-tenth by weight, and the density of the latter does not appear to vary nearly so much as that of cane-juice. At this average, the yield by the above calculation from 160 trees would be bazar mnds. 78–30 (5702 lb.) of goor, or nearly 19¾ seers from each tree, or 49 maunds 8¾ seers (3554 lb.) per 100 trees per annum.

Cost.—The expense to the native ryot of extracting and collecting the juice, and converting it into goor, is calculated as follows; taking for example, as before, a cultivation of 160 trees in full yield:

	R.	A.	P.
The expense of cultivating this number on one beegah of ground was before calculated at R. 21–3–2; and assuming these trees to yield in full bearing for the average of 20 years, the expense under this head would fall at per annum ..	1	0	11
Add half the annual rent at R. 2 per beegah, the other half being chargeable on the annual crops raised between the trees..	1	0	0
For the labour of collecting and boiling the juice,			

	R.	A.	P.
it is computed that two men, or *Gaucheas*, at R. 3 per month each, and one headman at R. 4 per month to boil the goor, can fully manage 200 trees, on which their wages for 3½ months will amount to R. 35. By the same rule, 160 trees would require an expense in labour of..	28	0	0
Earthen pots for holding goor, say 296, of 10 seers each, and costing 12 annas per 100, is	2	3	6
Earthen pans for boiling, extra jars, &c., say ..	6	0	0
Soondry wood fuel (in addition to dried date-tree leaves) for boiling goor, 400 mds. at R. 5 per 100 mds	20	0	0
Knives, ropes, and boiling utensils	1	0	0
Setting up furnace and *chopper* roof	1	0	0
	60	4	5
Deduct value of *soondry* wood charcoal from the furnace	1	0	0
Leaving as the net cost of 78¾ bazar mds. (5645 lb.) of goor at the average rate of 12 annas (1*s*. 6*d*.) per maund	59	4	5 (5*l*. 18*s*. 6½*d*.)

In the foregoing account, the yield of trees in full bearing only has been computed, that is, their produce after the 7th year of growth. It has previously been explained that for their first 2 years of bearing, that is, for the 6th and 7th years of growth, the trees yield respectively only one-half and three-fourths of their full yield, and this would consequently enhance somewhat the cost of the goor made in these 2 years. To compensate for this, the total duration of the period of yielding is estimated in the above account at 20 years, in lieu of the fair average of 25 years, so that the return of the cost of 12 annas per maund for the goor may be considered as not much affected by this irregularity.

It has been already mentioned, that it is customary for a ryot having a few trees only, to lease them to any neighbour who has a larger number. Wealthy owners of large plantations also frequently lease them for the season to ryots, who engage themselves specially in the business of goor making. Before the value of sugars rose in the date districts, under the influence of competition for the supply of the English markets, engagements of this nature were generally made at the rate of 16 to 20 trees per rupee (2*s.*) as their yearly rental. But since the increased demand alluded to, the rate has gradually risen to more than double the former standard, and 8 or 10 trees per rupee per annum is a common bargain. Even at the first-mentioned rate, it will be seen that the yield per beegah to the cultivator would be 8 to 10 rupees (16 to 20*s.*) per annum, being a very remunerative return on the expense of cultivation, and, at the rates current of late years, the profits must have been enormous. It is true that the Zumeendar has, in most cases, stepped in and claimed his share of the profits by a tax on the trees (whether legally or not, is a question that would be irrelevant here to discuss), and in this manner has curtailed the profit to the ryot. Yet even with this drawback, after looking at the above details, we shall cease to wonder at the enormous and rapid increase in the cultivation of late years; and the traveller through Jessore and the neighbouring districts will be less surprised at the interminable groves of date-trees in all stages of growth which surround him in every direction.

History.—The history of the cultivation of the date-tree, and manufacture of its sugar by Europeans, is an almost uninterrupted blank. The very existence of such an article as date-tree sugar appears to have been almost forgotten during the latter periods of the East India Company's trade monopoly; though in former times occasional reference was made to it in the correspondence between the Court of Directors and their Board of Trade in Calcutta. In 1793, a shipment of 54 factory maunds (36 cwt.) was consigned home by the latter; but the smallness of the parcel probably caused it to be overlooked, and the result of its sale is not recorded. In a Minute of the same Board's Consultations, dated 4th September, 1792, the whole annual produce of date-sugar in Bengal was estimated at 15,000 maunds (10,000 cwt.). The cultivation was probably, therefore, in its infancy at this period; and its further cultivation was checked for the next quarter of a century, as well by the restrictions of the Company's monopoly, as by the high discriminative rates of import duty imposed on East India sugars by the home government. Previous to 1830, it certainly appears to have been unknown as an article of commerce in the home markets, though long previously used in Calcutta by the native refiners, and as an article of native consumption.

No means exist of tracing, with anything approaching to correctness, the yearly rate of increase in the production of date sugar since that period, nor of ascertaining its present extent. From an estimate of the quantities purchased for the European refineries, added to the amount of native refined sorts sold for export in the Calcutta market, under the names of *gurpatta* and *dobarrah*, Robinson concluded that 9500 to 10,000 tons, or at least one-fifth of the whole annual quantity exported to England, was in 1850 composed of date sugars.

The attention bestowed by Europeans on the production of these sugars for the Calcutta or home markets, has been confined to the remanufacture or refining of the native raw material, such as *khaur*, *dulloah*, &c.; and for this purpose, it has been deservedly held in very great esteem, producing a good-coloured and well-crystallised sugar, and yielding a greater percentage in weight of refined goods than can be obtained of equal quality from the same weight and class of cane sugars. On the other hand, the raw date sugars are more liable to deteriorate by being kept in store, losing both colour and strength more rapidly than the former; this applies, however, to the raw products only, the refined or reboiled sugars undergoing the voyage home, or being kept in store in India, equally well with those from cane.

The cause of the above-mentioned peculiarities appears to lie in the larger proportion of gluten present in date sugars; and the tendency of this substance to decomposition, when in contact with saccharine matter, seems sufficient to account for most of the characteristics distinguishing it from cane sugar. These are no less remarkable in the molasses than in the sugar itself, that from date sugar possessing far less saccharine matter, and being of much darker colour than that from cane, which is probably caused by the gluten being partly decomposed by the lime and heat of the boiling process. Another distinguishing feature, however, worthy of remark, is the absence from the date sugar of the empyreumatic oil, so observable in all cane produce, and which affords to the rum made from cane molasses its well-known flavour.

On considering the low cost of date sugars as compared with cane, and the little trouble and risk incurred in rearing the trees, it seems, at first glance, remarkable that the European planter has not been induced to avail himself of this cultivation for producing sugar on a large scale. But great discouragements to the investment of English capital in this way no doubt exist in the uncertain and ill-defined nature of land-tenure in Bengal, the length of time the trees occupy in coming to their full bearing, as well as in the difficulty of collecting the juice for boiling into sugar by the European method after they may have been reared. Yet these are drawbacks which will probably be overcome.

In speaking of the native date sugar cultivation, it was shown that the annual produce of a full-grown date plantation was equal to 78¾ maunds of goor per Bengal beegah, which, converted into *khaur*, may be taken as equivalent to a yield of about 5½ tons of muscovado sugar per English acre. The calculations given subsequently on native sugar manufacture proved :— (1) That date sugars could be produced at about two-thirds the cost of cane sugar, of equal quality; (2) that the date crop involved little or no risk, and a comparatively small outlay in the cultivation; and (3) that good white sugar could be produced therefrom, by native methods, at a cost of R. 4–10–7 per maund, and fine crystallised ditto at R. 6–13–9 per maund, equal to 12*s.* 6*d.* and 18*s.* 3*d.* per cwt. respectively of English money, delivered in Calcutta. By the application of refining to the native raw date sugars, good white vacuum-pan sugar is produced at or within a cost of R. 5 per maund, or 13*s.* 6*d.* per cwt. delivered in Calcutta, and this with a fair profit to all employed in its production. Whether any reduction can be made on this cost, by the application of European means and machinery to the juice direct from the tree, and so converting it by one process into marketable sugar, is a problem which remains for the future to solve.

MAPLE SUGAR.

CHAPTER X.

THE rock, hard, or sugar maple (*Acer saccharinum*) is a tall and ornamental tree, flourishing throughout most of the North American continent. Its wood forms excellent fuel, and in consequence of the great demand for building timber and fire-wood in the long-settled States of the Union, the reckless cutting of the trees has there tended to extinguish the tree. Still many "groves" or "bushes" remain, where the collecting of maple sugar is a regular industry, and in the more thinly peopled parts there is said to be an increasing regard for the sugar-yielding qualities of the tree.

In sections of the United States where it prevails, the manufacture of sugar and syrup from it is a remunerative adjunct to other farming industries. The season of manufacture, beginning where winter ends, and concluding before the ground is sufficiently thawed and settled for "spring work" proper to commence, occupies a period in which little other farm work can be pursued. The apparatus for collecting the sap and manufacturing the sugar, involves a very small investment. The fuel consumed is usually on the ground, consisting of the prunings of the maple grove, which is benefited thereby; and within a month or six weeks from the time the process of production begins, the farmer may have the cash in hand for his surplus product, and that at a season when he rarely has other cash productions to dispose of.

Vermont has probably given more attention to the development of this industry, and been more on the alert to discover and promptly adopt improved processes of manufacture, than any other State. As a consequence, it has made large relative gains on other States having like resources. Though among the smallest in productive area, at the last census, in the amount of sugar produced, it had outstripped all others, exceeding New York, the next highest, by 2,202,262 lb., which, estimating the product of that season at a value of 10 cents (5*d.*) a lb., would be $901,453 (187,802*l.*). Except the labour of the ordinary force on the farm, at the most impracticable season for other farm work, the outlay is so small, that at least 90 per cent. of this gross sum is net income, earned, as it were, incidentally, while waiting for the frost to come out of the ground. It is not strange, therefore, that the beautiful maple orchards, which embower the declivities and crown the hill-tops of that agricultural State, are often held at a higher value than other land, covered with hardwood timber, or under cultivation.

The sugar-maple is a much larger tree than the red maple, and is at once distinguishable from it by the roundness of the notch between the lobes of the leaves. It is one of the largest trees of the genus, often attaining a diameter of from 3 to 4 feet, and out-topping the other deciduous trees, sometimes reaching a height of over 100 feet. For fuel and charcoal, its wood is especially valuable; it also produces the well-known "bird's-eye maple" used in cabinet work, supposed by Emerson to be a distinct variety of the sugar-maple, but from information obtained by Geo. Maw in Upper Canada, it seems probable that it is only of mere casual occurrence in individual trees. This species is pre-eminently the source of maple sugar, and was known to the Indians before the settlement of the country by Europeans.

A very interesting physiological point connected with the production of maple sugar, is the variability of the flow of the sap dependent on diurnal changes of weather, the whole life forces of the big old trees being apparently ruled by trifling changes of temperature and alternations of heat and frost. Changes of life-action occur which are inappreciable to the eye in the daily development of the spring growth, but which the flow of sap records with precision.

The rising of sweet sap commences immediately after the first break up of the long frost, from the middle to the end of February, continuing through March and into the early days of April, but varying in different localities and at different seasons. A cold north-west wind, with frosty nights and sunny days in alternation, tends to incite the flow, which is more abundant in the day than at night. It is, however, most sensitive to unfavourable changes, and a run of 3 gallons a day from one tree may almost cease in a few hours, and then gradually recover itself. From this, it will be seen, that the yield given from day to day is uncertain, and that reliable statistics of produce are difficult to record. A continuous course of favourable weather tends to the largest production, a rising and falling supply reducing the total of the season.

The time at which the flow commences varies, not only with the season, but with the exposure and elevation of the ground, being earliest in warm and low situations. A thawing night is said to promote it, and it ceases during a south wind, and at the approach of a storm. So sensitive are the trees to aspect and climatic variations, that the flow of sap on the south and east sides has been noticed to be earlier than on the north and west sides of the same tree. There are generally 10 to 15 good "sap days" in the sap season, which continues on and off for about 6 weeks; after this, as the foliage develops, the saccharine matter is reduced, and the sap is said to be "sour," though a restricted flow still continues. Emerson, in his work on the 'Trees of Massachusetts,' referring to Michaux's observations, considers that the product of sugar depends also on the character of the previous summer, and that a season of plentiful rain and sunshine prepares the trees for an abundant harvest of sugar in the succeeding spring. Open winters are thought to cause the sap to be sweetest; and much freezing and thawing, to make it most abundant and of the best quality. The sap of isolated trees is richer in sugar than that of those which are massed together in the forest.

The best soil is a loose rich loam, and some prefer a limestone or slate formation to any other. The application of wood ashes has been found to increase the sugar yield. An elevated position is deemed superior, yet moist ground produces more sap, and according to the majority of growers more sap means more sugar.

In the Maple Bush, at Haysville, the produce of sugar was at the rate of 1 lb. to each 6 gallons of sap, and the average may be 1 lb. to 4½ or 5 gallons, but instances are given in which 1 lb. of sugar has been produced from 3 gallons of sap. With reference to the product of individual trees, in a good sap season, an average tree will run as much as 3 gallons of sap in a day, occasionally more, and produce about 4 lb. of sugar in the season; but Emerson records cases of the production of 10, 20, 33, and 43 lb. of sugar from single trees. Such weights are, however, altogether exceptional. The highest weight was produced from a draught of 175 gallons of sap from a single tree. The average quantity per tree would be 12 to 24 gallons in a season. Young trees under 25 years old are seldom tapped, the smaller trees scarcely paying for the trouble, apart from the debility it produces in them. Repeated tapping of the matured trees causes no apparent injurious effect on their vigour. In many instances, trees have been tapped for 40 consecutive years without harm, and it is said that both the quality and quantity of sap are visibly improved after the first tapping.

The trees are usually tapped at a height of 3 or 4 feet from the ground, with a ⅜ to ⅝-inch auger to a depth of 1 to 1½ inches, into which a perforated plug is driven, to lead the sap into the collecting vessels, preferably of tin and as light as possible; or a simple notch 1½ inches deep is cut with the axe. One to three taps are inserted in each tree, and these have to be removed in succeeding years to fresh places, generally alternated on opposite sides of the tree. The sap is evaporated either in iron caldrons or in shallow boilers, 6 feet long, 2½ feet wide, and about 8 inches deep. Those of copper are preferred to iron, as they are said to yield a whiter sugar. Care is taken to keep the boilers filled up with fresh additions of sap during evaporation, till the syrup attains a sufficient consistency, which is ascertained by its "breaking" or crystallising when dropped into cold water. The syrup is strained during evaporation, a small quantity of lime or soda being added to neutralise any free acids that are present, and a little white of egg or milk to clear it. After straining and skimming, the syrup is poured into pans or moulds to crystallise, and it may be further clarified by gently boiling in tapering cans, with a tap at the bottom, towards which the molasses gravitates, and is drawn off as the crystallised sugar sets.

Maple sugar is made not so much as an article of commerce, as for the home use of the producers; and the great bulk being consumed where it is made, it is difficult to arrive at anything like an accurate estimate of the total production. Emerson states that in Massachusetts alone between 500,000 and 600,000 lb. weight of sugar are annually produced from the maple, and he values it at 8 cents (4*d.*) a lb. In 1874, the price rose to 10 to 22 cents (5*d.* to 11*d.* a lb.). In Canada, at the beginning of April 1878, new maple sugar was selling at 10 to 11 cents (5*d.* to 5½*d.* a lb.), about the price of the best cane sugar; and in April 1882, the new season's sugar was quoted at 22 cents. A considerable proportion of the maple sap product is also preserved as syrup without crystallisation, and in this state it is used as sweet sauce, and for various culinary purposes.

The maple sugar crop of the year 1885 was officially estimated at Washington at about 550,000*l.* Maple sugar being a product of the forest, is chiefly confined to those regions of the interior where it is a convenient substitute for cane sugar. The sugar-cane can only be raised in the extreme southern latitudes of the United States, whereas the sugar-maple flourishes in the greater part of the inhabited sections; and though the sugar produced from it is inferior to that of the cane, yet it requires but little care, and is in some places cheaper.

In 1850, the production in the States was officially given at 15,520 tons; in 1855, at 14,500 tons; in 1858, at 24,000 tons; in 1860 and 1861, at an average of 27,000 tons; and in 1872 it was only 16,000 tons.

Maple sugar as an article of merchandise seems in a fair way of extinction. The maple forests of New England are being yearly cut down and converted into broom-handles. Thousands of splendid trees are annually felled. At the present rate of destruction, maple sugar will before long be unknown in the trade. The whole amount of maple sugar reported in the States was, according to the latest official agricultural statistics, about 40,000,000 lb. annually, but this was considered to be one-third below the actual quantity made. According to the last census returns, Vermont reported a yield of almost 10,000,000 lb. The production of New York is somewhat larger, but nothing compared with the difference in area. The only other States which return more than 1,000,000 lb. are:—Michigan, 4; Ohio, 3¼; Pennsylvania, nearly 3; New Hampshire, 2¼; Indiana, 1½; Massachusetts, a few pounds more than 1 million. The total production of maple molasses is 1,500,000 gallons, of which, Ohio returns nearly 400,000 gallons; Indiana, nearly 300,000; Kentucky, 140,000; and Vermont only 16,000 gallons. In addition to the large production of maple sugar in the States, the estimated quantity manufactured by the Indians living east of the Mississippi is 10,000,000 lb. per annum, and the quantity manufactured by those living west of the river is set down at 20,000,000 lb., but it is probably much greater. Of the American States, Vermont makes by far the largest quantity in proportion to its territory, and in some of the northern districts of this State the use of cane sugar is almost unknown. Two groves in North Harpersfield, Delaware County, New York, containing 4200 trees, yielded 7 tons of sugar. In 1876, the town of Harpersfield produced 200,000 lb. of sugar.

Many improvements have been made in the manufacture of maple sugar during the last few years. Formerly the highest attainments only resulted in the production of a fine muscovado-like sugar; but now, by improved processes, specimens are annually exhibited at the various agricultural fairs, vying with the most beautiful loaf sugar. This has been effected by greater attention to cleanliness in the preparation of the sap, and the improvements in draining and refining the sugar. A few years ago a premium was awarded by the Oswego County Agricultural Society, New York, to R. Tinkor, for the following improved method of preparing maple sugar. The sap is boiled in a potash caldron to a thick syrup; strained when warm, let stand for twenty-four hours to settle, then poured off, leaving back all that is impure. To clarify 50 lb., 1 quart of milk, 1 oz. of saleratus, and the whites of two eggs are well mixed; the sugar is then boiled again, until it is hard enough to lay upon a saucer, and finally allowed to stand in the kettle and cool. Very little stirring will prevent it caking in the caldron. For draining, a funnel-shaped tube, 15 inches square at the top, and coming to a point at the bottom, is used. The sugar is put in when cold; a tap is inserted at the bottom and a damp flannel cloth of two or three thicknesses is kept on the top of the mass. When drained, the sugar is dissolved in pure warm water, and clarified and drained as before.

In Canada, an incision or a hole is cut in the trunk a few feet from the ground; in the United States, the large branches are also punctured; a recipient is placed to catch the sap. To save transport, and to accelerate and simplify the manufacture, a rough shed is run up in the woods, and a large boiler is suspended over a brisk fire. The sap is thrown into it, and stirred with a wooden spade. When it boils, it thickens, exchanges its white colour for a golden yellow, and is poured out into wooden moulds, in which it solidifies on cooling; sometimes it is turned out into earthen pots, which bleaches it, but the quality is sacrificed to colour. Michaux states that three persons can attend to 250 trees, which would yield 1000 lb. of sugar, or about 4 lb. per tree. The period during which the sap flows from the trees is about six weeks, at a time when there is little to be done in farming or other operations. In the State of New York, there were in 1860 about 10,000,000 acres planted with the sugar maple, in the proportion of about 30 trees to the acre. The maple sugar product of Canada was stated in 1849 at 2,303,000 lb. for the Lower Province, and 4,161,000 lb. for Upper Canada. The census of 1851 gave the total at 10,000,000 lb., exclusive of what was used locally without being brought to market.

The following tables are given by Lewis S. Ware:—

TOTAL PRODUCTION OF MAPLE SUGAR IN THE UNITED STATES.

	lb.		lb.
1861	42,000,000	1870	28,443,645
1862	44,000,000	1871	30,756,000
1863	41,500,000	1872	31,682,000
1864	40,500,000	1873	32,157,000
1865	39,740,796	1874	33,044,200
1866	37,532,000	1875	43,197,930
1867	35,654,000	1876	43,288,080
1868	33,421,000	1877	41,000,000
1869	29,114,500		

There can be no doubt that the sugar supply from the true sugar maple is considerably supplemented by the saccharine sap of other species of this same genus, notably the white, soft, silver, or river maple (*A. dasycarpum*), the black maple (*A. nigrum*), and the swamp, red, or water maple (*A. rubrum*), besides in a lesser degree the cabinet maple (*A. macrophyllum*) and the vine maple (*A. circinatum*). In fact, most maple groves contain the three first named, interspersed among the sugar maples, and the sap is drawn from all four indiscriminately.

MAPLE SUGAR MANUFACTURED IN THE UNITED STATES.

State.	Sugar.		
	1870.	1860.	1850.
	lb.	lb.	lb.
Illinois	136,873	134,195	248,904
Indiana	1,332,332	1,541,761	2,921,192
Iowa	146,490	315,436	78,407
Kentucky	269,416	380,941	437,405
Maine	160,805	306,742	93,542
Massachusetts	399,800	1,006,078	795,525
Michigan	1,781,855	4,051,822	2,439,794
Minnesota	210,467	370,669	2,950
Missouri	116,980	142,028	178,910
New Hampshire	1,800,704	2,255,012	1,298,863
New York	6,692,040	10,816,419	10,357,484
Ohio	3,469,128	3,345,508	4,588,209
Pennsylvania	1,545,917	2,767,335	2,326,525
Tennessee	134,968	115,620	158,557
Vermont	8,894,302	9,807,781	6,349,357
Virginia	245,093	938,103	1,227,665
West Virginia	490,606	—	—
Wisconsin	507,192	1,584,451	610,976
United States	28,443,645	40,120,205	34,253,436

While in Nebraska no maple sugar is made, an article equally good is manufactured to a considerable extent from the ash-leaved maple, or box elder (*Negundo fraxinifolium* [*aceroides*]), growing on the banks of rivers from Pennsylvania to Carolina, which gives great promise as a sugar-producing tree. Some investigations made in Illinois, with reference to its value for sugar, are reported to decide—(1) That it produces more sap than the sugar-maple of equal size, half a gallon per day being obtained from a small tree of 3½ inches in diameter and 5 years old; (2) that the sap is richer in sugar—the yield of dry sugar averaging 2·8 per cent. of the weight of the sap; (3) that the sugar produced is in general whiter than that from the sugar-maple treated in the same way. These facts should recommend this tree to the early attention of all planters, especially in prairie regions.

MELON SUGAR.

CHAPTER XI.

THE preparation of syrup from the melon (*Cucumis Melo*) is fast assuming some importance in America. The long delta between the rivers Sacramento and San Joaquin, California, is submerged at high water, and therefore unfit for ordinary culture. But when reclaimed by embankments, it is exceptionally productive. Melons constitute a crop that never fails in this climate, and a factory has been erected on Andros Island to work up the melon juice derived from a large area at small expense for transport. Water melons with white pulp are preferred, and it is said that seed obtained from Hungary has yielded plants whose fruits surpassed any produced from native American stock. The plants are set out at distances of 12 feet apart one way and 6 feet the other. Their leaves cover the ground and kill all weeds before the latter have time to develop. Besides, they form an impenetrable mulching, which keeps the soil moist.

The juice of the melon is asserted to be free from those non-saccharine bodies which make the extraction of beet and cane sugars such an expensive matter. On the other hand, the sugar is uncrystallisable, and does not amount to more than 7 per cent. of the weight of the fruit. Usually the juice is only evaporated to such an extent as to afford a syrup, the ordinary yield being 1 gallon of syrup from 8 gallons of juice. The flavour of melon syrup is said to be much superior to that of common beet sugar. The cost of production is set down at $5\frac{1}{2}$ cents ($2\frac{3}{4}$*d.*) per lb., as against beet sugar at 7 cents ($3\frac{1}{2}$*d.*). One grower in California made 125 barrels of syrup in a single season several years since; and an excellent syrup was produced in South Carolina so long ago as previous to 1844. No doubt is felt that melons would thrive luxuriantly in New Jersey, Delaware, and Maryland. The same may be said of all sub-tropical lands possessing a sufficiently damp climate. It must also be remembered that the seeds afford a valuable oil, and that the pulp and seed-cake are excellent food for cattle; but as a source of commercial solid sugar, melons cannot compete with cane and beet in any country.

BEET SUGAR.

CHAPTER XII.

CULTIVATION OF THE PLANT.

The Plant.—The beetroot (*Beta vulgaris*) is a hardy biennial plant, indigenous to the south of Europe, long under cultivation in France, Germany, Belgium, Holland, Scandinavia, Austria, Russia, and England, and more recently established in Canada, the United States, and New Zealand. A great many varieties are known to cultivators, but the most important to the sugar-maker is the white Silesian, sometimes regarded as a distinct species (*B. alba*), and exhibiting several forms. Grown to perfection, the Silesian beet is pear-shaped, shows very little above ground, and penetrates about 12 inches into the soil, throwing out numerous rootlets. It has a white flesh, the two chief varieties being distinguished by one having a rose-coloured skin and purple-ribbed leaves, the other a white skin and green leaves. Both are frequently seen growing together in the same field, and do not exhibit any marked difference in their respective sugar-yielding qualities.

The selection of seed deserves the greatest attention on the part of the beetroot grower. Experience has show that roots rich in sugar transmit their richness to the next generation, whilst seed from light, ill-shaped roots, poor in sugar, produce similar inferior roots. In France, great trouble has been taken by Vilmorin, the celebrated seedsman, of Paris, in the selection and crossing of beet, and Vilmorin's improved beet, which by some is regarded as a special variety of the Silesian, is justly esteemed in France and Belgium for its sugar-yielding capabilities.

Great attention is also paid in the north of Germany, more particularly in the neighbourhood of Magdeburg, in Prussia, to the growing of superior beetroot seed. Owing to the fact that, in Prussia, the duty is levied on the roots, and not on the manufactured sugar, as in France, special care has been taken in Prussia to propagate roots rich in sugar, and speaking generally, beets grown in Germany yield 3 to 4 per cent. more sugar on an average than those raised in France.

M. Georges, President of Central Committee of French Sugar Manufacturers, in a recent letter to his colleagues, gives the result he had obtained from experiments made in conjunction with, and on the estates of, M. Fouquier d'Hérouel, beet grower in Vaux-sous-Laon. Weary of varying results, and the losses experienced by use of bought seed, the latter determined to raise his own seed, and hoped by a process of judicial selection to obtain a stock of roots which should be at the same time rich in sugar and specially adapted to the soil of his estate. Starting with the best roots he could obtain, and always choosing the best of each year's crop for the next year's seed, he considers he has obtained results which reward him for his trouble. This is an experiment which other beet growers may do well to copy.

Good sugar beets possess the following broad characteristics :—

1. They have a regular pear-shaped form, and smooth skin. Long, tapering, carrot-like roots are considered inferior to pear-shaped Silesian beets.

2. They do not throw out forks, or fingers and toes.

3. They have white and firm flesh, delicate and uniform structure, and clean sugary flavour. Thick-skinned roots are frequently spongy, and always more watery than beets distinguished by a uniform firm and close texture.

4. They weigh, on an average, 1½ to 2½ lb. apiece. Neither very large nor very small roots are profitable to the sugar manufacturer. As a rule, beets weighing more than 3½ lb. are watery, and poor in sugar; and very small roots, weighing less than ¾ lb., are either unripe or too woody, and in either case yield comparatively little sugar. As the soil and season have a great influence upon the composition of the crop, it is quite possible in a favourable season, and with proper cultivation, to produce beets weighing over 4 lb., which, nevertheless, yield a good percentage of sugar. Speaking generally, good beetroots in average seasons seldom exceed 2½ lb. in weight.

5. Good sugar-beets show no tendency to become necky, and their tops are always smaller than those of inferior beets. Corenwinder has shown that beets with large leaves are generally richer than those with small leaves, and he prefers the former for seed.

6. Good beetroots are considerably denser than water, and rapidly sink to the bottom of a vessel filled with water. The specific gravity of the roots affords a pretty good test of their quality, for the greater their specific gravity the richer in sugar they will be found, as a rule. A still better test than the gravity of the root is the specific weight of the expressed juice. The juice of good roots has usually a density varying between 1·06 and 1·07. When very rich in sugar, the gravity of the juice rises above 1·07, even reaching 1·078 in English-grown roots, indicating over 14 per cent. of crystallisable sugar. Juice poor in sugar always has a density below 1·060. Estimating the sugar-value of juice by its density has already been alluded to under Cane Sugar (see pp. 112–3).

7. In a well-cultivated soil, the roots grow entirely in the ground, and throw up leaves of moderate size. This tendency to bury itself in the soil is characteristic of good sugar-beet. But it may be greatly frustrated in thin stony soil, and in stiff clay, resting on an impervious subsoil.

At the Paris Exhibition of 1878, Vilmorin showed a fine collection of beets, with the proportions of sugar they were respectively capable of yielding. They form five classes :—

The white sugar beet of Silesia (Fig. 105), the mother-plant of all the white varieties now grown, which, by acclimatisation or degeneration, has developed an innumerable crowd of varieties, more or less suited for sugar-making ; such are the "Magdeburg," "Imperial" (Fig. 106), "Electoral," &c. The "acclimatised" (in France) white Silesian, is highly recommended, analysing 12 to 14 per cent. of sugar, and returning 45,000 and even 50,000 kilogrammes of roots, or 6500 kilogrammes of sugar, per hectare (say 39,600 to 44,000 lb. of roots, or 5720 lb. of sugar, per acre).

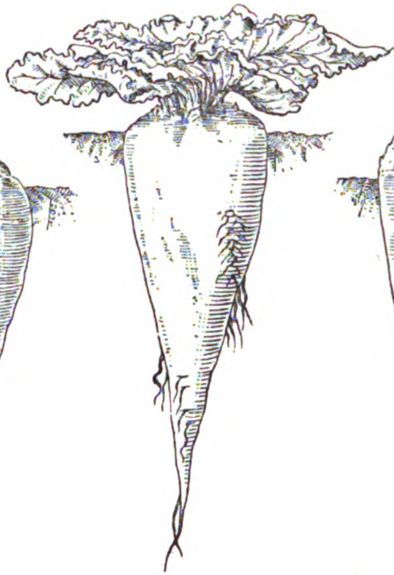
The "green-neck" of French culture (Fig. 107) is more gross, better formed, and smoother, than the preceding. It will give 60,000 kilogrammes to the hectare (52,800 lb. per acre), and titrates 11 to 14 per cent. of sugar, or a mean yield of 7800 kilogrammes of sugar per hectare, sometimes rising to 8300 (say 6864 to 7304 lb. per acre). This sort is less cultivated now, preference being given to the following :—

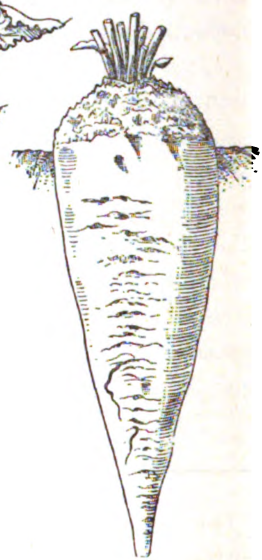
The "red-neck" (Fig. 108) is very vigorous, a heavy cropper—70,000 to 75,000 kilogrammes per hectare (61,600 to 66,000 lb. per acre),—of regular form, and titrates 10 to 13 per cent. of sugar, equal to 8400 kilogrammes of sugar per hectare, occasionally even 8800 (say 7392 to 7744 lb. per acre) ; the foliage is vigorous and abundant, the neck is small, and it stores well ; it is the most highly esteemed of all kinds by French growers.

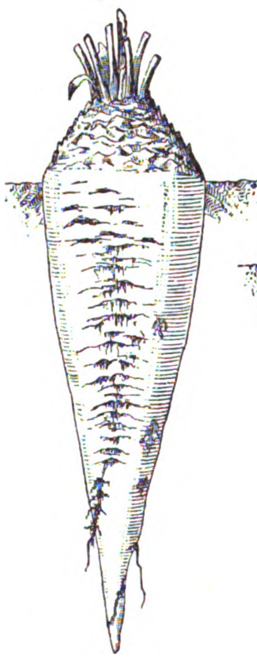
The "grey-neck" or "northern rose-grey" (Fig. 109) is the most productive of roots, but least rich in sugar, and is consequently the last in the sugar-maker's estimation.

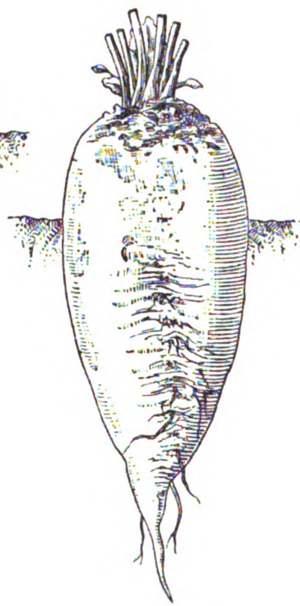
"Vilmorin's improved white" (Fig. 110), educated directly from the Silesian white, is the richest of all in sugar-yield, containing 15 to 18 per cent., and the juice is extremely pure ; but the return per acre is small, though it has been raised of

FIG. 105. FIG. 106. FIG. 107.









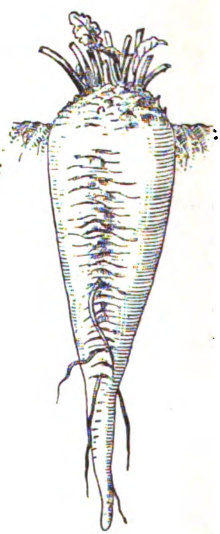


FIG. 108. FIG. 109. FIG. 110.

Types of Sugar Beets.

late years to 45,000 kilogrammes per hectare (39,600 lb. per acre). It is the most highly esteemed in those countries (Germany and Russia) where the duty is levied on the roots, but is little grown in France.

The comparative values of the chief sorts will be more readily seen from the annexed table, premising that the figures here given are not attained on a working scale :—

Name.	Gross yield per acre.	Sugar in 1 gallon of juice.	Sugar yield per acre.	Working yield of Sugar. per ton.	Working yield of Sugar. per acre.
	lb.	lb.	lb.	lb.	lb.
German	50,776	1·54	6925	226	4541
Green-neck	67,936	1·42	8496	177	4775
Rose-neck	65,560	1·47	8562	186	4835
Grey-neck	72,072	1·32	8333	152	4417
Vilmorin's	36,168	1·90	6103	296	4144

The following figures show the results of a series of comparative experiments as to the value of different varieties of sugar-beet grown in Saxony, and as far as possible under the same conditions of manure, &c. The plants were grown in rows of 11 inches wide :—

Variety of Beet.	Yield expressed in Centners per Morgen.	Sugar in the Beet.	Sugar in the Juice.	Coefficient of Purity.	Yield of Sugar expressed in Centners per Morgen.
		per cent.	per cent.		
Kl. Wanzlebener Original..	228	11·7	12·7	84·0	26·68
Dippe's Wanzlebener Nachzucht	218	12·0	13·6	85·0	26·16
Kl. Wanzlebener Möhringen	216	11·4	12·7	83·1	24·62
Bestehorn's Imperator ..	210	11·2	12·3	82·4	23·52
Vilmorin blanche améliorée (Original)	183	12·9	14·4	85·8	23·61
Simon Legrand de mères blanches	241	11·7	12·7	83·4	28·20

(Märcker.)

Durran affirms that beets which run to seed in their first year are less valuable than those which are biennial. This running to seed is the result of certain external causes, e.g.

beets sown earlier in the year exhibit this tendency more strongly than those sown later. It may also result from a hereditary disposition of the plant. The sugar-beet is a biennial, as the result of cultivation ; in the natural state it is an annual. Hence this tendency to run to seed in the first year on the part of the sugar-beet may be considered as a case of atavism, i. e. a return to the characteristics of the primitive race. It is probable that this can be diminished, or even avoided, by a rational selection, i. e. by the elimination of individuals which have the tendency to seed in the first year. The following facts have been noticed :—(1) The exposure of young plants to cold night air favours this atavism ; (2) plants from small seeds exhibit this tendency more strongly than those from large seeds ; (3) variation in the depth of sowing does not appear to have much influence ; (4) any check on the growth of the plant, at whatever period of its development, increases the atavic tendency ; (5) by a continuous series of selective experiments, always choosing seed from annuals, in five years an entirely annual crop was obtained, from which it has been concluded that the abnormal phenomenon of sugar-beets becoming annual is reproduced constantly and regularly. Certain plants, in their second year even, do not run to seed, but develop just a tufted ring of leaves. These plants the growers call *trotzer*. Seed from these plants, instead of producing new *trotzer*, give rise to normal triennial sugar-beets, which are as good and as rich in sugar as those obtained from normal seed.

Composition of the Roots.—Internally, the beetroot is built up of a number of concentric rings, formed of a much larger number of small cells, each of which is filled with a juice consisting of a watery solution of many bodies besides sugar. These include several crystalloid salts (most of which are present in minute traces only), such as the phosphates, oxalates, malates, and chlorides of potassium, sodium, and calcium, the salts of potash being by far the most important ;

and several colloid bodies (albuminous [nitrogenous] and pectinous compounds): as well as a substance which rapidly blackens on exposure to the air.

The sugar present in fairly ripe beets is crystallisable, and, when perfectly pure, identical in composition and properties with crystallised cane-sugar; but it is more difficult to refine this sugar so as to free it from the potash salts, and commercial samples have not nearly so great sweetening power as ordinary cane-sugar. Beetroots do not contain any uncrystallisable sugar, and the molasses produced in beet-sugar manufactories is the result of the changes which cannot be entirely avoided in extracting the crystallisable sugar from the roots.

The saccharine values of several kinds of beet grown on the farms of M. Simon-Legrand, at St. Quentin, are shown in the following analyses, by Duror, and indicate what progress can be attained by careful selection :—

	Sugar per cent.
Blanche améliorée	15·00
Rose améliorée	14·776
Blanche No. 1	14·825
Rose No. 1	14·027
Rose No. 2	12·55
Blanche No. 2	11·565
Rose No. 2, lisse (smooth)	11·582
Collet vert No. 3, améliorée	10·473
Jaune de Hesbaye	11·50
Blanche rosée	11·025
Blanche à collet vert	12·787
Rose du Nord	9·76
Gris rosé	10·256

The following selected analyses by Voelcker, of roots grown in various parts of Great Britain in 1868–69–70, are well calculated to give information as to the fitness of the English beet as raw material from which sugar may be profitably extracted on a manufacturing scale.

These analyses may be taken as fairly representing the composition of English sugar-beets of good quality. It will be noticed that the Suffolk roots, in 1868, contained from

9¾ to 11 per cent. of sugar, in round numbers. In the second table are placed together the results of analyses made of Silesian beets, grown in 1868, in the counties of Norfolk, Berkshire, and Buckinghamshire.

The roots grown in Norfolk, Berkshire, and Buckinghamshire contained from 9 to 11 per cent. of sugar, and thus were well suited for the manufacture of sugar.

COMPOSITION OF SILESIAN SUGAR-BEETS GROWN IN THE NEIGHBOURHOOD OF LAVENHAM, SUFFOLK.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Description of root ..	Green top, white skin.	Red top, rose-coloured skin.	White pear-shaped root.	Long red root.	Long red root.	Pear-shape white root.	Small red top.	Pear-shape white root.
Weight of root	2¼ lb.	2lb.4½oz.	1¼ lb.	2 lb.	1¾ lb.	2 lb. 5 oz.	1lb.4¾oz.	2 lb.12¼ oz.
Specific gravity of juice	1·0637	1·0689	1·058	1·0612	1·0628	1·0589	1·0659	1·0643
At a temperature of ..	64° F.	64° F.	62° F.	62° F.	..	..	58° F.	58° F.
Moisture	83·11	82·72	83·03	83·43	82·70	82·27	81·76	83·34
Albuminous compounds*	1·25	1·44	1·71	1·53	1·23	1·08	2·13	2·12
Crude fibre (pulp) ..	3·43	3·38	4·31	3·49	3·60	3·73	3·77	3·04
Crystallisable sugar ..	10·51	10·94	9·31	10·04	10·72	11·14	10·55	9·74
Pectin, colouring matter, &c. ..	0·63	0·45	0·60	0·50	0·68	0·74	0·70	0·52
Mineral matter (ash)	1·07	1·07	1·04	1·01	1·07	1·04	1·09	1·24
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	0·200	0·231	0·275	0·245	0·197	0·173	0·341	0.340

COMPOSITION OF SILESIAN SUGAR-BEETS GROWN IN NORFOLK, BERKSHIRE, AND BUCKINGHAMSHIRE.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Kind of root	Small white.	Large white.	Red.	White.	Red.	White.
Weight of root	1 lb.	2 lb.	1lb. 13oz.	2 lb. 4 oz.	2 lb. 9 oz.	2 lb. 14¾ oz.
Specific gravity of juice	1·059	1·0558	1·0558	1·0465	1·0659	8·0588
At a temperature of ..	60° F.	60° F.	64° F.	64° F.	62° F.	62° F.
Moisture	84·32	85·22	85·23	86·71	82·35	83·93
Albuminous compounds*	1·28	1·51	1·70	2·13	1·55	1·76
Crude fibre (pulp) ..	3·51	4·11	2·92	3·13	3·25	3·21
Crystallisable sugar ..	9·42	7·46	8·86	6·67	11·09	9·31
Pectin, &c.	0·48	0·55	0·47	0·50	0·52	0·63
Mineral matter (ash) ..	0·99	1·15	0·82	0·86	1·24	1·16
	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	0·206	0·243	0·273	0·341	0·248	0·283

ANALYSIS OF LAVENHAM BEET PULP.

Moisture	70·11
*Albuminous matter	2·25
Sugar	3·39
Mucilage, &c.	1·93
Digestible fibre	15·13
Woody fibre	5·32
Ash (mineral matter)	1·87
	100·00

* Containing nitrogen .. .. 0·361

Climate.—The mean temperature of the Continental beet-growing districts, and of those localities in England where beets may be successfully cultivated for sugar-making purposes, ranges from about 16½° to 18° C. (62° to 65° F). The formation of the sugar is favourably influenced not so much by heat as by dry weather and unclouded sky during the autumnal months. Hence the root succeeds far better in the north of France and of Germany, than in central France or southern Germany, where the summers are very much warmer and longer. Hence also the prospects of remunerative culture of the plant in Canada and New Zealand, and the failure attending efforts to introduce it into Australia.

Observations show that a bright and dry August favours an increased secretion of sugar in roots to a far greater extent than a hot summer; and nothing is so conducive to heavy crops as an abundance of rain distributed over the first 2 months' growth of the plant. It would thus appear that the eastern, south-eastern, and northern counties of England, together with many localities in Scotland, and a portion of Ireland, are, so far as climate is concerned, well suited to the cultivation of beet as a sugar-yielding crop.

Soil.—Although beet will grow in a great variety of soils, all are not equally well adapted to grow this crop to perfection. The best soils are those in which neither clay, nor sand, nor lime greatly preponderates, but which contain these constituents, together with a fair proportion of organic matter, so mixed together that the land is neither too stiff nor too light, and crumbles down, after being ploughed, into a nice friable loam. There should be a sufficient depth of soil, for all soils incapable of being cultivated to a depth of at least 16 inches are unsuited for the growth of sugar-beet, which, unlike the common yellow globe mangold, grows almost entirely underground, and therefore cannot be cultivated with advantage in shallow soil. The subsoil should be thoroughly well drained, and be rendered friable by autumn cultivation and free admission of air. A deep friable turnip-loam, containing a fair proportion of clay and lime, on the whole appears to be the most eligible description of land for sugar-beets. Lime is a very desirable element, for, in land deficient in lime, beets are liable to become fingered-and-toed. When well-worked, clay soils, especially calcareous clays, are well adapted for beet cultivation, provided they are properly drained, and of sufficient depth. On such soils, a succession of beetroots may often be grown without manure, for many clays abound in all the elements of fertility. These, however, require to be rendered available for the use of plants. The most effectual means of thus providing plant-food are deep autumn ploughing, stirring of the subsoil, and similar mechanical operations, all of which tend to bring into action the fertilising materials which lie dormant in many clay soils in practically inexhaustible store, and which, at the same time, improve the texture of the land, rendering it more friable and more readily penetrable by the roots.

Many persons entertain the mistaken notion that clay soils are not suited for the cultivation of beets, and that the crop will only flourish in light, sandy soils. Some of the finest crops of beet are grown on clay soils, and some of the worst crops on light sandy land. It is true, a badly-worked, half-drained clay soil does not raise beet to perfection; but even stiff clays, when well drained, may be brought into a fine, friable condition, whcn the land is broken up by the cultivator early in autumn, left in ridges as roughly as possible during the winter, and not touched until the season of sowing the seed arrives, when it suffices to pass a pair of harrows over the land. The land in general is much improved by deep autumn cultivation and exposure to the air in a rough state; and, according to the testimony of the most successful heavy-land farmers, it is far better never to touch the land after it has been put roughly into ridges, than to give it a second ploughing in spring.

On light, sandy soils, beetroots grow well, if the land is in a good agricultural condition; sandy soils, however, are poor in plant-food, and not well adapted for the cultivation of sugar-beets. It is true, such poor, sandy soils may be enriched by the application of dung or other suitable manures; but as it is not desirable to grow sugar-beets on newly-manured land, poor sandy soils, which will not yield a moderate crop without manure, are not nearly so suitable for beets as soils which contain naturally a larger proportion of the mineral elements which enter into the composition of the ash of beet.

Peaty soils and moorland produce watery spongy roots, poor in saccharine matter; they ought to be avoided, as well as all soils which are either too dry, like the thin gravelly soils resting on pure silicious gravel sub-soils, or too wet and cold, like many of the thin soils which are found resting on impervious chalk marl.

Speaking generally, the best soils for sugar-beet are precisely those on which other root crops can be grown to perfection; that is, land which is neither too heavy nor too light, which has a good depth, is readily penetrated by the roots, and naturally contains lime as well as clay, and sand as well as organic matter, in such proportions as in good friable clay-loams.

An analysis of the soil should always be made previous to planting it with a new crop. This is particularly necessary with the sugar-beet, as the salts presented to it in solution in the soil will pass with the juice, and greatly interfere with the processes of sugar manufacture from such juice. Certain soils may be at once indicated as unsuitable for sugar-beet growing on this account; they are clover land, recent sheep pastures, forest land grubbed during the preceding 15 years, the neighbourhood of salt works, volcanic and saline soils of all kinds.

Manures.—If possible, sugar-beets should be grown with as little farm-yard manure as possible; and when dung has to be used, as in the case of very poor soils, care should be taken to apply it in autumn, or as early as possible during the winter months.

Heavy dressings of common farm-yard manure, such as are generally applied to land upon which mangel-wurzel is grown for feeding purposes, must not be employed if the land is intended for sugar-beets.

The effect of heavy dressing of dung, and of all animal nitrogenous matters, as well as of ammoniacal salts, is to produce abundance of leaves, and big but watery and often hollow roots, which latter are not only comparatively poor in sugar, but also contain nitrogenous matters, which greatly interfere with the extraction of sugar in a crystallised state.

Common salt, and saline manures in general, although useful when used in moderate doses, say at the rate of 2 or 3 cwt. per acre on light soils, should be avoided on the majority of soils, for experience has shown that sugar-beets grown on soils highly manured with common salt, produce roots whose expressed juice is largely impregnated with salt, a constituent which is dreaded by the manufacturer of sugar even more than the albuminous impurities of the juice.

Peruvian guano, sulphate of ammonia, and nitrate of soda require to be used with discrimination. If the land is in a good agricultural condition, in which it always contains a sufficient amount of available nitrogen to meet the requirements of the crop, neither guano nor sulphate of ammonia should be used as a manure for beets. It is true guano and sulphate of ammonia largely increase the weight of the produce per acre; but at the same time, it has to be borne in mind that heavy crops, produced by the aid of guano and purely ammoniacal manures, generally are poor in sugar. Beets grown with an excess of guano or sulphate of ammonia, moreover, furnish a juice that presents much difficulty to the sugar manufacturer.

If the land is very poor naturally, it will be found necessary to manure it; and if farm-yard manure cannot be obtained in the required quantity, and be applied in autumn, it may be desirable to use some guano or sulphate of ammonia. In that case, 3 to 4 cwt. of Peruvian guano, or 2 cwt. sulphate of ammonia, mixed with 2 cwt. of superphosphate of lime, per acre, may be sown broadcast in autumn; and when the seed is sown in spring, 2 cwt. more of superphosphate may be drilled in with it.

Superphosphate of lime and bone-dust, or the refuse bones of glue-makers, are excellent manure for sugar-beets, and other phosphatic manures are suitable for every description of land; they never injure the quality of the beet crop, like the indiscriminate use of ammoniacal manures; on the contrary, superphosphate decidedly favours early maturity, and for this reason many would never sow a crop of beets without drilling in at the same time 2 to 3 cwt. of superphosphate.

On light soils, in which potash is often deficient, the judicious use of potash salts has been found serviceable. The salts of potash, however, should not be used by themselves, but always in conjunction with superphosphate and phosphatic guanos; for such soils, 3 cwt. of superphosphate, 2 cwt. of crude sulphate of potash, and 1 cwt. of sulphate of ammonia, or 1½ cwt. of Peruvian guano, have been found very useful for common mangolds, and no doubt this mixture would be equally good for sugar-beets.

Analyses of sugar-beet ash show that this crop takes from 1 acre of land :—

	Lb.
Potash	161·92
Nitrogen	105·60
Phosphoric acid	40·48
Lime, &c.	31·68

In illustration of the injurious consequences of a heavy spring dressing of dung for sugar-beets, the annexed analyses may be given, representing the composition of 2 very large white Silesian beets grown in Suffolk :—

	A.	B.
Weight of root	11 lb. 6 oz.	6 lb. 8 oz.
Specific gravity of juice at 18° C. (165° F.) ..	1·0431	1·0553
Moisture	92·58	88·13
Albuminous compounds*	1·40	2·16
Crude fibre (pulp)	1·73	2·74
Crystallisable sugar	2·22	4·82
Pectin, &c.	0·47	0·44
Mineral matter (ash)	1·60	1·71
	100·00	100·00
* Containing nitrogen	0·225	0·347

According to the observations of Ferdinand Knauer, the alpha and omega of beet-growing is to get the roots ripe ; and from this point of view the manure has an important influence, especially Chili saltpetre and Peruvian guano. Rapidly developed under the influence of these manures in the spring, the plant is manured in September ; but with farm manures and a dry summer, the manure remains undecomposed until the autumn ; then with moist weather the root quickly develops, forms luxuriant leaves, attains a great weight, but becomes saline, rich in pectin, and poor in sugar. If, however, the farm manure be added in the autumn, the crop is increased without such a serious falling off in quality. Professor Märcker, of Halle-sur-Saale, confirms these views.

As to the influence of potash salts on beet-roots, Professor Märcker has arrived at the following conclusions by collecting and averaging the results of many authors. Most cases indicate an increase in quantitative yield, but a falling off in quality of the crop, and this is especially the case with potash containing chlorides. The percentage of sugar is perceptibly lowered. This latter evil effect may, however, be diminished by manuring in the autumn. Cases have been known in which the saccharine richness has been improved by the use of potash salts. Its use is recommended for soils yielding very poor beets, for marshy soils, and for soils rich in humus.

Sowing.—The best time for sowing beetroot is the beginning or middle of April. If sown too early in the spring, the young plants may be partially injured by frost; and if sown later than the first week in May, the crop runs the risk of requiring to be taken up in autumn, before it has had sufficient time to get ripe.

From 10 to 12 lb. of seed, or about double the quantity of seed usually sown for common mangolds, is the quantity of seed required per acre. Much more seed is sown, because sugar-beets are planted more closely than common mangolds. As regards the width between the plants, generally speaking, the distance between the rows and from plant to plant should not be less than 12 inches, nor greater than 18 inches.

Should the young plants be caught in spring by a night's frost, and suffer ever so little, it is best to plough up the crop at once and to re-sow, for plants attacked by frost are certain to run to seed, and beets that have run to seed are practically useless for the manufacture of sugar.

Like root-crops generally, sugar-beets require to be frequently horse- and hand-hoed. As long as the young plants are not injured by hand-hoeing, the repeated application of the hoe from time to time is attended with the greatest benefit to the crop. It is advisable to gather up the soil round each plant, in order that the head of each root may be completely covered with soil. Champonnois' researches point strongly to the advantages to be derived from planting in ridges, by which the supply of air to the roots is greatly facilitated.

On the Continent, minute attention has been given to a study of the conditions best calculated to ensure the roots possessing the characters previously described as being the most desirable from a sugar-maker's point of view. They are chiefly as follows :—

1. Not to sow on freshly-manured land. The manures should be applied before the previous winter, so as to become well mixed with the earth. It is eminently preferable not to manure the land at all for the beetroot crop, but to manure heavily for wheat in the preceding year, and let the beet follow as a second year's crop.

2. Not to employ strong forcing manures, such as nitrates, and especially not to apply liquid or pulverulent manure during growth. Sheep must never graze on beetroot land.

3. To use seed from a variety rich in sugar.

4. To sow early, in lines 16 inches apart at most, the plants being 10 to 11 inches from each other. There will thus be 38,000 beets on an acre, weighing 21 to 28 oz. each, or 52,800 to 70,400 lb. of roots per acre.

5. To weed the fields as soon as the plants are above ground, without waiting for them to be choked ; to thin out as early as possible, and with great care ; and to weed and hoe often, till the soil is covered with the leaves of the plants.

6. Never to remove the leaves during growth.

7. Finally, not to take up the roots, if it can be avoided, before they are ripe, the period of which will depend upon the seasons.

According to Grouven, the depth at which the beet-seed is sown has a great influence on the plant, the failure in the harvest being due to this. Seeds were sown at depths from ½ to 3½ in. At ½ in. in five days the first plant appeared, and in sixteen days there were 24 plants, whilst at 3½ in. there were only seven plants in sixteen days, it taking ten days for the first plants to appear. Walkhoff recommends from ½ to 1 in., whilst Achard advocates a depth of an inch, or half an inch. These limits, however, are not absolute, but depend on the nature of the soil. Fühling recommends that the seed be sown as superficially as possible, but adds that if the soil be light, forming only a thin crust, and drying quickly after rain, the seed must be planted more deeply than if the soil be heavy. These results are confirmed by Wolsey. The distance between the seeds is a more important factor in obtaining a good harvest, and this also varies with the nature of the soil, and according to Achard it seems that the distance is inversely proportional to the richness of the soil, and this has been confirmed by other observers. Pagnoul has shown that the percentage of sugar is increased by shortening the distance, and whilst the sugar increases the salts decrease. Petermann has shown that all things being equal, lessening the distance between the roots, increased the richness in sugar, and often the weight of the harvest; but, on the other hand, he shows that the opposite effect is produced by passing a certain limit. The space required by each root varies from 15 × 11 to 15 × 10 in., and by reducing it to 13 × 7½ in. the total weight was reduced 37·5 per cent. in one case, and 46 per cent. in another. The distance 15 × 10 causes a diminution in the proportion of water in the root, and so increases the density of the juice, and sometimes the proportion of sugar. The coefficient of purity of sugar, i. e. the ratio of the quantity of sugar to the total soluble matter, is not changed. Schultze planted three crops of beetroot, the distance between the lines being 20, 16, and 12 inches, whilst the distance between the roots was in every case 12 in. The ground was manured with various quantities of sodium nitrate, superphosphate, animal charcoal, Ohlendorf guano, and ammonium sulphate. From the results he concludes that the richness in sugar is highest when the smallest space is given to the roots. His results also show that the injurious effect of sodium nitrate is lessened by lessening the space for each root. The maximum weight of harvest, however, is attained with a distance 16 × 12 inches, there being no increase when the distance between the lines is reduced to 12 inches.

Good seed may be bought of first-class seedsmen, or may be home-raised. In the latter case, the means to be adopted are as follows. Choice is made of the best roots which show least above ground; these are taken up, placed in a cellar or a *silo* (subterranean store), replanted in good soil, and allowed to run to seed. This seed is already good; but it may be still further improved by sowing it in a well-prepared plot possessing all the most favourable conditions; the resulting plants are sorted, set out in the autumn, put into the cellar, and in the spring, before transplanting, those of the greatest density, and which will give seeds of the best quality, are separated. These are transplanted at 20 inches between the rows and 13 inches between the feet, which are covered with about 1½ inches of earth. Finally, they are watered with water containing treacle and superphosphate of lime, as recommended by Corenwinder.

Harvesting.—Sugar-beets must be taken up from the soil before frost sets in, or they suffer. When the leaves begin to turn yellow and flabby, they arrive at the stage of maturity, and the crop should then be closely watched, that it may not get over-ripe. If the autumn is cold and dry, the crop may be safely left in the ground for a week or ten days longer than is needful; but should the autumn be mild and wet, it is highly desirable to remove the roots as soon as possible after they arrive at maturity, for if left in the soil they are apt to throw up fresh leaves, and nothing does so much injury to beets as a second growth of tops after the roots have become ripe. Particular attention, therefore, should be paid by the grower of sugar-beets in watching the ripening of the crop. It is a good plan to test the gravity of the expressed juice. A root or two may be taken up at intervals, and be reduced to pulp, by grating it on an ordinary hand-grater. By pressing the pulp through calico, the juice is obtained, which is to be tested with an ordinary float used for ascertaining the density of liquids heavier than water. As long as the gravity of the juice continues to increase, when the roots are tested from time to time, the crop should be left in the land. The juice of beets of good sugar-yielding qualities has a specific gravity of about 1·065, and when rich in sugar it rises to about 1·070.

Immature roots cut across with a knife rapidly change colour on the surface laid bare by the knife, turning first red, then brownish, and finally quite dark. If the newly-cut slices of beet turn colour on exposure to the air, the ripening process is not completed; but if they remain for some time unaltered, or turn only slightly reddish, it may be assumed that they are sufficiently ripe to be taken up. By this simple means, the state of maturity may be ascertained with sufficient accuracy for practical purposes. The crop should be harvested in fine, dry weather. In order that the roots recently removed from the ground may part with as much moisture as possible, they are best left exposed to the air on the land before they are stacked, but they should not be left longer exposed to the air than a few days, and need to be guarded against the direct rays of sunlight. Perhaps the best plan is to cover them loosely with their tops in the field for a couple of days, and then to trim them, and at once to stack them.

Storing.—For storing roots, especial care should be taken to prevent their germinating and throwing out fresh tops, which is best done by selecting a dry place for the storage ground. The roots may conveniently be piled up in pyramidal stacks, about 6 feet broad at their base, and 7 feet high. At first, the piles or stacks should be but thinly covered with earth, in order that the moisture may readily evaporate, and subsequently, when frosty weather sets in, another thick layer of earth, not exceeding 1 foot in thickness, may be placed on the stacks. This is essentially the same method as is generally adopted in this country for storing potatoes and mangold.

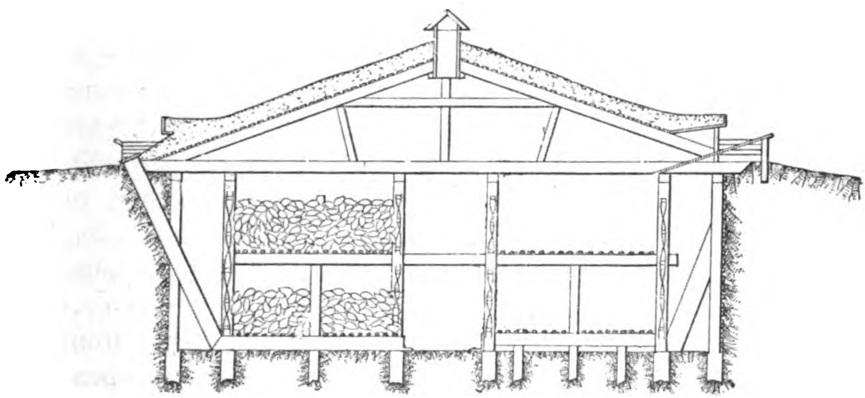
In continental Europe and in Canada, extra precaution is necessitated by the more rigorous climate. In Southern Russia, the plan illustrated in Fig. 111 is sometimes used. The beets are disposed completely below the surface of the soil, in a trench dug with sharply-sloping sides. At a depth of about 15 inches from the bottom, is an openwork floor made of rods, on which the beets are piled to within a few inches of the level of the exterior soil. On the top, and following the apex of the heap, is laid a triangular ridge-piece *a*, for the purpose of keeping the heap and the covering apart, and thus facilitating evaporation. The whole is covered with a layer *b* of straw and fine earth, the thickness of which is varied according to the indications of the thermometer *c* placed in the centre of the mass of roots. Between the floor of the trench and the openwork floor, is an empty space *d*, which is made to communicate with two vertical channels leading to the external air, thus providing a sort of ventilation. The outlets of the ventilating channels can be opened and closed at will, thus aiding in maintaining the desired conditions within.

FIG. 111.

Russian Beet Silo.

The Russians also often employ regular cellars, as shown in Fig. 112. The structure consists of two storeys, and is covered with a bed of earth. Each storey is furnished with a floor of hurdles or open planking, on which the beets are piled to the depth of about a yard. Lateral passages facilitate ventilation, and openings in the roof permit the heated air to escape. The cost of erecting these cellars is rather heavy,

FIG. 112.



Russian Beet Cellar.

but, on the other hand, there is a great saving of labour in storing the beets, as it suffices to simply pile them up on the floors. Moreover, the arrangement permits of the actual examination of the contents of the cellar, beyond the mere indications of a thermometer, and enables any portion to be removed, even during snowy weather.

Diseases and Enemies.—The insects injurious to beet are principally, the beet carrion-beetle, the beet fly, the silver Y-moth, and a fungus. The beet carrion-beetle (*Silpha opaca*) was considered to feed only on putrid matter, till 1844, when it was found both on beet in France and on mangold in Ireland. The leaves of the plants were gnawed away till the fibres alone remained, but the roots escaped. The egg is commonly laid in putrid matter. The attacks of the grub last from about the third week in May to the end of June; no damage seems to be done by the summer brood of beetles. Remedies are to be found in (1) sprinkling the plants with a mixture of 1 bushe of gas-lime, 1 bushel of quick-lime, 6 lb. of sulphur, and 10 lb. of soot, made into a fine powder, and applied at morning while the dew is on the leaf, this quantity sufficing for about 2 acres; (2) the substitution of superphosphate of lime for farmyard dung; (3) the application of dung, when used, in the autumn instead of the spring.

The beet or mangold fly (*Anthomyia betæ*) damages the crops by the attacks of its voracious legless maggots, which feed on the pulp of the leaves, and reduce them to a dry skin. Their worst effects are seen on peat and fen lands, and in wet seasons. A dressing of superphosphate seems to be effectual.

The silver Y-moth (*Plusia gamma*), extending from Abyssinia to Greenland, and met with in China, Siberia, and North America, occasionally does great damage to the continental beet-crops while in the caterpillar state. It is large, and consumes the leaves very rapidly. Dustings of caustic lime, soot, or salt, as well as drenchings of liquid manure or simple water, are beneficial.

The phenomenon known as the *fatigue betteravière* is a disease which was noticed in Saxony about 1860, at which period much potash was being exported in the form of molasses, and the *fatigue* was naturally attributed to a lack of this substance. The addition of potash salts was tried, but without any beneficial effect. In 1860 Schacht noticed filiform worms on the hairs of the roots, which he found to be nematodes. Kuhn and Liebscher have studied the phenomenon from this new aspect, and find that the intensity of the disease is proportional to the number of nematodes. Thus the *fatigue* can no longer be directly attributed to the mere absence of potash. But as the result of numerous experiments, Prof. Märcker has come to the following conclusions:—(1) When the *fatigue* is not too intense, good results may be obtained from the use of potassium salts, these latter strengthening the roots, and so enabling them the better to withstand the attacks of the nematodes. (2) It is probable that roots obtained from fields suffering from the nematodes, and possessing the property of keeping in only a weak degree, may be improved in this respect by addition of potash. (3) It is doubtful if very intense *fatigue* can be overcome by the use of potassium salts.

The symptoms of this disease are very marked. The leaves, especially the young ones, become covered with a grey lilac powder, then dry off, and die. This is followed by death of the plant in the case of most of the roots attacked. The lilac powder is due to the conidia of a fungus (*Peronospora*). This beet *Peronospora* has been studied for some years by Prof. H. Schacht, of Bonn, and has been called by Fuckel *P. Schachtii*. It has already caused great havoc in various parts of Germany, but has not long been known in France, and is not included in Cornu's list of French *Peronosporeæ*. Like all *Peronosporeæ*, it has a mycelium which develops in the interior of the nourishing plant—ramifying, but without transverse partitions. It has, moreover, suckers which penetrate into the cells and ramify in tufts in their interior. In the case of *P. Phytophthora*, which infests the potato, one cannot find any oospores or hibernating spores, and it is probable that there are none. In the potato the mycelium winters in the tubercle, and the parasite can thus perpetuate itself from year to year without hibernating spores. In the beetroot *Peronospora*, Prillieux has found the oospores in abundance on the dead leaves of the affected beets. He says they resemble those of the *Peronospora* of the vine. They are globular, and have a thick white integument. The oogonium which surrounds them is slender. Thus it is by the leaves that the disease is propagated from year to year, and care should be taken not to allow diseased leaves to get amongst the manure used for preparing the ground for a new crop.

CHAPTER XIII.

EXTRACTION OF THE JUICE.

Purchase.—In the beet-sugar industry it seldom or never happens that the manufacturer grows the whole quantity of beet which he works up, though he almost invariably raises a considerable proportion. The basis upon which the manufacturer purchases from the grower is obviously a matter of paramount importance to both. It is to the interest of the manufacturer to base his payment upon the quantity of sugar delivered to him in the form of roots, rather than upon the weight of the roots themselves, as it has already been shown that large, and therefore heavy, roots contain proportionately less sugar and more saline impurities than those of less weight and size. To buy and sell on the weight of the roots is unfair to both, as taking no account of the quality of the article, and removing all inducement to the cultivator to grow the most highly saccharine kinds of root. But to make an average analysis of a crop of beet would be a long and very inconvenient process. It has been found, however, that the juice of the beet is denser according as it is richer in sugar and poorer in other salts. It has therefore been customary to base the value on the density of the juice, taking for foundation a density of 1·055, called 5·5 degrees. and raising the price proportionally above this figure. It has in like manner been suggested that the price should be subject to a corresponding reduction for juice below 5·5°, but this is generally deemed unfair to the grower, as it would only arise through unpropitious seasons and other causes not within his control.

The "Société Centrale d'Agriculture du Pas-de-Calais" proposes the following scale:—

Density.	Sugar Yield.	Price	
		Per 1000 Kilos.	Per Ton
sp. gr.	per cent.	frs.	*s.* *d.*
1·045	8	16	12 10
1·050	9	18	14 6
1·055	10	20	16 2
1·060	11	21	17 0
1·065	12	22	17 10

An objection to this scale is that the progressive value is not geometrically increased with the greater richness, whereas it is known that the yield of sugar is augmented disproportionately in the case of rich juice. Thus, for example, to produce 100 lb. of sugar will require

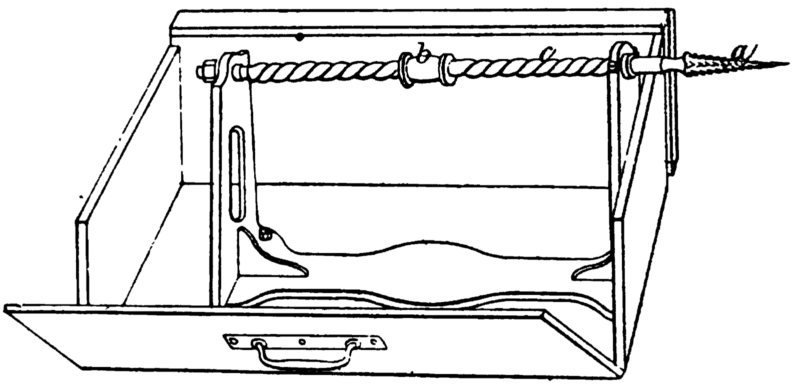
1333 lb. of beetroot at 12½ per cent.
1593 " " 11 "
2213 " " 9 "

in other words, while 620 lb. are needed to compensate for the difference between 9 and 11, only 260 are necessary to counterbalance that between 11 and 12½.

When the roots themselves are delivered at the factory, after having been deprived of their leaves, rootlets, and necks (the portion growing above ground), they are received by an overseer, who weighs them, and estimates the "tare" which is to be deducted for earth, badly trimmed necks, and other useless matters. In France, this is of importance as being the point at which the manufacturers' and cultivators' interests clash. In Germany, additional importance is lent to the operation by the fact that this weight is the basis of taxation of the industry. Where the manufacturer is his own grower, and where the taxation is based upon the out-turn of sugar, the weighing is only useful for purposes of comparison.

When the crop is paid for according to the density of the juice, a certain number of roots are selected as a sample, their pulp is rasped up, and the juice is expressed, and tested by a hydrometer. Several instruments have been devised for rapidly dealing with sufficient roots for this purpose. That of Possoz is shown in Fig. 113; it consists of a conical bronze

FIG. 113.



Possoz's Beet Rasper.

auger *a* furnished with teeth and rotated alternately to the right and left by means of a screw-nut *b*, which is held in the hand, and passed backwards and forwards along the stem *c*. The centre of the root is pressed against the revolving auger, which latter rasps out several cubic inches of pulp into any convenient recipient.

Violette's apparatus for the same object, which may be fastened upon a table, is composed of a little bronze rasping-drum, with saw-blades about 2 inches in diameter, against which the sample slices are thrust mechanically. The pulp falls into a little bronze vessel with perforated sides, in which works a piston, actuated by an iron eccentric, driven by the same wheel that gives motion to the rasper. In a few seconds it affords juice enough for a test.

Achille Thomas et Cie., of Lille, also make a little analysing table, with a rasping-drum, and an open press, but suitable only for the examination of whole roots, and not for sample slices.

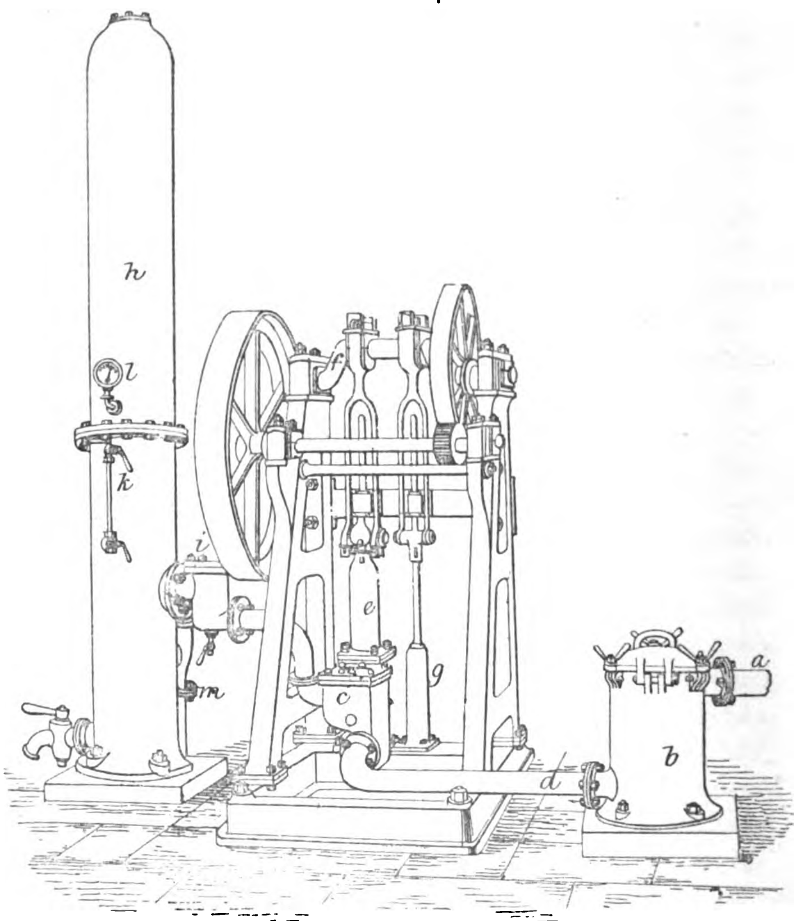
Transport.—The transport of the beetroots from the fields to the factory may be performed by rail, road, or river, where such facilities exist; but the rope tramway system presents many advantages over all others, as it abstracts nothing from the land under cultivation, is very cheap, and can be moved about from field to field, or from farm to farm, as circumstances require. It has been further described on pp. 79–82.

The labour, cost, and difficulty of conveying enormous quantities of roots to the factory, where the juice only is to be utilised, have caused attention to be turned to means of transporting the juice alone.

A few years since, Linard, of Cambray, introduced a plan of sending the juice to a central factory by means of an underground system of piping, which is rapidly gaining favour in France and Belgium. A single factory is thus enabled to work up what would otherwise have to be distributed among several factories, effecting at the same time great economy of transport, fuel, plant, and labour. In outline, the plan is as follows. The juice, obtained by any of the methods to be described later, is received in gauge-tanks, treated with 1 per cent. of lime, and pumped into the cast-iron subterranean conduit, capable of withstanding a pressure of 15 atmospheres, and of a diameter (varying with the distance) of 2½ to 5 inches. The juice is received at the central factory in large store-tanks. There is no apparent effect upon the pipes after several years' constant use. The set at Cambray takes the juice produced by 10,250 acres of beet.

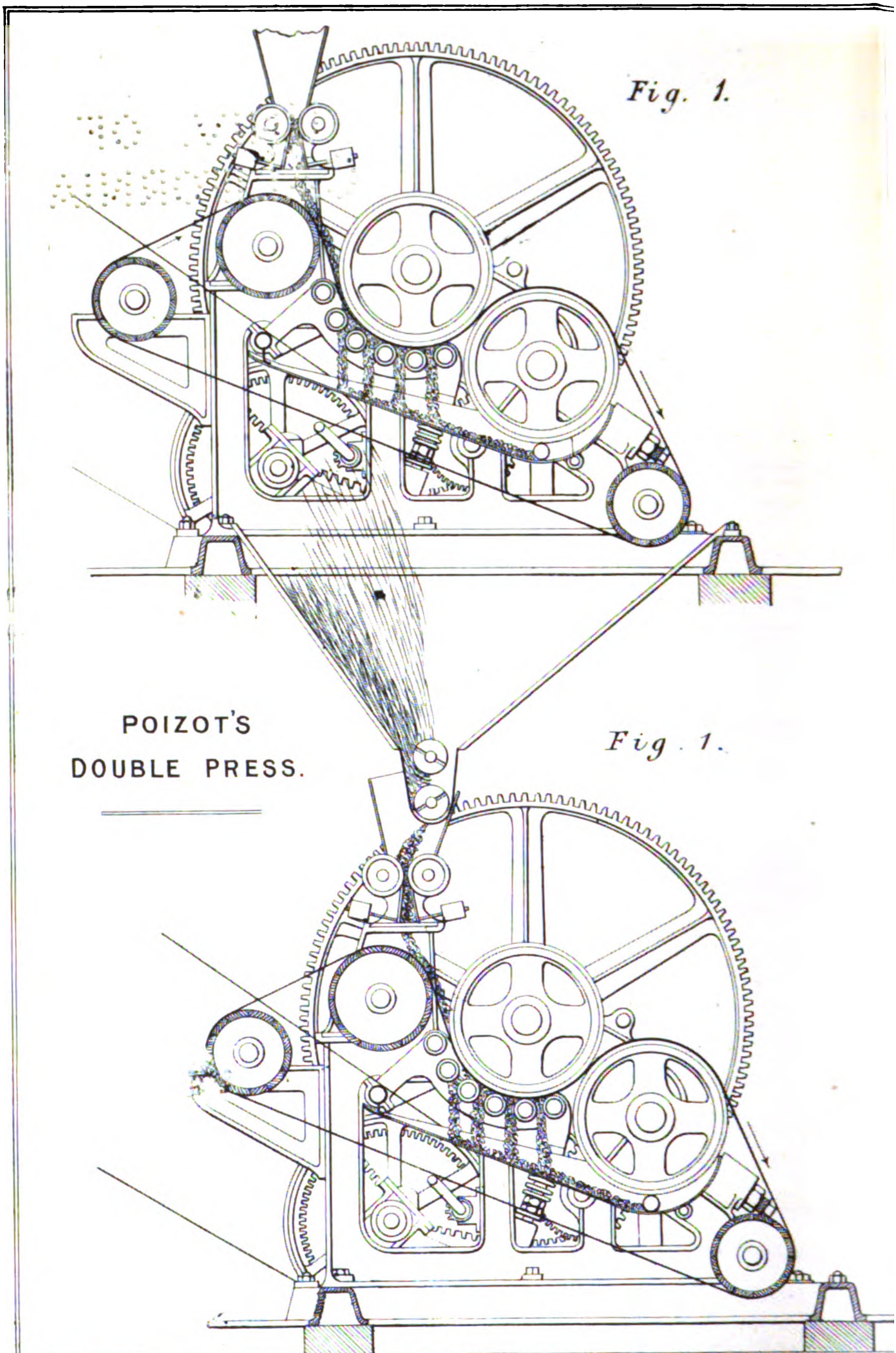
The pump employed by the firm of Fives-Lille, is shown in Fig. 114. The depulpified and limed juice passes by *a* into the filter *b*, thence to the pump *c* by the pipe *d*. The plunger *e* of the pump is worked by the elbow shaft *f*, to which is also attached the piston of a water-pump *g*, used in conjunction with the raspers. The juice is forced into the column *h* by passing the stop-valve *i*. The column *h* is surmounted by a large air-chamber, and provided with a tap *k* and pressure-gauge *l*. The juice finally escapes into the pipe-system by the tube *m*.

FIG. 114.



Beet Juice Pump.

Cleansing the Roots.—The first step towards extracting the juice from the roots is to free the latter from foreign matters. With this object, the roots are conveyed to a room

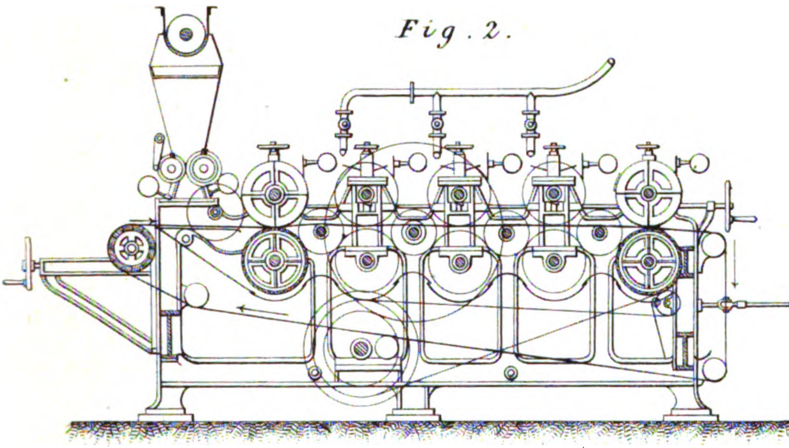


POIZOT'S
DOUBLE PRESS.

E. & F. N. Spon.

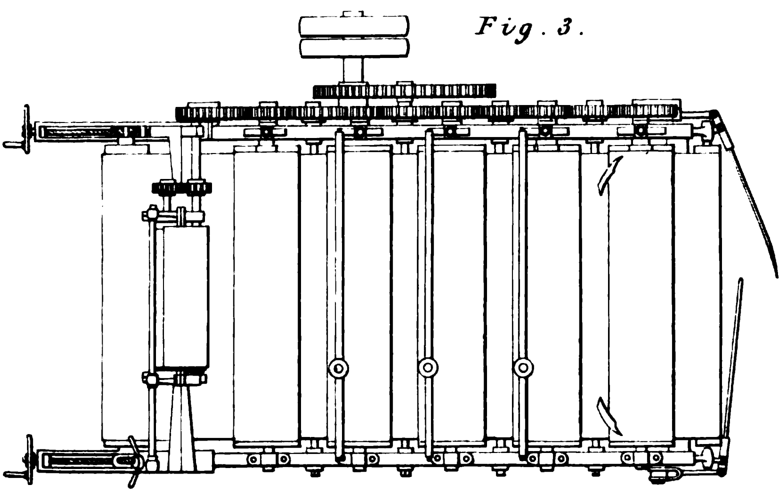
MANUEL ET SOCIN'S
CONTINUOUS PRESS.

Fig. 2.



Elevation

Fig. 3.



Plan

London & New York

of sufficient capacity to contain a supply for 2 or 3 days' working, in case of anything preventing a regular delivery from the cellar or *silo*. When the floor of this room is on a level with the ground floor of the factory, as is usually the case, it is necessary to raise the roots by some means, so that they may fall into the hopper of the washing-machine. Where the roots are grown on stony land, they are sure to have stones hidden in the dirt and rootlets, which would soon destroy the rasping-machine, unless previously removed. This has led to the introduction of "stoning-machines."

The stoner invented by Collas, of Dixmude, and made by Lecointe et Villette, is shown in Figs. 115 and 116. The tank *a* is divided into two compartments by two partitions *b c*, forming between them a right angle, the vertical one *b* constituting a strainer at its upper part, and the horizontal one *c* occupying only about $\frac{2}{3}$ of the length of the box, fixed at a certain distance above the bottom, and having a circular central orifice. Here is placed a horizontal screw *d* with 4 arms similar to those used in navigation. A horizontal grating is provided in the compartment *m* on the left, in prolongation of the horizontal partition, and an inclined grating *e* in that (*n*) on the right, above the vertical partition. The apparatus being filled with water, and the screw set in motion by the bevel-wheels *f*, a circulatory movement is communicated to the water, which rises in the compartment *m*, passes above the strainer, and, traversing the inclined grating *e*, returns to the compartment *n*, and again comes under the influence of the screw. If some beets are thrown into this rapid current in the compartment *m*, the stones rest on the grating or fall to the bottom, while the roots, in virtue of their relatively small specific gravity, are taken up by the current of water on to the inclined grating *e*, and tossed out of the machine by a little drum *g* armed with sloping flanges *h*, and driven by cog-wheels *i*. A trap-door *k* allows the vessel to be emptied of dirty water and of the mud and stones which collect on the bottom. A vertical panel *l* of sheet iron, placed above the compartment *m*, prevents the beets falling directly on the inclined delivery-grating, and protects the driving-gear from splashings of water. The machine is simple, and occupies

FIG. 116.

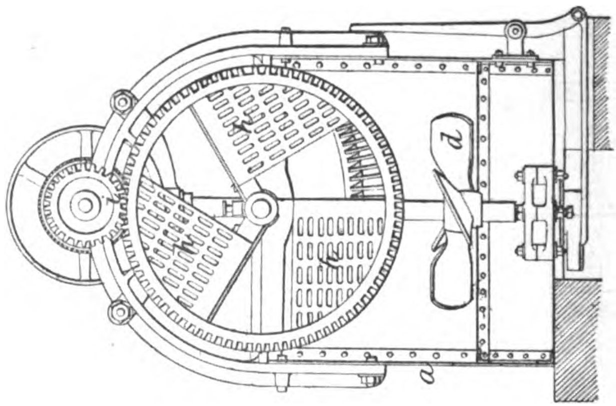
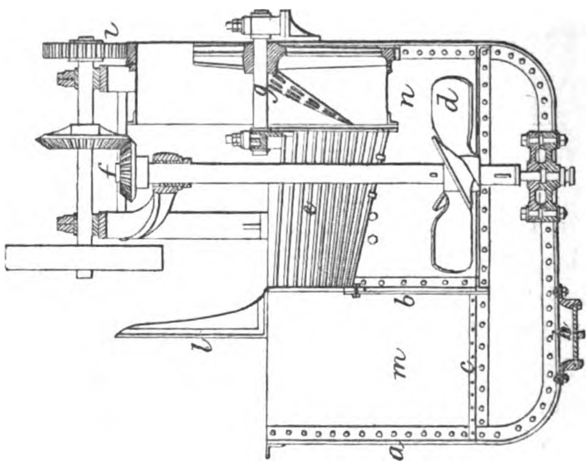


FIG. 115.

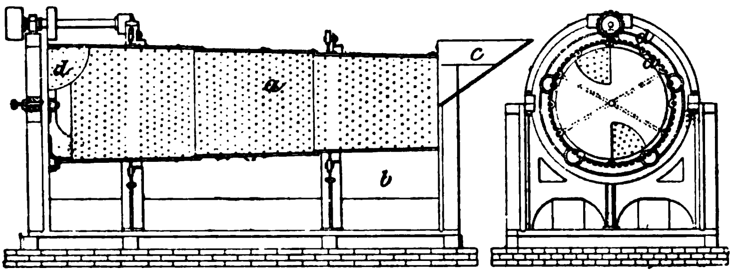


Collas's Beet Stoner.

little room. It is already employed in several factories, being generally placed after the washer, and performing a second washing, which is especially valuable when the diffusion process is adopted.

The washer, Figs. 117, 118, consists of a perforated sheet-iron cylinder *a*, revolving on its axis in a tank of water *b*. In front of the tank is bolted a hopper *c*, into which the beets fall; behind is a strainer. The cylinder, without its extremities touching the tank, leaves a space of only about $\frac{1}{3}$ inch at each

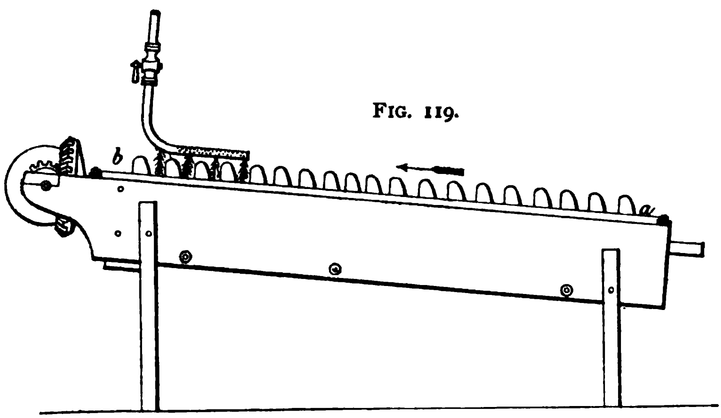
FIG. 117. FIG. 118.



Beet Washer.

end, so that the roots may not get wedged in there. The washed roots are thrown out by a helical grating *d* placed at the end of the cylinder opposite to the hopper. The rounded

FIG. 119.



Beet Washer.

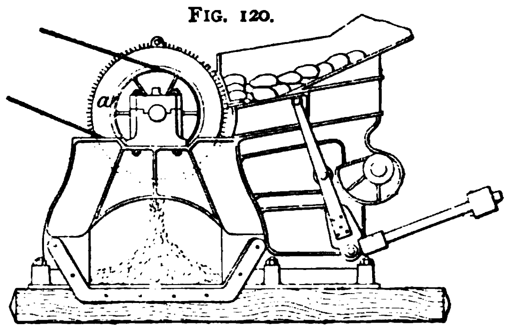
bottom of the tank is inclined towards an opening, by which the whole of the dirt and rootlets accumulated in the operation can be discharged.

Another form of washer is shown in Fig. 119, which is designed to overcome the disadvantage manifested by the preceding, in requiring frequent stoppages, while the water is being changed. It consists of an archimedean screw working in a trough. The beets are fed in at *a*, and are carried by the screw against a descending stream of water in the direction indicated by the arrow, escaping at *b* perfectly clean.

The processes described thus far are of universal application; the stoning and washing of the roots are preliminary operations needful to be performed whatever special mode of extracting the juice may be adopted. But here the parallel ends, and it now becomes necessary to classify the succeeding methods of manipulation. They may be grouped under the following heads:—(A) Rasping and Pressing, (B) Maceration, (C) Diffusion.

Rasping and Pressing.—The principles which govern this process of extraction are essentially mechanical. The aim of the operations is to first comminute the root so as to effect the rupture of the greatest possible number of cells, and then to separate the liberated but still absorbed juice from the solid matters by means of pressure, whether of a press or of a centrifugal hydro-extractor.

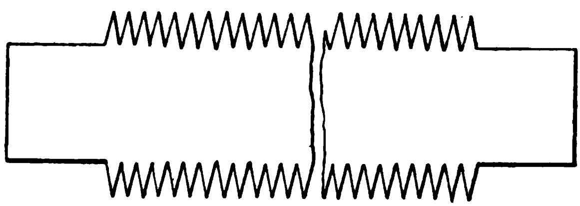
FIG. 120.



Beet Rasper, external.

Raspers.—Machines for reducing beets to a pulp are of multitudinous forms, and it would be impracticable to describe all of them. They universally consist of a revolving drum armed with teeth, and differ mainly in having the dentition external in some cases and internal in others. The type of the first class is shown in Fig. 120. The cylinder *a*, which is 24 to 28 inches in diameter, has its surface formed by a series of saw-blades (shown full-size in Fig. 121), separated by wooden washers. The cylinder is divided into 2 or 3 compartments by intermediate false bottoms, and is driven at a speed

FIG. 121.



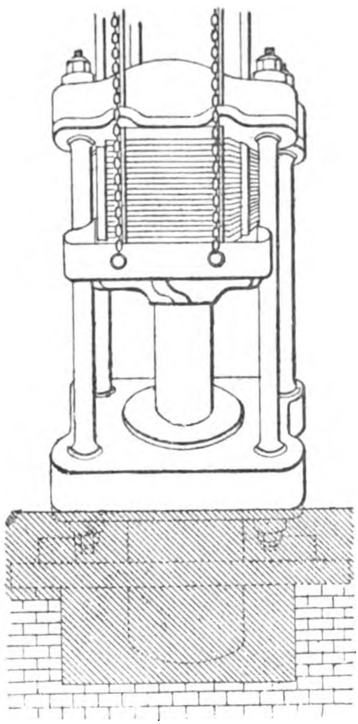
Saw-blades of Beet Rasper.

of 800 to 1000 revolutions a minute. It rotates in front of an inclined table, which it nearly touches, and on which a pusher, placed before each compartment, is driven by an alternating motion, in such a way that each beetroot that falls from the washer on to this table is pressed against the teeth, which reduce it to a pulp, more or less fine according to the dimensions, form, number, and wear of the saws.

The typical representative of the internal system of grating is Champonnois's rasper. The beets are introduced by a hopper, and are forced by the rapid rotation of fliers, which make 800 to 1000 revolutions a minute, against the short saw-like teeth of the raspers; water is at the same time injected. Fast and loose pulleys are provided, and a fly-wheel is fixed on the end of the shaft. The motion of the machine is reversed every 6 hours to equalise the wear, still the saws require sharpening after 48 hours' use. The pulp falls into a receptacle beneath.

Presses.—The pulp obtained from the raspers is carried or pumped up from the cistern in which it has collected, to be submitted to expression. The presses used are of two kinds, alternating (including screw and hydraulic) and continuous. When using a hydraulic press, Fig. 122, the pulp is placed in woollen sacks; these sacks, containing 10 to 12 lb., are superposed in the press with their mouths doubled under, and separated by iron plates; about 25 are collected, and the pile is put into a screw press, called a "preparatory" press, which extracts about 45 to 50 per cent. of the juice. These pressed sacks are piled anew on the movable plate of a powerful hydraulic press, which takes 50 at a charge. Each preparatory press can supply 4 hydraulic presses which are ranged round it, so that of the 4 presses, there will be one charging, one commencing to press, one in full pressure, and one discharging, at the same moment. Motion is communicated to the 4 hydraulic presses by 4 pumps mounted on the same bed, and tended by the same workman who directs the pressing.

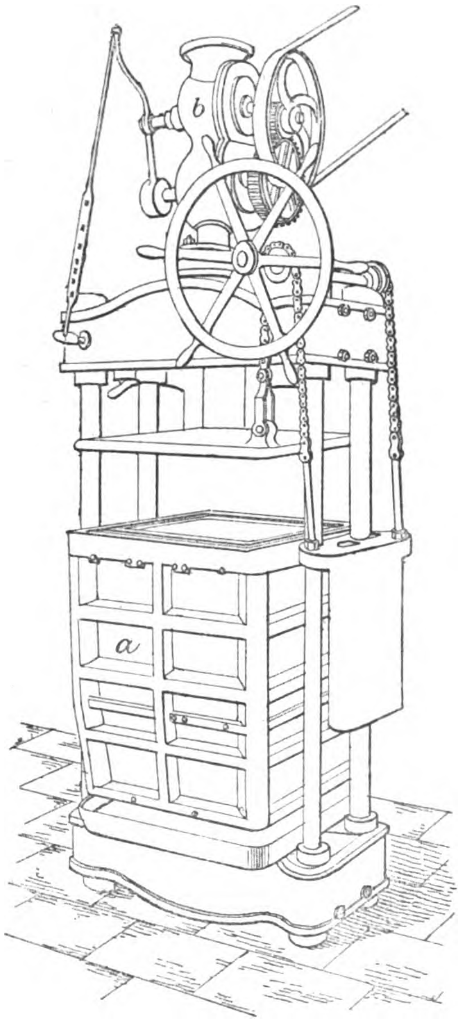
FIG. 122.



Hydraulic Pulp Press.

An improvement upon the general form of hydraulic press is that devised by Lalouette, which enables 2 men and 1 boy to keep 5 presses at work. The system consists of a cast-iron chest *a* (Fig. 123) thickly perforated with vertical slits, fitted internally with a sheet of iron pierced by small holes, and which is placed on the lowermost plate of the ordinary hydraulic press. On the plate is spread a woollen cloth; a

FIG. 123.



Lalouette's Pulp Press.

hose fixed in the centre of the head of the press deposits on the cloth a certain quantity (about 2 gallons) of the pulp, which is regularly distributed over the cloth by turning the hose circularly, without putting the hand in. The pulp is fed by a pump, which takes it from the rasper, and delivers it into the automatic distributer *b* above the head of the press. When one cloth is covered, a second is introduced, and the work progresses. The pressing is effected in several different ways, to be mentioned presently. These presses turn out about 300 cwt. per 24 hours in the first pressing, and 600 in the second.

There are three ways in use for working the press. In that of Lecointe et Villette, shown in Fig. 122, the filtering-box is fixed, and the piston of the press moves internally.

Much more might be written about hydraulic presses, but this is rendered unnecessary by the fact that they are rapidly falling into disuse in the beet-sugar industry, by reason of the superior merits of continuous presses, and the extended adoption of the diffusion system.

Continuous presses are of three sorts. The idea of continuous presses for beet was suggested by the roller mills used in the cane-sugar industry. But the conditions in the two cases are widely different: the begass of the cane is solid, and readily parts from the juice; whereas the pulp and juice of the beet have a strong tendency to combine. It was thus necessary to invent a roller whose surface should be permeable only by the juice, and Isnard sought to secure this by interposing cloths between the rollers. Thus constructed, the press yielded scarcely 60 to 65 per cent.

Pecqueur, in 1836, was the first to devise a machine possessing the requisite qualifications. The rollers consisted of hollow cylinders, pierced by a large number of holes, and covered with metallic cloth. They were immersed in a bath, of which they formed so to say the water-tight cover, and into this bath the pulp was forced by the pressure of a pump. The juice, in order to escape, was obliged to traverse the sides of the cylinders. The sides of the cylinders soon became coated with a mat of pulp, which the juice penetrated, and thus passed out quite limpid. The cylinders were put in motion so as to force this matted surface closely together, and thus complete the desired end. A knife removed the laminated pulp in a dry state from the cylinders. Unfortunately, the filtering surface which worked so well soon became choked; the meshes of the metallic cloth became so filled up that cleaning was impossible, and Pecqueur's press soon fell into disuse.

Many attempts have since been made to overcome the foregoing drawbacks, either by using cloths, or by finding filtering cylinders for the Pecqueur press which would not choke.

Poizot et Druelle have constructed a press in which the pulp passes between two cylinders, carried by two endless cloths. Their object is to unite as far as possible the best features of the pressing by hydraulic presses. To this end, the first pressing, which should be gentle, is produced against the first cylinder by the elasticity of the principal cloth on which it is borne. There, encountering a series of 4 little rollers, performing the functions of the preparatory press, it is next seized between the second and first cylinders, and deprived of the maximum quantity of its juice. The press has been much improved since it first appeared. Its present form is shown in Plate VIII., Fig. 1, where it is working in duplicate.

Manuel et Socin have made a press on analogous principles. The pulp falls upon a cloth which conducts it between a series of rollers, arranged in pairs at varying distances apart, so that the pressure exerted is constantly increasing; rakes remove the pulp between each pair of rollers, and the lower ones, being perforated, form a filtering surface for the juice, which escapes in a very pure state. The form of this press, as made by Cail et Cie., is shown in Plate VIII., Figs. 2 and 3. An ingenious modification is that by which the hair cloth carrying the pulp is kept of a constant width. For this purpose, the tender-roller is provided with a stout cord wound on its surface, in a double and crossed spiral, each starting from the centre of the roller and terminating at the end, so that the cloth is drawn out both to the right and left, and kept taut. Each press, worked by one man, will treat the pulp of 1375 and even 1570 cwt. of beet per diem, requiring scarcely 1 H.P. The juice, filtered through the hair cloth, is free from pulp. The cost of manipulation is about 4*d.* per ton of root; the yield is 26 to 28 per cent. of pulp. The juice can only be perfectly extracted by a second pressing. To effect this, two first-pressure presses are used for one second-pressure. The pulp falls from the first into the trough of a screw, where it is mixed with a large quantity of water. Between the second and third presses, is another screw, which raises the softened pulp to the third press for a second pressing. The whole operation only occupies 25 to 30 seconds. The juice of the second pressing is used instead of water in the raspers, as the rapidity of the work prevents it undergoing any change, so that the juices are sent to the carbonation stage almost at the degree of density which they possessed while in the root, and the pulp retains but little sugar.

Champonnois's press, Plate IX., Figs. 1 and 2, is composed of two permeable rollers *a*, immersed for $\frac{2}{3}$ of their surface in a cast-iron tank *b* of proportioned size and shape, forming a water-tight joint with their bases and with the portion emerging at the surface. The pulp can only escape between the two rollers. A pump conveys the pulp leaving the raspers, and forces it into the tank at *c* under a pressure of one or two atmospheres. The juice passes out between the rollers, while the expressed pulp is raked away by two knives, which seize it immediately at the exit, and falls by its own weight in front of the press, inclined for the purpose at 45°. The cylinders are driven in opposite directions by the gearing shown.

The most interesting part of the machine is the filtering surface. This is formed by spiral windings of a triangular thread, the spaces being determined at 0·004 to 0·008 inch. In this way is produced a filtering surface having narrow openings on the outside, and widening inwards. On leaving the press, the juice is received by a sieve, which prevents the loose pulp from mixing with the juice. The press has been further improved in the hands of Cail et Cie., and is now one of the most perfect and least costly in the market.

Lebée's press, Plate IX., Figs. 3 to 5, on the same principle, is also composed of two filter-cylinders, in appearance somewhat resembling Champonnois's, but essentially different in construction. It is formed of a series of portions of filtering surface, screwed on side by side, and enveloping the cylinder. Each portion, shown on a larger scale in Figs. 4 and 5, is composed of ten little strips of copper, curved longitudinally, soldered at the ends, and separated by intervals of 0·004 to 0·008 inch. This press has the advantage of allowing the filtering surface to be changed more easily than in the Champonnois press, without removing the cylinders, but it is not so simple.

Cuvelier's press, constructed by Lobbedez, has been at work for some years at Louez near Arras, and gives 28 to 30 per cent. of pulp retaining very little sugar.

Piéron's system has been adopted at the Montigny factory: the preparatory press treats nearly 2000 tons of beetroot per 24 hours; the ordinary first press, nearly 800 tons; and the second press, over 1500 tons.

Sufficient has now been said to illustrate the principles and essential features of continuous presses for separating the juice from the pulp of mashed beets. Examples might be multiplied almost indefinitely.

Depulpers.—The term "depulpers" has been applied to a class of apparatus rendered necessary by the inability of the ordinary filters to remove completely the fine pulpy matters from the juice. They are really nothing more than effective mechanical filters. That of Loynes, made by the Cie. de

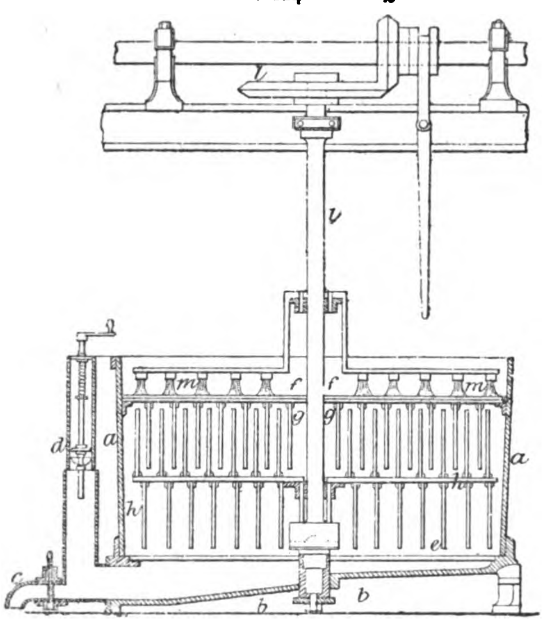
Fives-Lille, is largely used in other industries besides beet-sugar making. Those of Mariolles and Mesnard are constructed by Cail.

Centrifugals. — Centrifugal hydro-extracting machines, several forms of which are described under Cane Sugar (p. 362) and Sugar Refining, have been tried for separating beet-juice from the pulp of the grated roots. The rapid revolution of these machines creates an intense outward pressure against the sides, which was supposed to be sufficient to ensure the filtration of the juice. In practice, however, these machines are incapable of extracting more than 60 to 65 per cent. of the juice under the most favourable conditions, and consequently they are not superior to hydraulic presses for this purpose. Their use in this sphere is virtually a thing of the past.

Maceration.—The shortcomings of the expression processes gave an impetus to experiments in other directions, and notably with regard to the dissolving and displacing powers of water when applied to the pulp. One of the earliest plans based upon these principles was the maceration system of Schutzenbach.

This is illustrated in section in Fig. 124. The essential part consists of round vessels of sheet iron *a*, the bottom *b* of each being made sloping towards one side, so that by means of taps *c* the liquid can be completely drawn off. If the tap *c* is closed, the liquid, which arrives in the vessel *a* as will be described presently, rises in the tube *d*, and flows thence by a lateral pipe into a second similar vessel placed at a lower level. Above the bottom *b*, is a false bottom *e*, furnished with a metallic strainer, which retains the solid pulp while the juice escapes. At the top, in *f*, is a second similar strainer, formed in two pieces, and easily removable. The vertical bars *g* suspended from *e* are for breaking up the pulp, and preventing its making a simple rotation, under the influence of the mechanical agitator *h*, attached to the axis *i*, and actuated by bevel-wheels *k l*. The same axis carries cleaning-brushes *m*, which keep the orifices of the upper grating clear for the passage of air and water; and a similar set perform the same function for the lower strainer.

FIG. 124.



Schutzenbach's Macerator.

The working of the apparatus is very simple. Each vessel receives at first a little juice (except at starting, when the juice is replaced by water). Then the desired quantity of pulp is introduced, the agitator being meantime kept in motion, as, without this precaution, the densest pulp would fall to the bottom, and soon obstruct the orifices of the strainer. At the same time, the speed of the agitator must be carefully regulated. Too rapid movement would create a large quantity of froth; too slow would reduce the rapidity of the maceration, and therefore the effective capacity of the apparatus. A speed of 20 to 24 turns a minute would seem to give the best results. Later, when the juice is partly expressed, the agitator may be left at rest; the ligneous portion of the cells being lighter than the water, remains on the surface, and has no longer a tendency to choke the metallic diaphragm.

Unfortunately, whatever precautions are taken, a large proportion of pulp always finds its way through the strainer, and these solid matters render the defecation more difficult and imperfect, in consequence of the large quantities of scum to which they give rise. This inconvenience is partially remedied by passing the juice, on its exit from the maceration battery, and before defecation, into another vessel, whose strainers serve to detain some of the ligneous matters held by the juice. With the same object, it is well not to reduce the root to too fine a pulp; but it is necessary to avoid extremes in either direction, as a too coarse pulp will not be completely exhausted, and will thus cause a loss of sugar.

The process is only suitable for use where fuel is abundant and cheap, in consequence of the very large quantity of water added, amounting in all to 3 or 4 times the weight of the roots. It is therefore more applicable to rich than to poor juice.

The cost of erection is moderate. Thus, for a factory taking 50 tons daily, the outlay would be:—

	£
Rasping-machine	180
Macerating-battery complete	600
Press	200
Steam-engine, 8 H.P.	200
Total	£1180

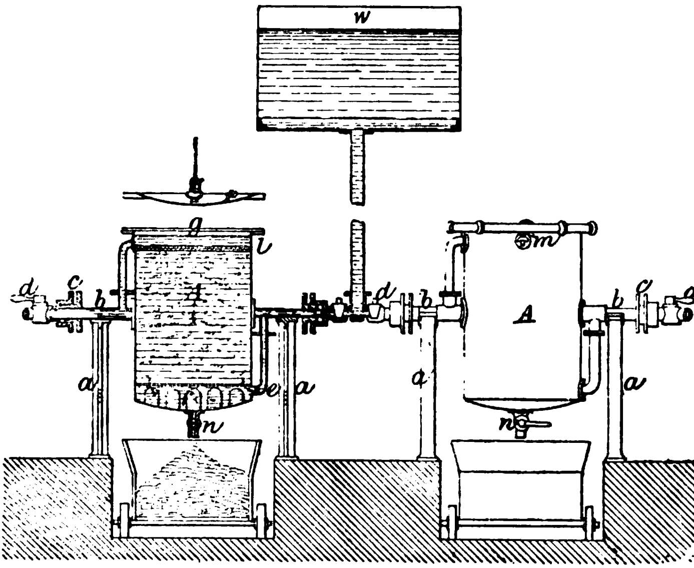
The expenses attending the extraction of the juice would then be:—

	£
6000 tons of beet at 19*s*.	5700
Transport and washing	160
Interest at 10 per cent.	180
Repairs, strainers, brushes, &c.	120
Wages of 24 workmen	134
Washing the cloths, &c.	14
Fuel for the steam-engine, 105 tons coal	150
Fuel to evaporate 35 per cent. of water, 420 tons coal	605
Total	£7063

The yield is 89 per cent. of juice, or 5034 tons in the season. The cost price is therefore 31*s*. a ton.

L. Walkhoff's "mixed method" of extraction next claims attention. The apparatus is illustrated in Fig. 125. Its most

FIG. 125.



Walkhoff's Extractor.

essential part is the filter-press or swinging vat A. This vessel rests by the axles *b* on cast-iron supports *a*; it can be turned round on its axis, and thus completely emptied. One or both of the axles *b* are hollow, and furnished with a stuffing-box, so that water can circulate in the interior of the axles, whatever the position of the vessel. A tap *d* regulates the delivery of water from a reservoir *w*, which may be 10 to 30 feet above the apparatus. The water admitted by the hollow axles *b* passes by the pipe *e* into a perforated worm, whence it escapes beneath the double false bottom *f*. Thus its level is raised slowly and uniformly. At *g* is a cover pierced with holes, forming a diaphragm, and provided with a handle.

This cover rests in the interior of the vessel upon circular bearers, where it is held by means of screws. To prevent the water passing directly along the sides, the double false bottom is fixed to a T-iron rim riveted to the vessel. The tap *n* is for letting out the water rapidly when the juice is displaced; it is of large bore to hasten the operation. At the top of the vessel A, is a tap *m* for the outflow of the juice.

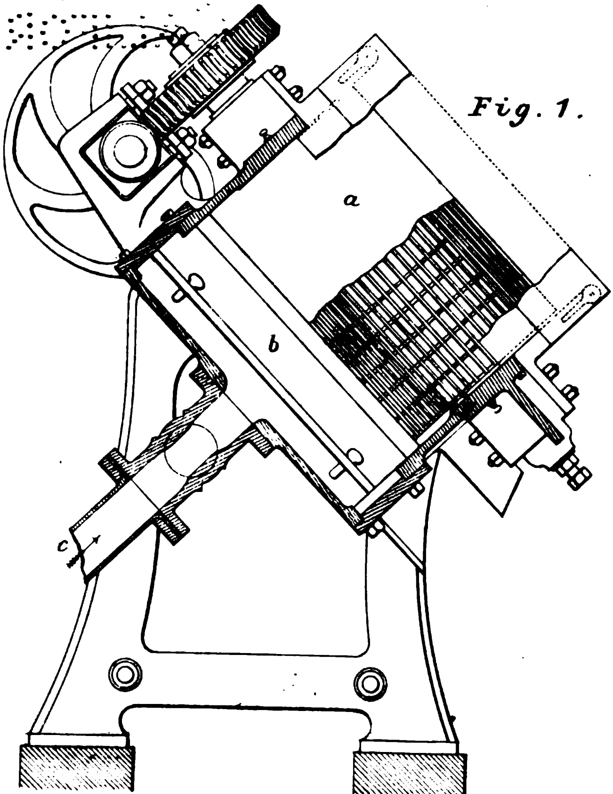
Once the vessels A are full, the metallic strainer *l* is placed on the pulp, and the cover *g* is adjusted. The tap *d* is then opened, so that the water occupies 15 to 20 minutes in filling the vessel A. The water enters at the bottom, and as it rises it displaces the juice in the pulp, mixing more or less with it. The liquid thus approaches the tap *m*, and escapes at about the normal density of the juice. The workman soon learns the correct adjustment of the tap *d* necessary to give the proper duration to the operation. The pulp, being lighter than the water, rises as a scum up to the strainer *l*, but is there retained, so that the liquid escapes quite clear. The usual length of operation required is 20 minutes.

In practice it is found that the diameter of the vessels A should not exceed about 28 inches. With this size the pulp of about 8 tons of beet can be worked in a day of 24 hours, or say 6 vessels for 50 tons per diem.

This system has been very largely adopted in continental Europe, on account of its good working results. The appended table exhibits its capabilities in comparison with other modes:—

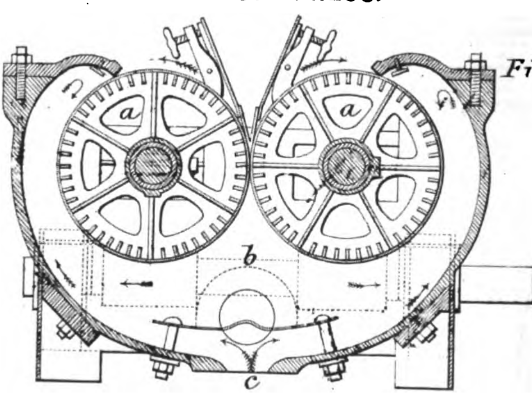
	Yield of Juice.	Yield of Pulp at uniform dryness.
	per cent.	per cent.
Ordinary presses	80	20
Simple presses, with 50 to 60 per cent. of water added in the rasper	84	16
Kuhne and Bökelmann's double pressing ..	87	13
Schlickeysen's process	88½	11½
Walkhoff's "mixed method"..	92	8

Fig. 1.



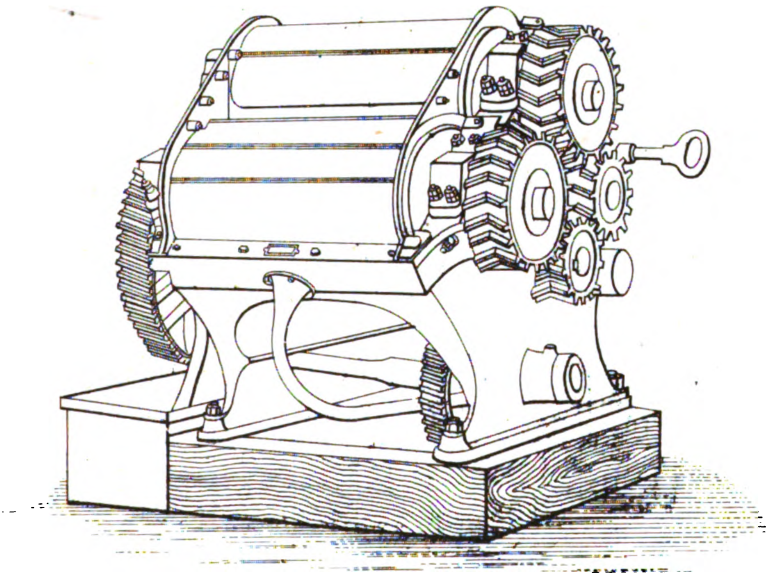
CHAMPONNOIS'
CONTINUOUS PRESS.

Fig. 2.



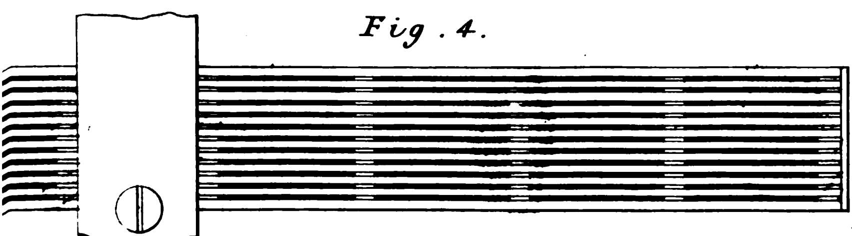
E & F. N. Spon, Lo

Fig. 3.



LEBÉE'S PRESS.

Fig. 4.



DETAIL OF FILTERING SURFACE.

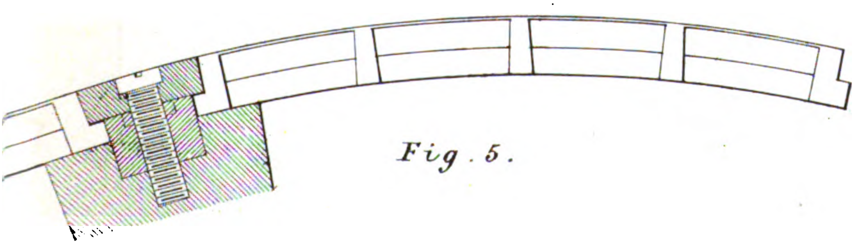
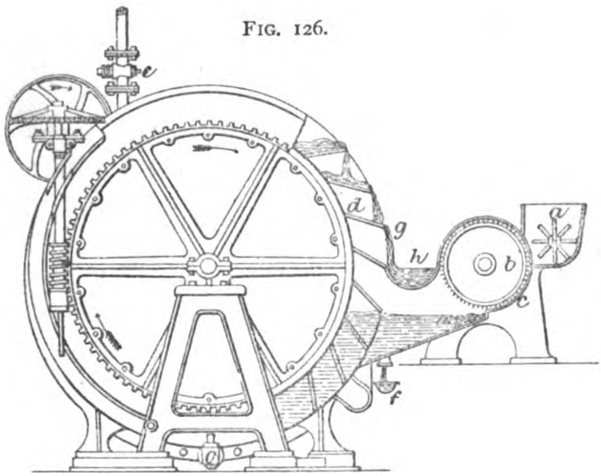


Fig. 5.

don & New York.

More recently Walkhoff has introduced some modifications greatly tending to reduce the labour bestowed upon the operations. His principle is to remove about 75 to 80 per cent. of the juice by a preliminary treatment, of the simplest possible character, for which many mechanical appliances already exist. The pulp coming from this treatment is thrown at *a* into the apparatus shown at Fig. 126. Thence it

FIG. 126.



Walkhoff's Revolving Extractor.

passes under a great number of blades, which divide it into small fragments, and thus it reaches the large drum *b* in a uniform and continuous stream, there to be still further comminuted by the edges *c*, and delivered to the juice-extractor. This latter, called a "revolving-filter," is provided with paddles, and resembles a water-wheel. This revolves slowly, and causes the pulp to circulate in opposition to a current of water entering at *e*. The completely exhausted pulp is discharged at *g*, and falls into the gutter *h*, whence it is conveyed to store.

The whole apparatus rests by its axis *n* on a support *m*, and is actuated by the wheels and pulley shown. The tap *o* serves as an outlet for the water from the apparatus. The water, entering in the desired quantity at *e*, passes successively into each compartment, and escapes at *f* as concentrated juice. The apparatus is very simple, and effects the complete extraction of the sugar, without adding more than 5 per cent. of water on the weight of beetroot.

Many other plans depending more or less upon maceration have been proposed, such as Pelletan's, Reichenbach's, Hallette et Boucherie's, Martin et Champonnois', Schiskoff's, Robert's, Schutzenbach's, &c., but they do not possess any valuable feature entitling them to notice. The preceding systems are those most generally and successfully applied.

A comparison of the results of the foregoing processes, in tabular form, on the authority of Walkhoff, may fitly conclude this section.

For 120 days' work and 6000 tons of beet, the production of juice requires :—

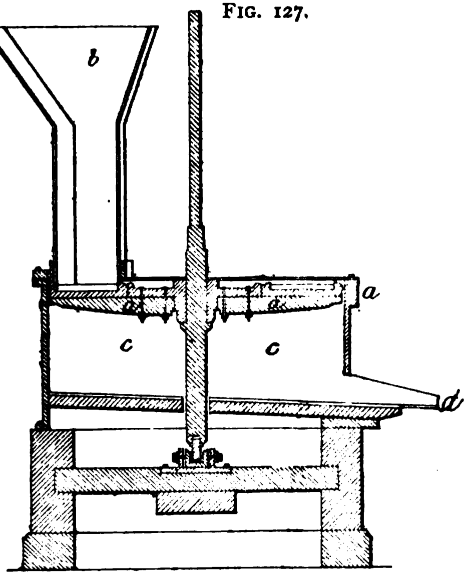
Processes.	In Labour: For Collecting and Cleaning the Beet.	In Labour: From the Rasping to the Defecation. Per Shift.	In Labour: From the Rasping to the Defecation. Total No. of Days.	In Fuel: For the Engines. (In tons of English Coal.)	In Fuel: For Evaporating the added Water. (In tons of English Coal.)	Cost of First Establishment.	Annual Expenses for Repairs.	Percentage of Juice obtained.	Cost of Production per Ton of Juice at the Initial Density.	Percentage of Water added to the Juice.
						£	£		s. d.	
Simple expression	3360	28	6720*	118·8	..	1340	288	80	28 0	
Expression with second rasping of the pulp ..	3560	35	8400*	145·2	240	1540	300	87	27 9	20
Expression with the charging tables adopted at Smela in 1862..	3260	14	3360*	118·8	..	1200	288	80	27 6	
Centrifugals	3360	10	2400	237·6	360	1450	120	88	27 0	30
Schutzenbach's maceration	3360	12	2880	105·6	420	1140	120	89	31 0	35
Walkhoff's method	3360	80	4800	130·2	125	540†	272	89‡	36 0	8–12

* Not including the washing of the sacks.
† Plus the presses.
‡ This method gives up to 94 per cent. of juice, and the figure given is the absolute minimum.

Diffusion.—The principles which form the basis of the diffusion process have been already described at length under Cane Sugar (see pp. 195–201). They remain precisely the same in the case of beet sugar.

The first step in the process is to cut the roots into thin slices, great importance attaching to the thickness of the slices being quite uniform. The machine in common use for the purpose is the same as was invented in 1850 for slicing beets for the hot maceration process, and is shown in Fig. 127. The

FIG. 127.

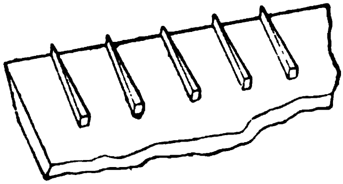


Beet Slicer.

cleaned roots fall into the hopper *b*, and encounter a plate *a* which turns horizontally, and carries 3 series of steel blades arranged at right angles. The roots are thus divided (for maceration) into rectangular prisms of the thickness of the finger, and of varying length, without suffering any crushing or pressure. The slices fall into the space *c*, and escape at *d*. With 1½ H.P., this machine is said to slice 100 tons of beet per 24 hours. By using two feed-hoppers, the effect is doubled. For diffusion, the slices are about $\frac{4}{100}$ inch thick and $\frac{40}{100}$ inch wide. The cutting disc is furnished with knife-edges *a b*, as shown in Fig. 128.

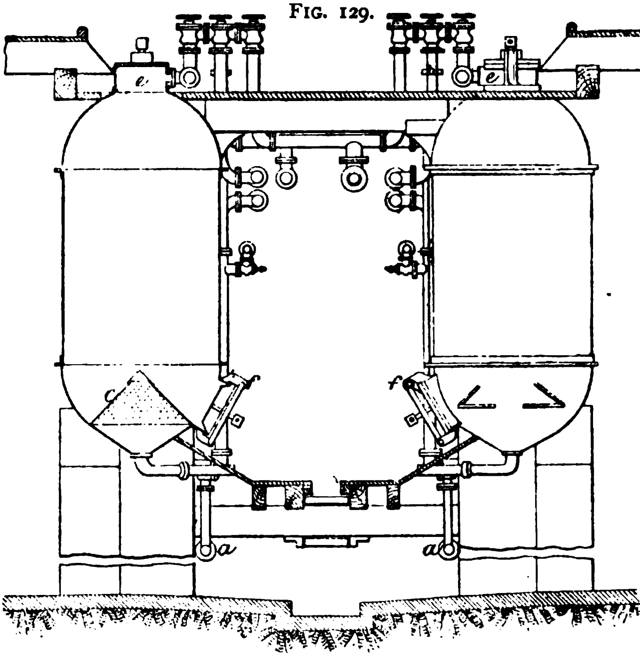
Robert's diffusion process would seem to amount to only a modification of Dombasle's maceration system, and the diffusion vessel closely resembles the macerator adopted by Robert for the hot maceration plan introduced by him at Seelowitz, in Moravia. The ribbon-like slices of beet are conducted to large closed vessels, there mixed with the heated juice from a previous operation, and then exhausted with cold water. The diluted juice is first heated to between 75° and 90° C.

FIG. 128.



Knives of Beet Slicer.

FIG. 129.

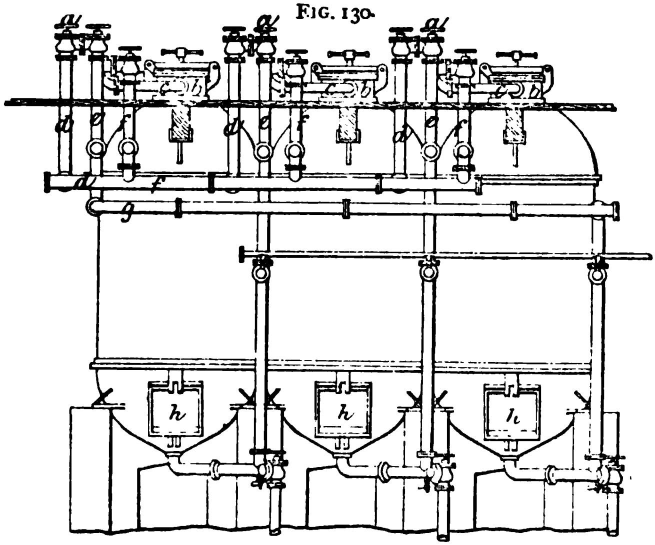


Robert's Beet Diffusor.

(167° to 194° F.), so that the mixture with the beet assumes a mean temperature of 50° C. (122° F.), which is considered essential to the success of the process. Displacement of the juice is performed by a flow of cold water throughout the whole battery (of 5 to 8 vessels).

The arrangement of these vessels will be readily understood from Figs. 129 and 130. The cylinders are furnished

FIG. 130.



Robert's Beet Diffusor.

at the upper part with man-holes *e* for the introduction of the slices. Near the bottom, a door *f* hinged at its upper edge permits the exhausted slices to fall upon an endless web, which conveys them away. In the interior of the cylinder is a case *c* pierced with holes, which prevents the pipes being obstructed by solid particles. The pipes *a v* put the vessels in communication with the re-heating boilers, while the conduits *h h′ w z* maintain the circulation in the various cylinders of the battery. The steam-pipe *o* furnished with a tap *p* serves for the introduction of the steam to the several vessels. Finally, the pipes *y* bring the water necessary to the operation, while the rich liquor passes away by *x* to the defecating-boilers.

Each vessel receives 2½ tons of slices, occupying a space of over 12 square feet. The vessels are not filled until the juice or the diffusion water, as the case may be, has a temperature of 87° to 97° C. (189° to 207° F.). The vessel is ⅓ filled with this hot liquid, and then the slices are fed in through *e* from trucks holding about ½ ton. On emptying the fourth truck, the reheated juice is allowed to run in at top, so that when the charging of the slices is completed, the vessel is full of juice. The proportions of juice and pulp entering the vessel should be carefully adjusted. Whilst charging, it is well to mix up the juice and pulp so that no part shall be left imperfectly exhausted, and the liquids shall have uniform circulation. As the contents of 6 or 7 trucks are needed to fill the vessel, and as the discharging of each occupies about 4 minutes, the whole charging requires nearly half an hour.

The vessel once full, the cover *e* is closed, and the matters are left for about 20 minutes. At this moment, the pressure of a column of water from the tanks above the factory is brought to bear upon the nearly exhausted pulp in the last vessel. As this vessel communicates with the 7 others forming the battery, the pressure can be conveyed to them all; the juice is thus displaced from the cylinder filled with fresh pulp, and proceeds while still hot to the defecating boilers. In practice, each vessel furnishes two full boilers of juice, varying in density according to the duration and the number of vessels (5, 7, and even 10). Generally, the density fluctuates between 4° and 7° B., so that the juice is mixed with about 40 per cent. of water on the weight of beet.

The estimated cost of establishing a factory on the diffusion system to work 50 tons a day, according to Walkhoff, is as follows:—

	£
1 slicing-machine	144
10 cast-iron diffusors, weighing 1 ton each	288
50 cast-iron valves	180
20 taps	52
30 elbow pipes	13
15 straight pipes	22
600 screws, &c.	14
3 trucks, weighing 6 cwt.	50
Total	£763

Then the cost of extracting 100 parts of juice may be calculated thus :—

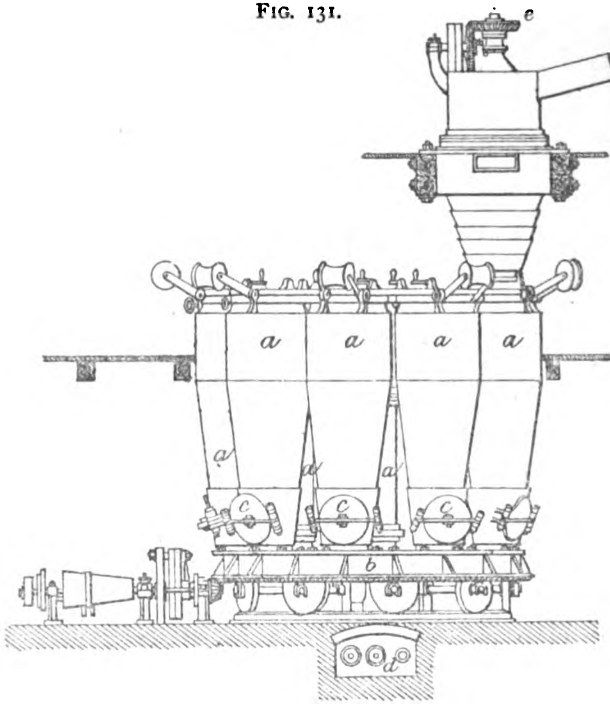
	£
6000 tons of beetroot	5760
Transport and cleaning	161
Interest and insurance at 10 per cent.	76
15 workmen per shift, or 30 per diem	173
Removal of the residues (60 to 70 per cent. of the weight of beet), 4 workmen	46
Repairs, sharpening knives, &c.	58
Residue-press, interest, repairs, &c...	50
Fuel for 8 H.P. steam-engine, 88 tons of coal ..	127
Evaporation of 40 per cent. of water, requiring 480 tons of coal	691
Total	£7142

The product is 90 per cent. of juice at the initial density, or, on 6000 tons of root, 5400 tons of juice. The juice, therefore, costs about 26*s.* 5½*d.* a ton; thus diffusion presents no advantage in this respect over the best systems of maceration.

A novel arrangement of diffusion apparatus, constructed by the Prager Maschinenbau Co., is shown in Fig. 131. It is designed to take a maximum of 250 tons of beet per diem of 24 hours. This quantity is worked in Bohemia, where the juices are very dilute; if, instead of having juice at 3° B., it is desired to have it at 4° B., not more than 100 tons would be treated, at a sugar loss of 0·2 per cent. on the pulp. Four workmen suffice for the daily labour. In effect, the apparatus is rotary. The 9 diffusors *a* of which it is composed, having the form of inverted truncated cones, are borne in a circle on a wheeled table *b*. The motive power giving the rotation is ingeniously applied, and does not need to exceed 1 H.P. A complete turn is made in ¾ hour. The slicing-machine (*coupe-racines*) *c* is placed above on a special stage, and supplies the slices to each diffusor by means of an articulated funnel, formed of movable segments, so that its mouth can follow the slow rotary movements of the diffusor which it is filling, until the quantity suffices. The axis of rotation of the apparatus is composed of two concentric cast-iron conduits, one conveying the water, the other the steam.

Between each two diffusors, is a vertical cast-iron cylinder, which is the juice-reheater. This is tubular; each diffusor being furnished with a reheater, the temperature can be

FIG. 131.



Circular Diffusion Battery.

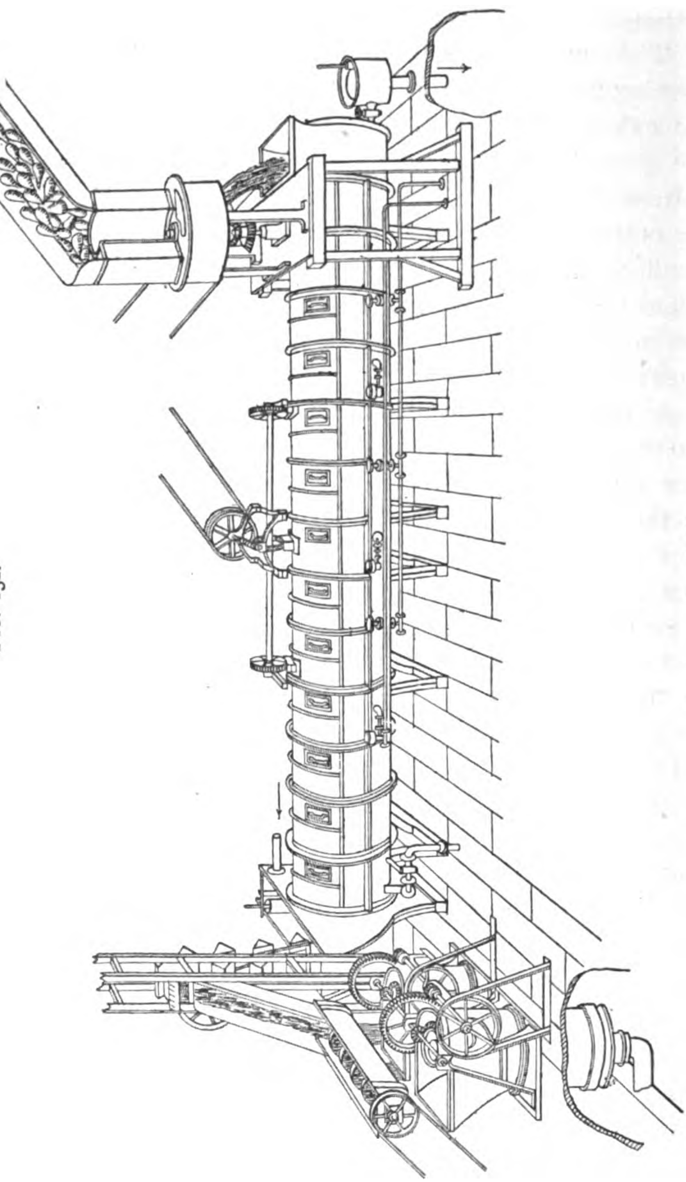
regulated at convenience, three taps sufficing for each apparatus. All these taps are placed at the centre of the system, at the height of the upper mouth of the diffusor. A stage is here fixed so as to allow a man to stand in the midst. Another stage is placed circularly at the same height for the workman who opens and shuts the diffusors, and for the one who directs the funnel. The diffusors are closed at top by a heavy cover, of the same diameter as the diffusor itself, and which rests upon a circular indiarubber tube, forming a hermetic joint, steam being admitted into the tube, so that it never flattens.

The outlet of the diffusors consists of a lateral door *c* opening from above; a trough is provided for the reception of the exhausted slices. The juice is let out by taps *d* below the ground. A perforated sheet-iron plate forming a false bottom prevents the slices from mingling with the juice, when the outlet tap is opened and the vessel is completely emptied of slices. A workman opens the lower doors each time a diffusor passes before the trough for the slices. A fourth workman is occupied at the slicing-machines.

The advantages claimed for this system are as follows:— Easy charging of the diffusors, the slices passing direct from the slicing-machines, whence arises great economy of labour. The discharge of the exhausted slices takes place always at the same point. The duration of the diffusion, being regulated by the speed given to the apparatus, is always the same, and not at the discretion of the workmen. There is great saving in the construction, the pipe system being central and necessarily short.

The continuous diffusor, invented by Charles and modified by Peret, shown in Fig. 132, consists of an iron cell of cylindrical form, supported horizontally on a foundation of brickwork. Within this cell is a perforated iron cylinder 36 ft. 9 in. long, and 4 ft. 3 in. in diameter. A smaller cylinder forms the axis, and between the two cylinders is a screw having a pitch of 2 ft. 4 in. The inner cylinder is rotated by means of a suitable connection with a shaft, the speed of rotation being so adjusted that 1 hour is consumed in the passage of the beet slices through the whole length of the screw. The slices (called *cossettes* in French, and *Schnitzel* in German) are kept constantly immersed in water, which enters the cell at the end from which the exhausted slices are expelled, the supply and level being controlled by an automatic arrangement. The water absorbs the sugar from the slices which it successively

FIG. 132.

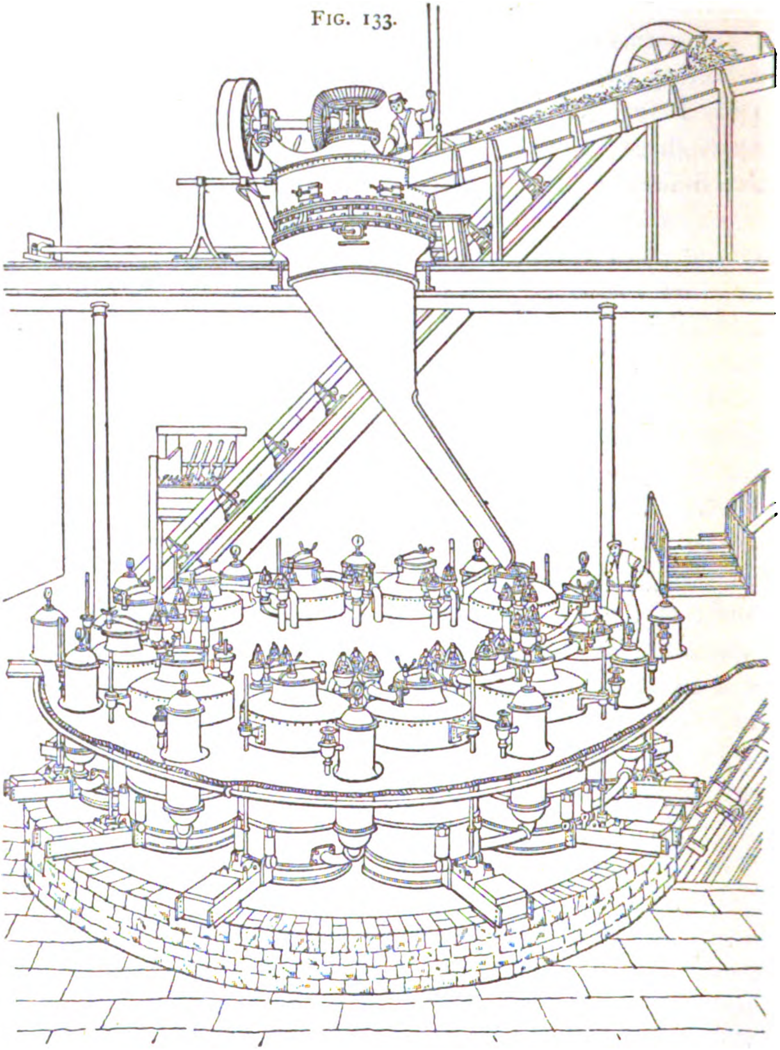


Continuous Beet Diffusor.

encounters, and escapes at the end of the cell where the fresh slices are being admitted. The temperature of the water on admission to the cell is kept at 86° F. (30° C.); but as the water passes the coils placed between the fixed cell and the revolving cylinder, its temperature gradually rises to 167°–176° F. (75°–80° C.); after this, the repeated contact with fresh slices gradually reduces the heat, till the water leaves the diffusor at 122°–140° F. (50°–60° C.). When once the attendant has adjusted the speeds of the slicer, the exhausted slice elevator and the rotating cylinder, with the steam pressure on the coils, and the juice exit (which governs the admission of water), the continuous diffusor works automatically, and the labour is reduced to a man and a boy for working the slicer, diffusor, and pulp-presser, the only conditions subject to irregularity being the quality of the beets and the temperature.

The circular arrangement of a diffusion battery as worked by the Fives-Lille Company is shown in Fig. 133. The beets, as brought in, pass through a first washer, which removes most of the attached soil. Thence they go into a second washer, which terminates in a stone-screener, destined to catch the small stones which remained after the first washing, and which would interfere with the slicers. The arms of the stone-catcher throw the beets on to an inclined plane formed of bars, where they drip, and whence they are carried automatically to a vertical bucket elevator, which deposits them in a slicer. The slices are distributed through a series of intercommunicating diffusors, and are there exhausted of their sugar contents by a flow of water which passes through each diffusor in turn. The temperature of the water is raised to the desired point by circulation in steam coil vessels called calorisers. The slicer, placed in the middle of the battery, distributes the slices by means of a revolving hopper, thus saving much labour. The diffusors are provided with calorisers and valve-boxes, and are erected over a well with a centrally inclined floor, into which the exhausted pulp is discharged.

FIG. 133.

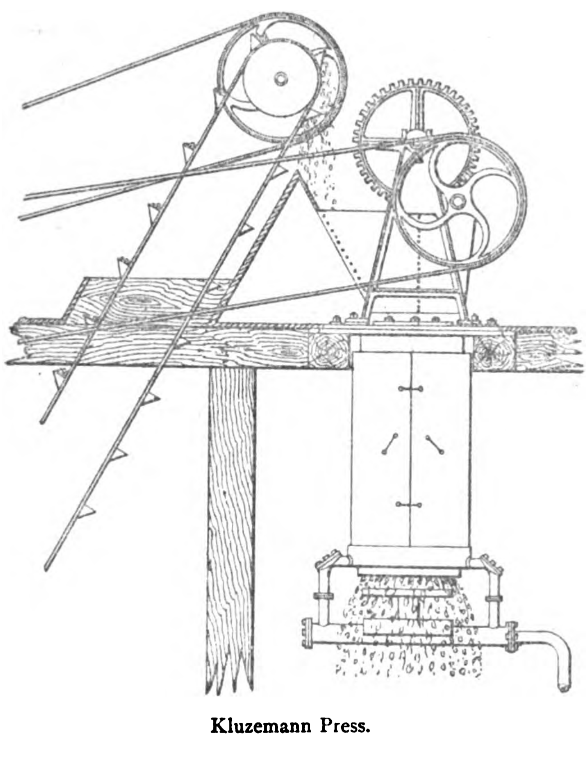


Circular Diffusion Battery.

Numerous other modifications are from time to time introduced. For instance, compressed air is employed instead of water pressure for effecting the final exit of the juice, so that the first diffusor, at the moment of emptying, contains only fairly dry slices.

Residues.—The exhausted slices derived from the diffusors form a valuable cattle-food. But as generally discharged they are too wet for immediate use, and require to be passed through a press for the removal of the excess moisture. This is commonly performed in the Kluzemann press, shown in

FIG. 134.



Kluzemann Press.

Fig. 134. It is composed of a screw working in a conical space, which squeezes the pulp till it contains no more than the desirable quantity of water. The objection to this press is that it breaks up the slices.

Skoda, of Pilsen, Bohemia, makes a continuous press, which avoids this disintegration of the exhausted slices submitted to it. It consists of two eccentric cylinders placed one within the other, of very different diameters, moving in the same direction and at the same peripheric speed. A screw causes the wet slices to fall into the interior of the larger cylinder, and they are carried by the general movement into the limited space between the outer surface of the small cylinder and the inner surface of the large one, and which is regulated by a double iron ring fixed to the inside of the large cylinder. This machine easily presses in the 24 hours the exhausted slices from 150 to 175 tons of beet, reduced to 40 or 45 per cent. of the original weight. The motive power required is about 1½ to 2 H.P. The price of the machine is about 280*l.*

The Selwig and Lange (Brunswick) press, Figs. 135 and 136, is specially designed for expressing the juice contained in beet pulp that has been exhausted through the different processes of extraction. The pulp, which is supplied continuously by a chain and buckets or an endless screw, enters the hopper *e*, and falls at *a* between two openwork disks, whose sides are inclined and covered with perforated iron plate. These disks are surrounded by the cheeks of the frame *b*, and the latter is securely bolted to wooden blocks fixed to the flooring. The disks revolve very slowly, and at an equal rate of speed, around stationary drums *c*, that are connected by tie rods *d*, and they form with each other an obtuse angle such as to make them further apart at their upper part. The pulp thus fills a chamber whose sides taper downward in the form of a wedge, and moves constantly over inclined axes. Owing to this arrangement it is carried along by the friction of the revolving disks, and is brought progressively into the narrowest interval of the pressure chamber. During this motion it undergoes a strong pressure, which reaches its maximum at *a*, and all the juice that it contains traverses the strainer and the disks *f*. The liquid afterwards escapes through wide orifices in the lower part of the frame, and falls into a funnel *h*, which connects with a drain.

As the rotary motion is continuous, the expressed pulp, on

FIG. 136.

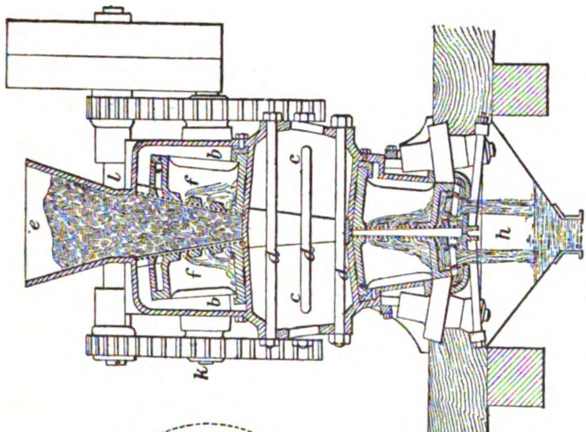
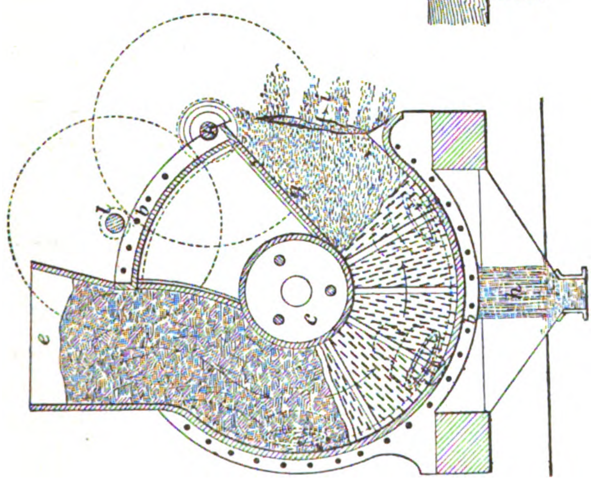


FIG. 135.



Selwig and Lange Press.

making its exit from the space *a*, passes into a wider cavity, and afterwards meets with a partition *g*, which forces it to make its exit from the apparatus in a state of considerable cohesion at *i*.

In order to permit of regulating the pressure, which depends upon the distance apart of the disks, the builders have arranged, externally to each of these parts, a sleeve, whose position is determined by screws connected with the frame. Each sleeve is capable of moving upon its axis in such a way as to increase or diminish the interval that exists between the straniers.

As shown in the figures, rotary motion is transmitted to the apparatus by a belt that passes over a pulley keyed to the shaft *l*. Two gearings then drive the shaft *k*, and this sets in rotation two pinions that gear with a system of toothing upon the circumference of the pressure disks.

In order that the motion of these latter may be properly guided, each of them is put in contact with three conical rollers that pivot on the frame and run in bearings that permit of the position of their axes being regulated. All the running parts have to be carefully looked after and kept lubricated with tallow and black-lead.

The use of this press in sugar works has demonstrated the fact that it is unnecessary to take out the strainers in order to clean them during one season's running.

This operation, although very easy, may be avoided by forcing in from time to time, a powerful stream of water against the external surfaces of the disks, which will then preserve all their efficiency.

CHAPTER XIV.

DEFECATION OF THE JUICE.

Composition of the Juice.—The juice of the beet rapidly undergoes a change which confers a dark-brown colour. The composition of this dirty-looking liquid is approximately as follows:

In 100 parts of juice:—

Sugar.	Diffusion. Potash and Soda.	Diffusion. Silica, Lime, and Magnesia.	Diffusion. Organic Substances.	Diffusion. Weight of Solid Matters.	Sugar.	Expression. Potash and Soda.	Expression. Silica, Lime, and Magnesia.	Expression. Organic Substances.	Expression. Weight of Solid Matters.
9·189	0·467		2·199	11·300	14·95	0·803		1·357	17·348
8·410	0·449		1·377	10·236	11·25	0·603		2·183	13·936
8·010	0·580		N o·109	9·810	7·50	0·820		N o·105	9·520
8·500	0·295	0·113	0·983	9·891	10·16	0·310	0·173	1·323	11·966
11·580	0·441	0·191	1·774	13·986	12·41	0·458	0·187	2·466	15·522
Mean 9·128	0·507		1·288	11·650	11·25	0·671		1·467	15·558

In 100 parts of dry substances:—

..	3·470	1·328	11·529	16·329	..	3·054	1·702	13 021	17·777
..	3·808	1·649	15·318	20·755	..	3·690	1·597	19·871	25·068
..	4·680		13·025	17 705	..	5·371		9·085	14·451
..	4·520		11·580	19·850	..	4·080		14·380	23·110
..	5·339		16·373	21·712	..	5·360		18·516	23.876
Mean 62·203	4·958		13·565	19·274	59·41	4·952		14·974	20·656

Defecation by Lime and Carbonic acid.—The impure juice can be clarified to a certain extent by simple boiling, as the albuminous (nitrogenous) constituents coagulate in the same way as those of cane-juice, and form a supernatant scum. But the coagulation is very imperfect. The addition of slaked lime greatly facilitates the aggregation of impurities owing to the formation of insoluble lime compounds; but a coincident effect of the lime is the prevention of the coagulation of the albuminous matters, which remain in solution till partially destroyed by boiling in the presence of the alkali. The part played by the lime is very complex, and not clearly made out, but it seems to displace many of the bases in combination with sulphuric, oxalic, and other acids, forming insoluble compounds with those acids, and further destroys some of the albuminous matters, as evidenced by the disengagement of ammonia when the temperature is raised.

The convenience and cheapness of lime as a defecator are obvious. Its use in the beet industry was copied from the cane-sugar makers, and at first it was often employed in excess, to the great detriment of the process. Thus it was that in 1792 a proposition was made to replace it by sulphuric acid, a still more dangerous agent, the excess of acid being neutralised by the addition of chalk. This process gained little favour, and the simple lime defecation continued in general practice till eminent chemists proposed to saturate the excess of lime by adding sulphuric acid. This last plan was succeeded by clarification with the aid of animal black and blood, decanting, and filtration through animal black. This system endured till 1849, when carbonic acid was proposed as a substitute for sulphuric acid in neutralising the excess of lime. This was unsuccessful at first, but Rousseau's plan, which overcame all practical difficulties, was as follows:—

The juice is raised to a temperature of 50° to 75° C. (122° to 167° F.), according to the time, and an addition of 1½ to 5 lb. of slaked lime per gallon of juice is made, the heat being thereupon increased to 85° or 90° C. (185° to 194° F.), or well below the boiling point. The juice is drawn off clear, the scums are pressed, and the juice is collected in a boiler and treated with carbonic acid till the remaining lime is saturated; the excess of carbonic acid is finally driven off by a short boiling. The carbonic acid gas was produced by burning charcoal in a small furnace, and was injected into the mass by a pump. This process rapidly extended, as it economised 3 per cent. of the black formerly used.

Ten years later, Périer et Possoz, in combination with the house of Cail, introduced a novel system of applying this process. It had long been known that lime had the property of preserving the juice from fermentation, and that a limed juice would keep unaltered for a long time. Dombasle recommended the application of a little lime to the juice before defecation, to avoid the fermentation which may be developed during the few hours the juice may have to wait in working; and Dubrunfaut insisted upon the necessity of adding a little lime to the cold juice immediately on its extraction, especially when dealing with large quantities. Out of these considerations, arose a patent process by Maumené, which was collateral with the plan of Périer, Possoz et Cail. Henceforward the process, termed "double carbonation" (*double carbonatation*), came into almost universal use; in Germany and Russia, it was connected with the names of Frey and Jenileck, who introduced it there with some trifling modifications.

The method of carrying out the double carbonation process is as follows:—

(1) Put lime into the juice as soon as possible, even into the mixture of juice and pulp, by introducing milk of lime into the rasper, or a weak solution of sucrate of lime, which, under proper conditions, does not appreciably alter the value of the pulp as a cattle-food.

(2) Let the contact of lime and juice be sufficiently long, such as when preserving juice in cisterns, in the store-tanks at the exit from the rasping, or when transmitting it through the Linard pipe system (p. 447). Thus the free acids which would

alter the sugar are saturated, and a very satisfactory cold defecation is obtained.

(3) Introduce the turbid juices into the first-carbonation vessels described further on, there adding 15 to 30 thousandths of lime in the state of milk of lime.

(4) Pass carbonic acid gas in the cold up to about the middle of the carbonation; then gently admit steam to warm the juice; the supply of carbonic acid is stopped when the juice does not contain more than 2 thousandths of lime.

(5) Turn the steam on full till the temperature reaches 90° C. (194° F.), to throw up the scum. Allow to rest, and decant.

(6) Transfer the clear juice to the second-carbonation boilers, add 2 to 10 thousandths of lime, and heat to boiling in order to destroy the nitrogenous matters not eliminated by the first carbonation.

(7) Pass carbonic acid till the lime is completely saturated.

(8) Give a rapid boiling, allow to settle, and decant.

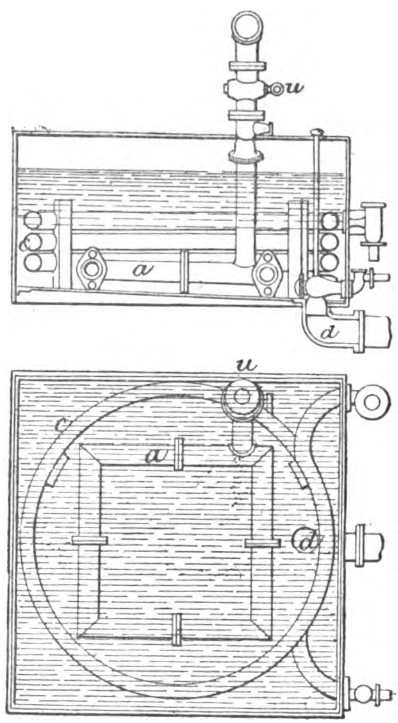
The double carbonation process, simple in practice, and easily applied in all cases, is now everywhere general in the beet-sugar industry, though a few adhere to Rousseau's plan. The purification of the juice is effected in two ways. The carbonic acid, in uniting with the lime in the midst of the juice, forms carbonate of lime, which on precipitating carries with it a large quantity of organic matters. In fact, the scums of the first carbonation are very dark; the supply of carbonic acid is stopped when its further action would redissolve the colouring matters. In the second carbonation, the lime boiling destroys the matters which resist the first carbonation. The excess of lime is finally removed by carbonic acid.

After this theoretical account, a description may be given of the apparatus and its manipulation.

At the exit from the presses and the diffusors, the juice is received either directly into the carbonation boilers, or into a tank communicating with a pump or *monte-jus*, for filling the carbonators placed at a higher level. The *monte-jus*, pumps, and defecating and clarifying boilers have already been described at length under Cane Sugar (see pp. 256, 261–7), and do not require further mention here.

The carbonating boilers are of various forms. They are composed essentially of large rectangular tanks, Figs. 137 and 138, which should generally be of greater depth than width. Around their circumference passes a steam-worm *c* of large diameter to rapidly heat the mass of liquor. At the bottom of the tank runs a pipe *a*, which separates into two branches, or takes the form of the tank. This pipe is pierced beneath with small holes, whose total area is less than the section of the pipe; at the end it rises in front of the boiler, and bears a large tap *u* within the operator's reach. It then conducts to the source of supply of carbonic acid, and serves for the introduction of this gas into the boiler. The bottom of the boiler is inclined towards the front, and has in the lowest part a large plug *d*, or a tap for rapidly drawing off the liquid. Large thermometers should be attached for ascertaining the temperature.

FIG. 137 AND FIG. 138.



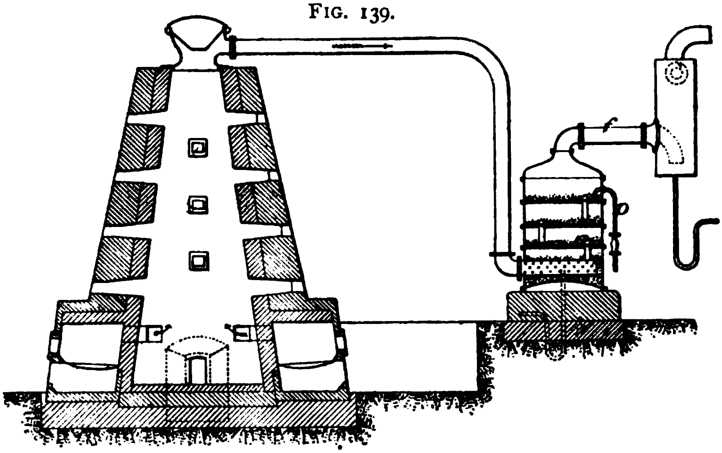
Carbonating Boilers.

The boilers are the same for the first and second carbonation, except that the first produces a tenacious scum which must be beaten down. This is effected in two ways: either by furnishing the boilers with strong offsets, and a cover provided with a long chimney, when the scum stops at a small height in this pipe; or by placing at the top of the boiler, throughout its whole length, perpendicular to the side where the workman stands, and on each side, two pipes of small diameter pierced laterally with little holes, through which steam is passed at high pressure. The steam escaping at the holes forms a draught which blows the scum back into the boiler. This latter apparatus, termed "Evrard's skimmer," works well, but requires much steam.

Below each carbonating tank is placed a decantation vessel, generally of the same form and dimensions. Into these the liquid flows when let out of the carbonators by the plug. These decantation vessels, whose floor is also inclined and furnished with a plug, have in front a large external tap, connected inwardly with a flexible tube furnished with a float which maintains the mouth of the tube at the clear surface of the liquor. When the turbid carbonated juice has been run into these vessels, it is allowed to settle and clarify itself, and is then decanted. The clear juice is received in a conduit which conveys it to the second carbonation, or to the filtration. When the float reaches the deposit, the workman closes the tap, opens the plug, and lets out the semi-solid mass into a trough connected with the filter-presses to be described presently. In some works, the decantation vessels are done away with, the operations being conducted in the carbonator.

The lime and carbonic acid employed in the operations are usually made at the factory. With this object, there is built near by a large continuous lime-kiln, as shown in Fig. 139. The gases escaping from the calcination of the limestone contain 25 to 30 per cent. of carbonic acid gas. The gases are drawn away from the exits of the kiln by the suction of a large pump, the speed given to the pump being regulated according to the state of the kiln. This pump forces the carbonic acid gas into the general pipe serving all the carbonators, which pipe is furnished with a safety-valve for

FIG. 139.

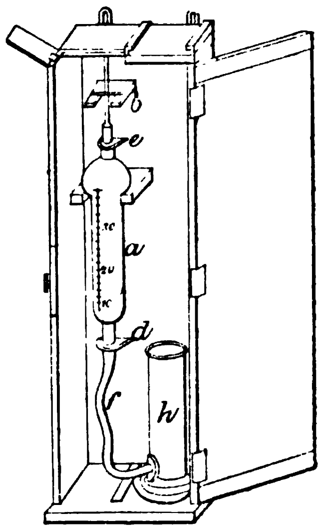


Lime-kiln for carbonating Beet Juice.

letting out the excess of gas supplied by the pump. Between the kiln and the pump, the gas traverses a "washer," a sort of vertical cylinder provided with perforated trays, entering at the bottom by a perforated pipe, and escaping at the top by the pipe *f*, while a stream of water, conveyed by the pipe *p*, falls in showers over the trays and comes into contact with the ascending gas.

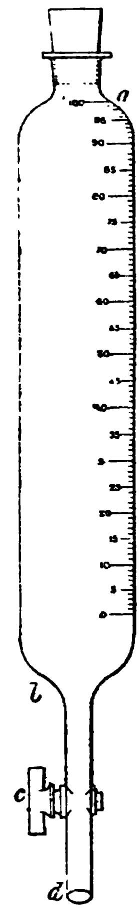
According to the richness of the gas, so the kiln is regulated. It thus becomes necessary to make frequent tests of the gas. A convenient instrument for this purpose is that of Possoz, shown in Fig. 140: *a* is a graduated glass tube; *h*, a vessel filled with water; *b f*, indiarubber tubes closed by pinch-cocks, *e d*. The tube *a* is filled with the carbonic acid gas with the usual precautions, and a few *cc.* of caustic potash are introduced at *b*, which is then closed; *a* is then taken in the hand and strongly agitated, that the potash may combine with the whole of the carbonic acid, and *d* is opened. The vessel *h* is next raised in the hand, till the level is the same

FIG. 140a.



Possoz's Carbonic Acid Gas-tester.

FIG. 141.



Wigner & Harland's Carbonic Acid Gas-tester.

in both the vessels, when the reading of the indicator in *a* gives the percentage richness of the gas.

A still more convenient apparatus for the purpose, which is much used, not only in sugar works, but in other factories, is that of Wigner and Harland, Fig. 141. It consists of a glass tube about $\frac{3}{4}$ inch diameter, and 16 inches long. It is furnished at the top *a* with a tapering neck fitted with an indiarubber cock; at the bottom, it terminates in a narrow glass tube *b*, provided with a stopcock *c*. It is graduated into 100 divisions. The lowest division (0) being at about ⅞ inch from the bottom, and the top division (100) at the base of the neck.

It is used as follows. The open end *d* of the narrow tube *b* is dipped into a saturated solution of caustic soda or potash, which is sucked up until the tube is filled to the 0 mark. The stopcock is then closed. The gas, when cool, is rapidly passed into the mouth of the tube for a few seconds by means of a leading tube, which passes well inside the apparatus. The contents are violently shaken for half a minute, and the tube *d* is immersed below water, and the stopcock opened. As soon as the water has risen in the tube, the cock is closed, and the shaking is repeated. Water is then admitted again in the same way, care being taken to level the water inside and outside the tube before the cock is closed. The reading on the scale gives the percentage of carbonic acid. If a solution of pyrogallic acid is now introduced, the percentage of oxygen can be determined in the same way.

The lime to be used in defecating is first slaked in special tanks furnished with agitators. It is then diluted with sufficient water, carefully strained, and constitutes a milk of lime having a density of 20° to 25° B.

Treatment of the Lime Scums.—The scums collected in the lime defecation process contain in the fresh state sugar, numerous nitrogenous matters, and other fertilising elements. Plicque, working upon scums, analysing

Water	52·70 per cent.
Sugar	3·50 ,,
Nitrogenous matter	3·72 ,,
Organic matter	9·24 ,,
Phosphates	4·77 ,,
Lime, silica, iron, &c.	26·07 ,,

obtained the following proportions of valuable products :—

Animal black	50·0 per cent.
Lime	35·5 ,,
Alcohol at 85°	2·0 ,,
Sulphate of ammonia	1·0–2·0 ,,

Much better value is thus obtained for the scums than by selling them in a crude state at a low price for manuring purposes.

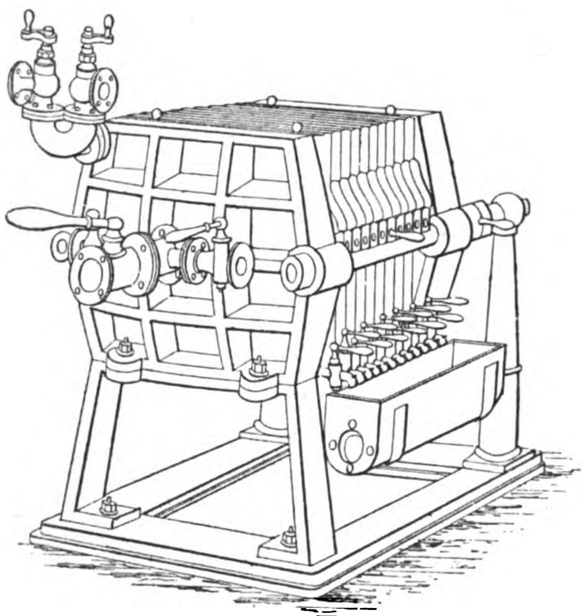
The method of treating the green scums to remove their excess of moisture is by the use of filter-presses. The scums of the two carbonations are collected in the same cistern, fitted with two *monte-jus*. The escape pipes from these *monte-jus* reunite into one, so that though the *monte-jus* are used alternately, there is no fluctuation in the supply of scum to the filter-presses. The systems most largely used are those of Trinks, and Durieux et Roettger.

Trinks's press, shown in Fig. 142, is composed of a series of cloth bags, held in all parts against metallic plates pierced with holes. The *monte-jus* forces the dirty liquid into these bags; the juice runs away clear, while each bag fills with the solid scum, which is strongly compressed by the action of the steam in the *monte-jus*. When the bags are full, the juice no longer escapes; then, to remove the superfluous moisture from the scum, steam alone is forced in. The system condenses and washes the scum, dissolving the last traces of sugar, and yielding a slightly saccharine liquor. The action of the steam is continued until, having forced a passage, it escapes at the lower part of the apparatus. Steam is then shut off, and the operation is concluded.

To enable the bags to be opened easily, they are formed of two quadrangular cloths put together, the four borders of which are pinched, two and two, between wrought or cast-iron frames, presenting only one opening for the passage of the scum and steam. The frames, and consequently the set of cloths forming bags, are separated by metallic plates, which permit the juices to escape; these juices run along the plates, and collect in a gutter closed by a tap, which serves to regulate the speed of the outlet, and even to suspend the working of a cloth, when it is torn for instance, without stopping the whole press.

Farinaux makes a press composed of plates analogous to those of Trinks. In the upper part of the frame are two bearers, on which is screwed a wrought-iron stirrup. A horizontal traverse is fastened to one side of the fixed frame,

FIG. 142.



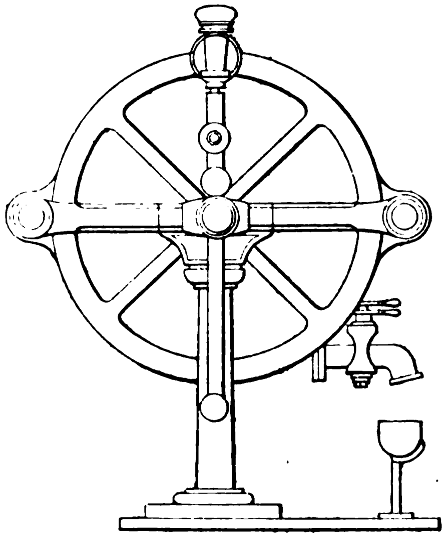
Trinks's Press.

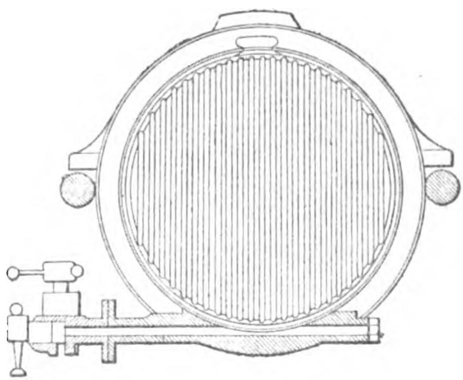
and passes through all the stirrups, supporting the frames. The advantages claimed for it are that it is easy to adjust all the frames to the same height, and that the dismounting and replacing of the frames is much facilitated. According to another plan of Farinaux's the working of the press is rendered largely mechanical, so that one labourer out of two is dispensed with. The bags are made of sail-cloth, and last 24 to 30 days, while those of jute endure only 5 to 8 days.

Durieux et Roettger's press is shown in Figs. 143 and 144.

Numerous other forms might be specified, but their effect is practically the same.

FIG. 143 AND FIG. 144.





Durieux et Roettger's Press.

Ammonium phosphate process.—A process was invented some years ago by Lagrange, chemist to the refinery of Guions, Paris, for separating the calcium and magnesium salts, with which beet sugar is especially liable to be contaminated, as may be gathered from the analyses at p. 481. The process was patented by the inventor, who, with the aid of Royer and Curely, sugar brokers, formed a company for working it. The calcium and magnesium are, according to this invention, thrown down as tribasic phosphates, by the addition of tribasic ammonium phosphate $(NH_4)3PO_4$ to the syrup.

Much, sometimes nearly the whole, of these earthy salts, exists in the form of sulphates, though a portion are usually chlorides or nitrates. Not only do the salts of the earthy bases exert a retarding influence upon the crystallisation of the sugar, with varying effect according to the particular metals they may contain, but the acids, especially if these be mineral acids, with which the earthy metals are in combination, would likewise appear to possess specific powers of their own, in retarding the crystallisation of more or less cane sugar.

Sulphuric acid would appear to be a most powerful retardatory agent, while phosphoric acid seems to exert little if any influence; small quantities of ammonium phosphate are indeed stated to rather favour the crystallisation. By Lagrange's process, it is simply and ingeniously contrived to not only get rid of the calcium and magnesium, but also, by one and the same operation, to precipitate and extract any sulphuric acid present.

A quantity of syrup having been made, the amount of sulphuric acid and earthy salts present is ascertained, the latter by means of the soap test. It is now heated to boiling, and a solution of barium hydrate in hot water is added in trifling excess beyond what is required to combine with and throw down all the sulphuric acid; this is immediately followed by an addition of ammonium triphosphate, equivalent to or slightly in excess of the total earthy metals. These will consist of any excess of barium hydrate that may have been added, together with any calcium or magnesium originally present.

A mixture of barium sulphate, barium triphosphate, and calcium and magnesium triphosphates, goes down, sweeping with it from the syrup some of the glutinous and colouring matters, with which beet sugar is invariably contaminated. The syrup is next passed through a Taylor filter, to separate the precipitate; if the operation has been properly conducted, the syrup should contain some free ammonia, and just a trifling excess of the ammonium triphosphate, but no earthy bases nor sulphuric acid. The syrup is now fit to be boiled and crystallised.

For some time after this process had been devised by Lagrange, it was found impossible to procure ammonium triphosphate at anything like reasonable prices, the only mode of manufacture being the production (1) of neutral ammonium phosphate, by saturating pure syrupy phosphoric acid with ammonia, so as to form a highly saturated solution of the salt, and (2) then adding one more equivalent of ammonia, so as to throw down ammonium triphosphate, which latter salt is only soluble in weak aqueous ammonia to the extent of about 6 per cent.

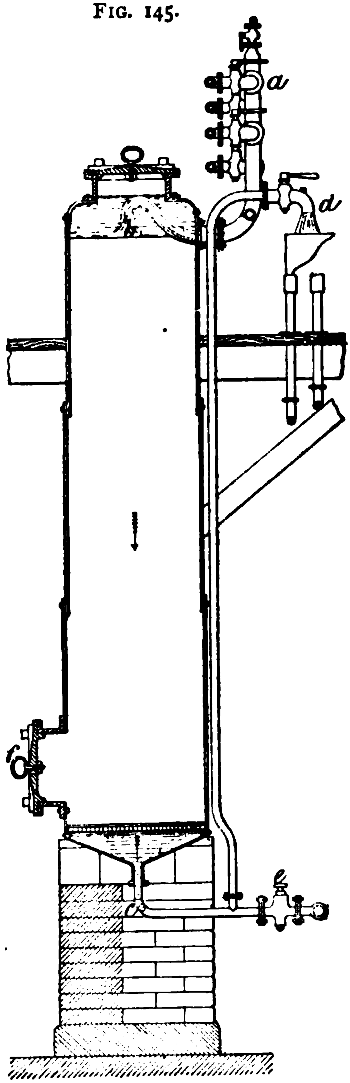
F. Maxwell-Lyte, however, introduced a method of producing pure ammonium triphosphate from the acid calcium phosphate afforded by natural phosphates, which at once reduced the price of ammonium triphosphate from 2*s.* 6*d.* a lb. to 8*d.* a lb., and thus placed the salt within easy reach of the sugar-makers. Guions, who employed the process in their refinery, state that besides affording an additional 5 to 10 per cent. of crystallised cane sugar, they are enabled to work with far less animal black (char), as the earthy phosphates not only carry down with them much glutinous matter, but also act as powerful decolorants on the syrup. The process is equally adapted to the defecation of raw beet syrups, and was worked for some time by Daniel, near Compiègne.

Filtration through Animal Black.—The defecated and carbonated juice has in a great measure lost its alkaline character having been deprived of the greater part of the dissolved lime by means of the carbonic acid. There is, however, still some lime to be removed, as well as a considerable quantity of gummy and albuminous substances. These, and the colouring matter which gives a brown tint to the juice, are in a large degree eliminated by passing the juice through animal black (char, animal charcoal). This is done by taking the juice from the carbonating pan into an iron cistern, and there heating it nearly to the boiling-point, afterwards passing it through vessels filled with granulated animal charcoal. The juice finds its way through this gradually to the bottom; and runs out while a fresh supply is poured in at the top. The charcoal has a considerable power of absorbing bodies such as dextrine, and with long time and hot liquor, as in the case of the beet juice, the action is intensified, and the purification materially great. The juice to be sent through the charcoal filters is a turbid sticky mass, owing to the changes that have been set up in it; pumps, therefore, cannot be used to elevate it, and recourse is had to the *monte-jus*, already described (see p. 256). After the filtration, the juice is in the condition known as "thin"; it is nearly colourless, and is largely freed from lime, and from gummy and albuminous bodies which escaped the action of the lime. In this state it passes to the concentrating system.

The filters used are of two kinds. The older sort, known as "Dumont filters," consist of cast-iron cylinders, 6 to 12 feet high, and 3 feet or more in diameter, open at the top, furnished with a false bottom covered with cloth, as well as a man-hole at the level of the false bottom. The cylinder is filled with black, and the juice is run in at top at such a speed that the black remains always covered with a thin layer of liquid. A pipe, leading from the bottom, curves up in the form of a swan-neck, to half-way up the cylinder.

The other kind, termed "closed filters," are shown in section in Fig. 145, and as a battery in Fig. 146. They have a diameter of 32 inches, and a height of 12 to 16 feet. The juice enters by a pipe *a b*, coming from a cistern placed at a higher level, and escapes by a pipe *c* leaving the bottom, and bent up to the summit *d* of the cylinder. This modification possesses the advantage of effecting the filtration in the absence of air and chills, and enables several filters to be in communication, so as to multiply the height of charcoal through which the juice passes.

FIG. 145.



Closed Charcoal Filter.

When a filter is judged to be no longer effective, as seen by the questionable colour of the liquor, the supply of juice is stopped and replaced by boiling water, and when the water has driven out the saccharine fluid, the tap *e* is opened at the bottom, the liquor is run out, the black is withdrawn at the man-hole *f*, and the filter is washed, and recharged with new black, over which a current of boiling water is passed. The filter is then ready for use again.

The animal charcoal used in these filters is rarely prepared in the sugar factory itself; but it usually there undergoes a washing operation, as well as a process termed "revivification," described further on.

BLAIZE FURNACE FOR REVIVIF

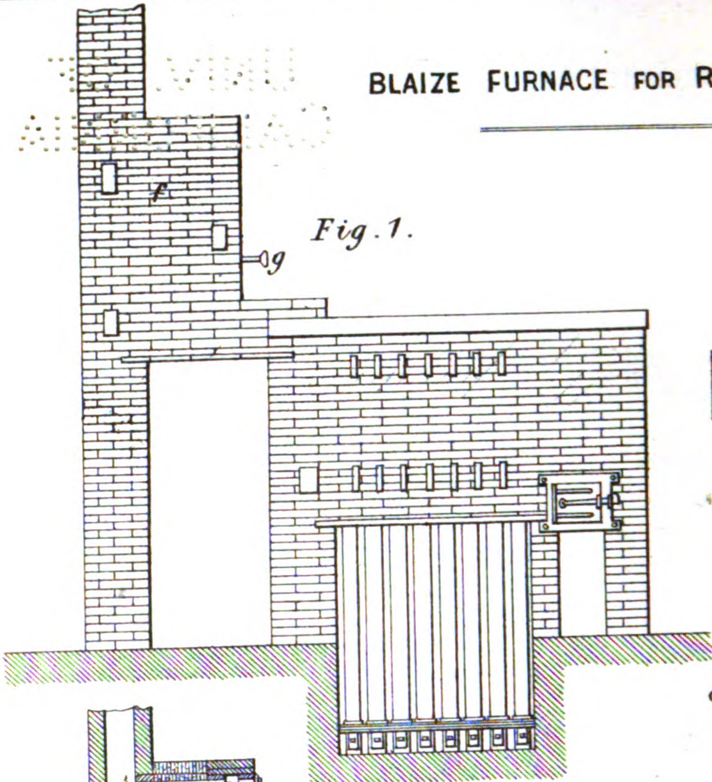


Fig. 1.

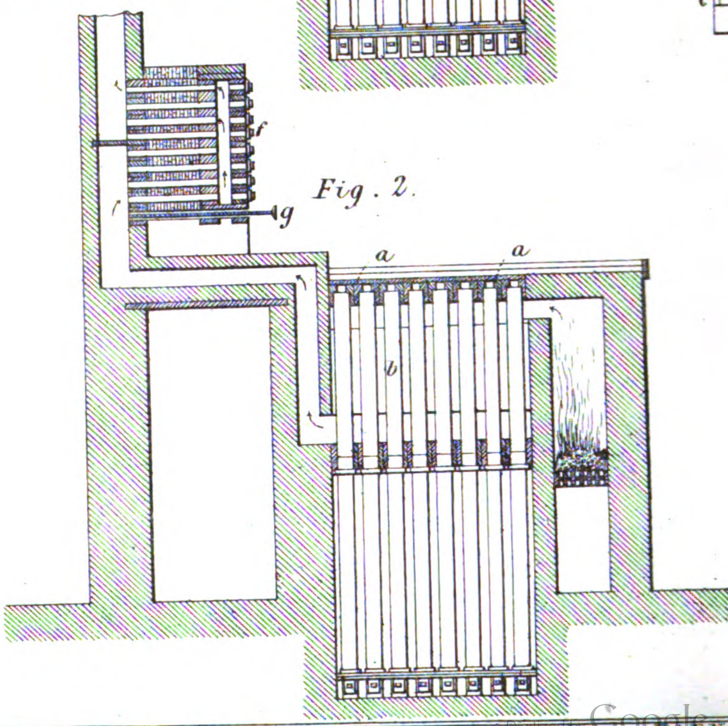


Fig. 2.

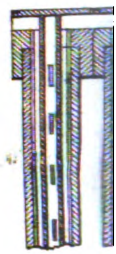


Fig. 5

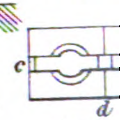


Fig.

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ING CHARCOAL.

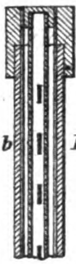


Fig. 6.

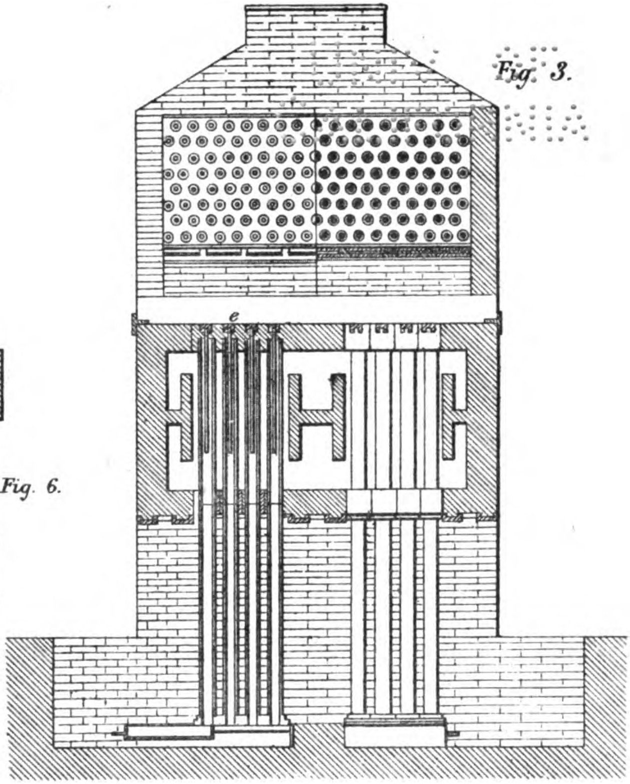
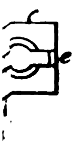


Fig. 3.



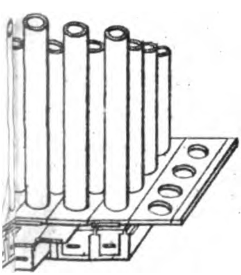


Fig. 8.

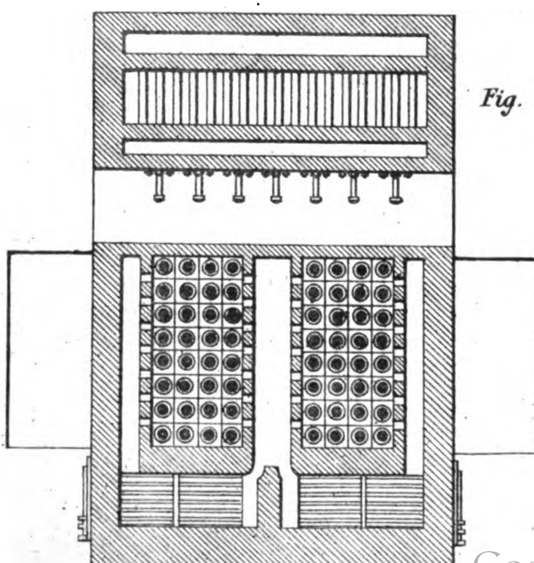
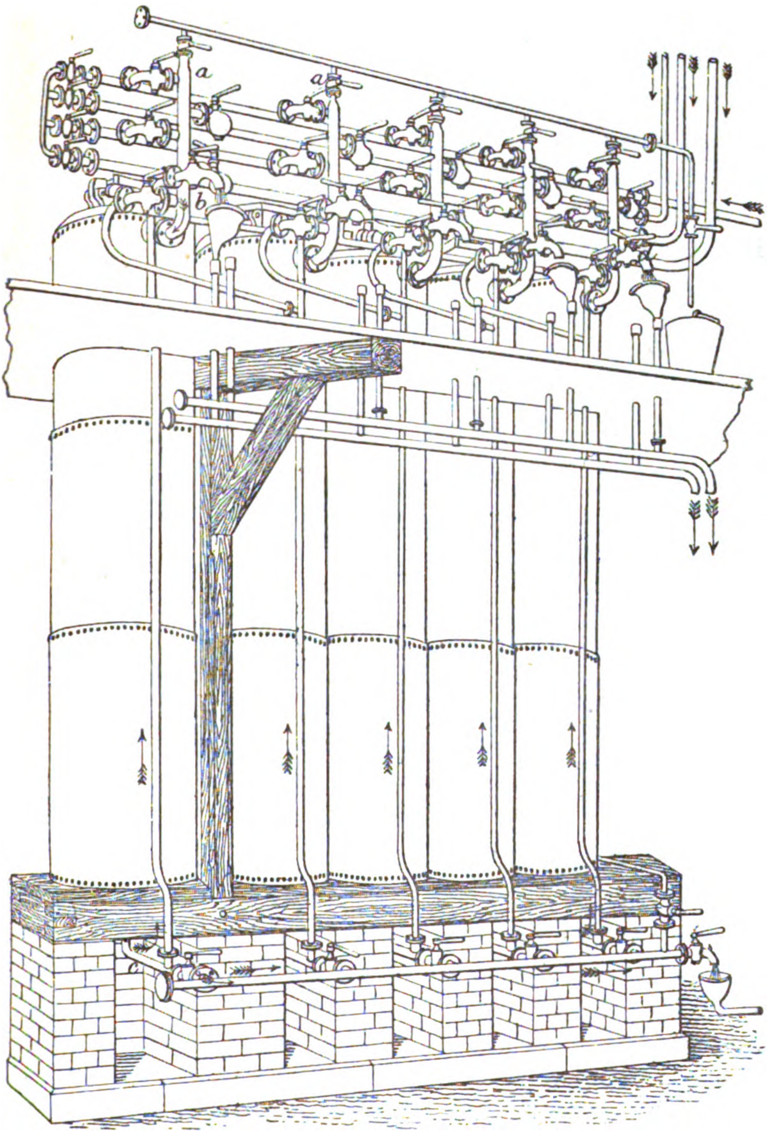


Fig. 4.

FIG. 146.

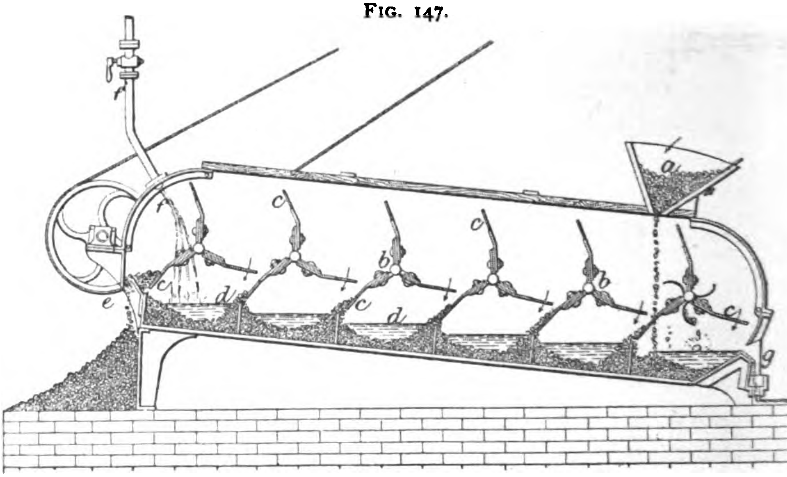


Battery of Charcoal Filters.

The washing is as follows. After having been subjected to fermentation, or to a treatment with alkali at 100° C. (212° F.), the black is washed with water till it ceases to communicate the least turbidity. Numerous machines have been introduced for carrying out these conditions, the main objects being to cleanse thoroughly, employ a minimum of labour, and avoid disintegration of the black.

A typical form of washer is Kluzemann's, shown in Fig. 147. It consists of a chamber divided by low partitions into com-

FIG. 147.

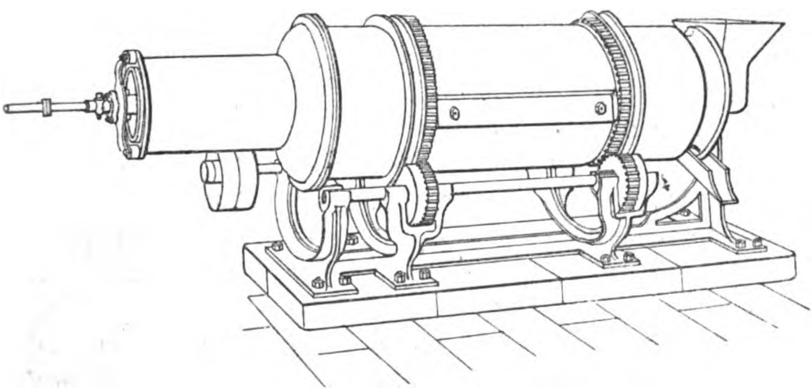


Kluzemann's Charcoal Washer.

partments *d*, in which slowly revolve arms *c* mounted on shafts *b*, and terminating in flexible iron blades. The black falls from the hopper *a* into the lowest part of the machine; it is successively passed from one compartment to the next by the revolving arms, each time attaining a higher level, finally reaching the upper end *e*, whence it is ejected completely washed. The water admitted by the pipe *f* passes in a contrary direction through the black, and runs out at *g*. The machine is cheap and efficient, and washes about 15 tons per 24 hours.

More recently, Schreiber, of Saint Quentin, has introduced a novel form of washer, Fig. 148, in which the black is placed in contact with a stream of water by means of its own specific gravity, without the intervention of any mechanical appliance to cause its disintegration. The machine consists of a horizontal air-tight cylinder, 6 feet long and 28 inches in diameter,

FIG. 148.



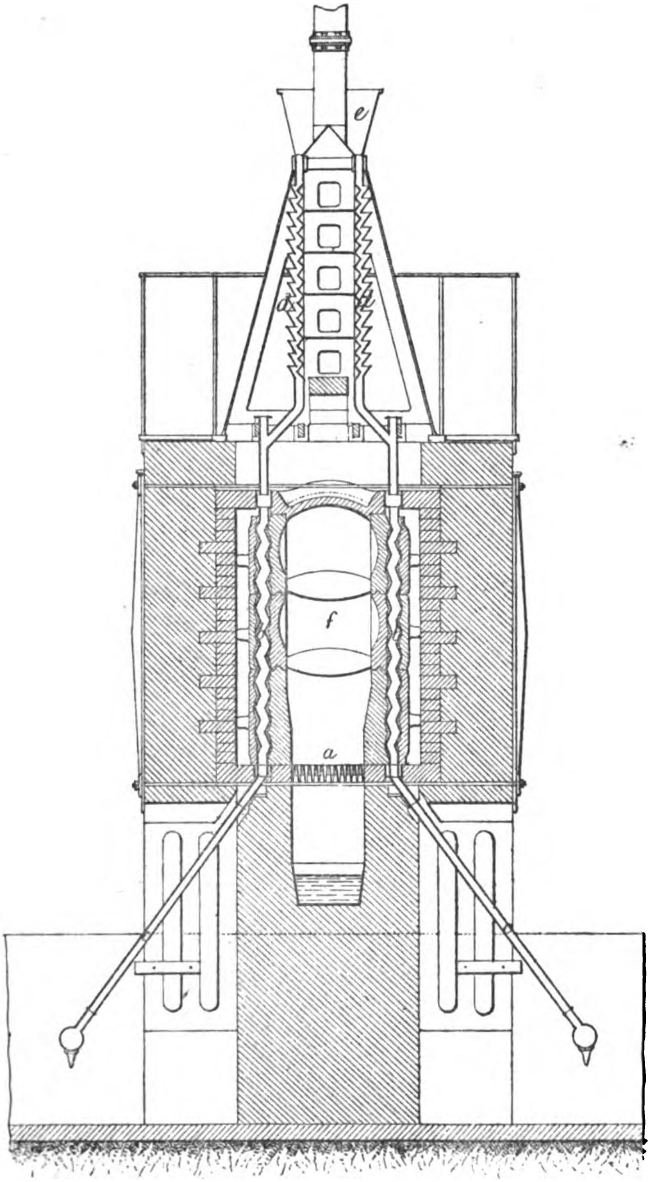
Schreiber's Charcoal Washer.

turning in external supports by means of toothed wheels engaging in toothed rings on the cylinder; in the interior of the cylinder are two paddles or curves. It is prolonged by a cylindrical part of less diameter. The pipe conveying water enters the cylinder at the axis of this smaller part. The black enters at the other end. In the centre of the cylinder revolves an endless screw, which catches up the black, and an annular space is left throughout the cylinder for the passage of the water. During the rotation of the cylinder, the black is continually lifted up by the paddles by the simple act of the rotation, and at the same time a certain quantity of water is taken up, and falls back into the same bath with the black. In this movement, the grains of black traverse the water, and the washing is effected without shock or injury. The paddles are so inclined, that the black entering at one end is propelled along one side to the other end, returning in the same manner along the other side, and escaping finally at the end where it entered. The machine is spoken of in the highest terms.

Revivification.—By "revivification" of the charcoal, is meant the separation from it of those saccharine and other matters which it absorbs in the filtering process, thus rendering it fit for re-use. With this object, it is fermented to destroy the organic matters; washed with acid, with hot water, with cold water, and with steam; dried; and finally calcined in furnaces of very various construction. These all consist essentially of a system of cast-iron or earthenware pipes, heated to dull redness, and closed at bottom by a method permitting the black to be withdrawn without admitting air, which would immediately cause the combustion of the red-hot carbon. This last condition is the one difficulty, and each maker strives to overcome it in a particular way.

Schreiber's kiln is shown in section in Fig. 149, and in perspective in Fig. 150. It consists of a drier, vertical undulating pipes for the calcination, and inclined cooling tubes, terminating in boxes for regulating the discharge of the tubes. The kiln is surrounded with masonry. On each side of the fire *a* are placed the rows of undulating pipes *b* made of cast iron, and each composed of three pieces, fitting one within another. They are prolonged downwards by flat tubes *c* of cast iron, serving to cool the black, and forming an angle of 45° with the vertical pipes *b*. At the top are similar undulating pipes *d*, with lateral openings forming Venetian blinds in front, and crowned by a hopper *e* for holding the supply of black for the kiln. This forms the automatic drier. The undulating pipes *b* serving for the revivification are plated inside and out with slabs of fire-brick; these protect the iron from the fire, and regulate the transmission of heat, preventing the temperature exceeding 375° to 450° C. (707° to 842° F.), beyond which the black might be vitrified.

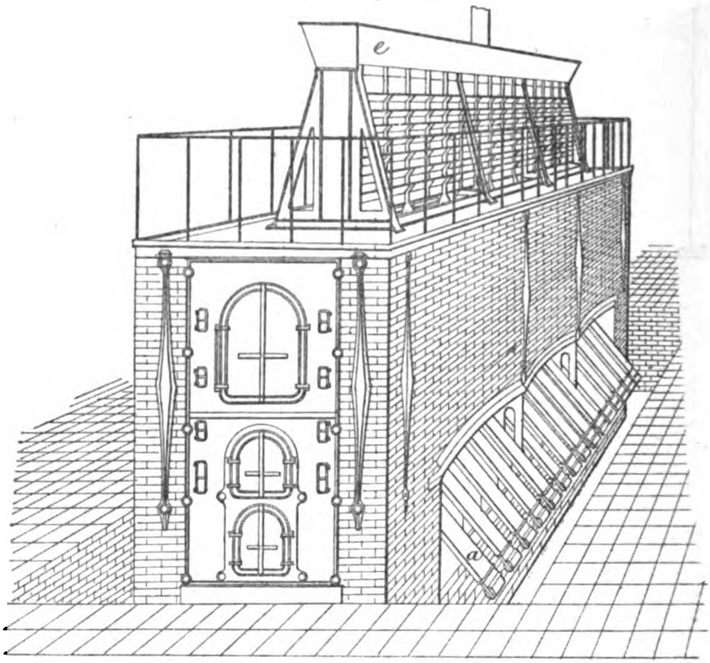
FIG. 149.



Schreiber's Revivifying Kiln.

The black is collected in the hopper *e* above; thence it descends into the driers *d*, enters the revivifiers *b* at about 90° C. (194° F.), and, when the operation is complete, escapes by the refrigerating tubes *c*. A fire of coke or other fuel being lit in the furnace *a*, the flame spreads throughout the whole

FIG. 150.

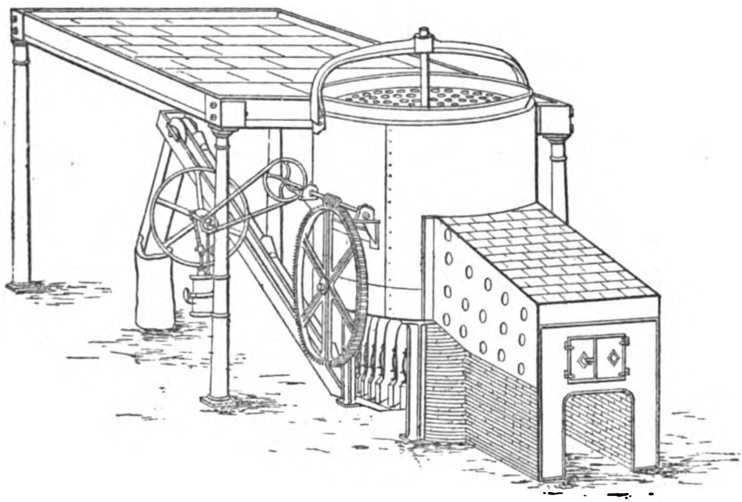


Schreiber's Revivifying Kiln.

space of the fire chamber *f* included between the two series of fire-slab coated tubes *b* and an arch at top, passes downwards, divides into two channels right and left, heats the backs of the tubes, and again rises into a single flue passing through the drier *d*. The kiln is easy to build and manage, and turns out a black of superior quality.

The Ruelle kiln, Fig. 151, has several advantages, and differs from most others in its general arrangement. It consists as usual of a series of revivifying and cooling tubes of cast iron. The whole of these are arranged in a bunch centred around a vertical axis, and suffer a slow, circular, automatic movement of two revolutions per hour, within a cylindrical furnace flanked

FIG. 151.



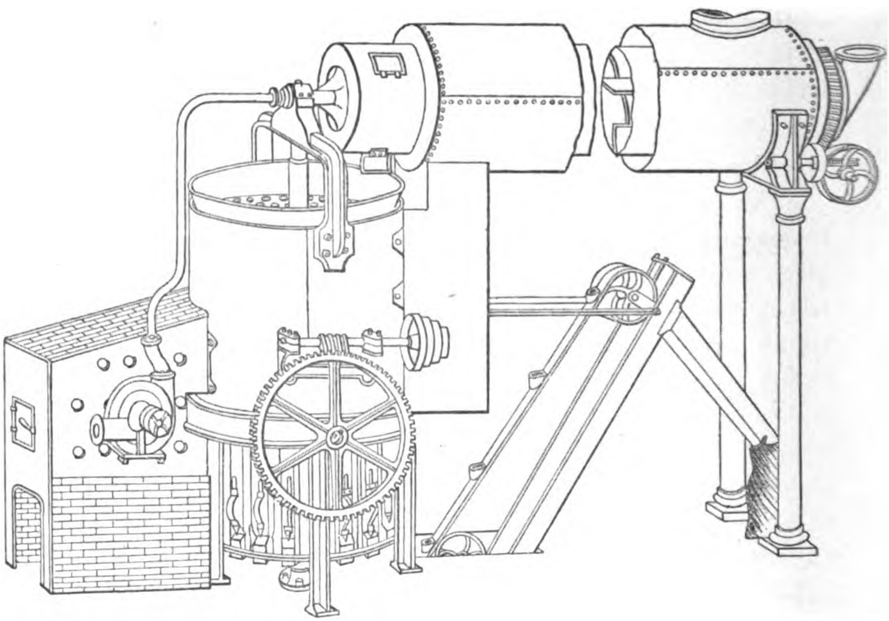
Ruelle Kiln.

by a lateral fire. The black is fed in a thin stream at the upper part of the kiln, and traverses the tubes, which are in turn presented to the fire, so that they are successively brought to a dull-red heat, thus ensuring regularity in the roasting, and avoiding those excesses of temperature which are always to be feared with fixed tubes.

The rotary movement of the kiln enables the discharge to be made automatically; each time a pipe reaches a certain point it meets a cam, which opens the outlet. A little elevator carries away the black as fast as discharged. The waste heat from the furnace circulates beneath a platform for performing the preliminary desiccation. This form of kiln is much used.

A recently improved form of the Ruelle kiln is shown in Fig. 152. In this kiln the furnace consists of a certain number of vertical retorts, designed for baking the black, and the upper extremity of which debouches into a hopper, into which the black to be revivified is thrown, while their lower extremity

FIG. 152.



Improved Ruelle Kiln.

debouches into cooling tubes. The whole is enclosed within a cylindrical casing of fire-bricks covered with plate iron. The first improvement added to the apparatus is the automatic method of emptying the tubes. With this object in view, the apparatus is so constructed that it may be revolved around a central axis by means of an endless screw and gear wheels. Each cooling tube is provided at its lower part with a distributing box of cast iron, and between this and the tube there is arranged a sheet-iron valve, provided with a steel spring which opens or shuts in passing into a bifurcation, and permits the black to enter the box. The distributing box is provided with a counterpoised door that is opened and closed by the same method as the valve just mentioned, so that on the second revolution of the furnace the black that is contained in the box falls over an inclined plane into a bag, or into a car.

Formerly the black to be revivified was, before being introduced into the retorts, dried upon a cast-iron table, which was heated by waste heat from the fire-place. For the last year and a half this table has been replaced by a mechanical drier.

This drier consists of two concentric sheet-iron cylinders, the external one of which is fixed, while the internal one is given a rotary motion through an endless screw and helicoidal wheel. This latter cylinder is provided internally with four spiral paddles, each forming a quarter circumference on the length of the cylinder, so as to constantly stir up the black and cause it to move forward progressively toward the furnace hopper. A furnace designed to revivify from 100 to 110 hectolitres of black every 24 hours contains 54 retorts, and burns but 5 hectolitres of coal. With the system of emptying the tubes just described there is a certainty of revivifying the same quantity of black—the latter remaining the same length of time in all the retorts. Moreover, as the latter receive the same degree of heat, the black will always be baked uniformly. The mechanical drier is not only advantageous because it is heated by waste gases, but also because it prevents the black from being crushed or wasted. In this furnace the internal cylinder is 6 metres in length by 0·85 m. in diameter at the entrance, and 1 m. at the outlet. The external one is only 6 metres in length, and its diameter is but 1·3 metres.

The apparatus is provided with a small blower for driving hot air into the movable cylinder. The bad odours from the black are thus forced out of doors.

The Blaize kiln is shown on Plate X., Figs. 1 to 8. Its most interesting feature is the manipulation of the revivifying pipes with regard to the escape of the gases and watery vapour during the heating. The black, after washing and vaporising, still retains some internal humidity which can only be driven off by calcination. If the kiln is charged with too wet black, this forms a plug at the top of the tube, preventing the escape of the vapour, which is thus forced throughout the column of black. The vapour, traversing the column of red-hot black, is decomposed, the carbon is calcined, and the combustible gases escape at the first opening which presents itself, usually between the joints of the pipes, dislodging them, to the deterioration of the kiln, the formation of white char, and the general interruption of the process. Ordinarily these evils are avoided by drying the black as strongly as possible before putting it into the tubes; the moisture then remaining can force a passage between the grains. In the Blaize kiln, the liberation of the vapours is facilitated in the following manner. The heads *a* of the tubes *b* are furnished with a transverse iron bar (Fig. 7), composed of two sections *c d d e*, united at *d* by a simple covering of sheet iron, and supporting in the axis of the pipe *b* another pipe (Figs. 5 and 6) of smaller diameter, made of wrought iron, pierced with slots throughout its whole length, and which, penetrating the mass of black to its hottest part, favours the ready escape of the vapours, and conducts them to the chimney.

The black reaches the tubes in a dry state, as it previously passes through the dryer *f*, a chamber traversed by a large number of metallic tubes, through which travel all the combustion-gases, and which can be cleaned by opening the end; *g* is a trap for discharging the dryer. As shown by the arrows, the black has to undergo many changes of position before reaching the floor, thus ensuring its complete desiccation.

The second important feature in the Blaize kiln, is the construction of the tubes, which are of enamelled fireware. Cast-iron tubes wear out rapidly, and unenamelled fireware tubes produce white char, by reason of their great porosity, which allows air to pass. There is no fear of the enamelled tubes suffering from the heat of the kiln, as the enamel is put on at a white-red heat, such as is never attained in the black-kiln. Finally, broken tubes can be readily mended by means of a special composition, and thus rendered as good as new. Moreover, earthenware tubes afford a much superior black to iron ones.

In the third place, the construction of the kiln is very simple, and obviates the use of arches, which never withstand fire well. The upper bed and the second floor are formed of square blocks of fireware, through the centre of which pass the tubes. The tubes support the blocks, so that the expansion is uniform, and does not damage the kiln. Broken tubes or blocks can be removed and replaced without pulling the kiln about. The second floor rests upon the cooling-tubes, which are of cast iron, and furnished at bottom with traps and drawers, facilitating the discharge of a set every 20 minutes (see Fig. 8).

The illustrations show two kilns, side by side. Any number can be so arranged.

Other forms of revivifying kiln are described under Refining.

Filtration through Gravel.—The substitution of gravel for charcoal as a filtering medium has been adopted with success in Hanover. The process was introduced by Otto Licht & Co., of Magdeburg, who hold the patent rights and charge a royalty for its use. It is said that gravel is as efficient as good char, and far better than inferior char, while in the matter of cost it is enormously superior, the first cost being very much less, and no outlay being incurred for reburning.

CHAPTER XV.

CONCENTRATION OF THE SYRUP.

THE next operation is the concentration of the "thin" juice, the removal from it of the excess of water, so that the liquid may become sufficiently dense, or saturated with sugar, to enable the latter to crystallise out. In this section, the treatment of cane sugar and beet sugar are precisely similar; but there are a few variations in the apparatus employed, the forms employed in the cane-sugar industry being largely of English manufacture, while those used in beet-sugar factories are essentially Continental.

The first step is to boil the watery liquor in a double-effect or triple-effect apparatus till so much of the water has been evaporated that the density marks 25° B. It is then known as "thick juice." It next goes to a cistern where it is heated to boiling, and again filtered through animal charcoal, by which more colouring matter is removed, as well as some albuminous bodies that are more readily absorbed from dense than thin liquors. After this second filtration, the juice is brilliant, transparent, and almost colourless, but still contains much water. This is finally removed by boiling *in vacuo*, by means of the vacuum-pan, already described at length under Cane Sugar (pp. 293–359).

CHAPTER XVI.

CURING THE SUGAR.

THE sticky mass of impure sugar crystals obtained from the vacuum pan has next to undergo treatment which will separate the crystals in a pure white state. The old methods of drainage have been described under Cane Sugar (see p. 360); in the beet-sugar industry, centrifugal machines are now exclusively employed for the first operation. The principles and construction of these machines have received detailed attention in a former chapter (see pp. 361–6).

First, Second, and Third Sugars.—The centrifugal charged with the dirty crystalline mass is made to revolve rapidly till the colour has changed to reddish, when, without stopping the rotation, a small quantity of *clairce* or pure syrup at 30° B. is poured in; the result of this is a clear yellow tint in the whole mass, whereupon dry steam is injected, and soon the sugar becomes perfectly white. This is termed sugar of *premier jet* or "first throwing." About $\frac{5}{7}$ of the total sugar recoverable in a crystalline form is obtained at this first treatment. The liquid flowing away thus contains the remaining $\frac{2}{7}$ of crystallisable sugar, besides that which is uncrystallisable. This liquor is run into large tanks, reheated, filtered through animal charcoal, boiled to a stringy consistency, and stored in cisterns during the whole period while the first sugars are being cured. It is then taken to be passed through the centrifugals, either alone, or with the addition of a little pure syrup, and thus affords a certain quantity of second sugar. The molasses drained from this in the centrifugals is stored in immense reservoirs in a room heated to 40° C. (104° F.), and termed the *salles des emplis* ("filling-room"). At the end of a year or so, these molasses are put through a centrifugal, and yield third sugars, with which are crystallised large proportions of saline impurities.

Yields.—The results ordinarily obtained in making beet sugar are as follows:—

100 lb. of beet afford 10 lb. of raw (uncured) first sugar, which loses 50 per cent. of its weight in the centrifugal, thus leaving 5 lb. of first sugars.

The flowings from the first sugars yield 82½ per cent. of raw second sugars, which, after curing, furnish 37½ per cent. of their weight of second sugars, or 1½ lb. on the 100 lb. of beetroot.

The curing of the second sugars gives a very variable quantity of molasses, which renders up about 19 to 20 per cent. of its weight of sugar, or about ½ lb. of third sugars on the 100 lb. of beetroot.

The molasses properly so-called contain 50 per cent. of sugar, and as they amount to 3 per cent. of the beet, they carry away 1½ lb. of sugar on the 100 lb. of beet, bringing the total yield of sugar to 8½ per cent., out of the 10 per cent. originally contained in the roots, the 1½ per cent. difference representing losses during manufacture. Thus

100 lb. of beetroot give

First sugars	5·00 lb.
Second "	1·50 "
Third "	0·50 "
Molasses	1·50 "
Losses: Sugar in the pulp	0·50 "
" " scums	0·35 "
" lost in the filters, &c.	0·59 "
Miscellaneous	0·06 "
Total	10·00

Thus the average yield of crystalline sugar from the beet is 7 lb. on the 100 lb. of root, or $\frac{7}{10}$ of what the root contains; while the final molasses take away as much sugar (which is lost so far as its sugar is concerned) as is represented by the actual yield of second sugars. The recovery of this 1½ per cent. of sugar in the molasses, and the better utilisation of the other constituents of the molasses, are subjects which have been much studied of late.

The treatment of the molasses is discussed in the chapter on Refining.

SORGHUM AND MAIZE SUGAR.

CHAPTER XVII.

THE saccharine value of the graminaceous plants known as North China cane, Guinea corn, millet, durra, imphee, sorgo, &c. (chiefly *Sorghum saccharatum*, *S. vulgare* and *S. caffrorum*), has for ages been recognised in Africa and China ; and it would seem that sugar was extracted from maize (*Zea Mays*) by the ancient Mexicans. Of late years, new attention has been attracted to these plants as sugar-producers, principally in the United States, but to a less degree also in Canada, Australasia, India, England, and France. It does not appear, however, that they possess any solid advantage over beet, not to speak of cane.

Qualities.—The cultivation of sorghum, maize, and pearl millet, and the manufacture of sugar from their stalks, have been made the subject of elaborate and extensive experiments by the Department of Agriculture in the United States.

These investigations appear to demonstrate that there exists little difference between the various kinds of sorghum as sugar-producing plants; and, that each of them is, at a certain period of its development, nearly as rich in sugar as the best sugar-cane. It is a matter, also, of importance that this maximum content of sugar is maintained for a long period, and affords sufficient time to work up a large crop.

From the results of analysis of the plants in successive stages of development, it has been observed that the amount of uncrystallisable sugar diminishes, and the amount of true cane-sugar increases. It has also been observed that the plants differ widely in the date when the crystallisable sugar is at its maximum, but are alike in that the maximum is attained at about the same degree of development of the plant, viz. at full maturity, as indicated by the hard, dry seed, and the appearance of off-shoots from the upper joints of the stalk.

Taken as a whole, the several series of analyses were convincing, as showing the rate and progress of development of saccharine matter in the plant. Analyses were made of several sorghums after they had been subjected to a very hard frost, sufficient to have formed ice ½ inch thick, and this cold weather continued for four days before the examination took place. There appeared no diminution of crystallisable sugar in either of the stalks examined, and no increase of uncrystallisable as the result of this freezing and continued exposure to a low temperature. An examination was made after a few days of warm weather had followed this cold spell, and the influence of this subsequent thaw was noticeable in the diminution of crystallisable sugar in each specimen examined.

From this, it would appear that the effect of cold, even protracted, is not injurious to the quality of the canes, but that they should be speedily worked up after freezing, and before they have again thawed out. This is a matter of such practical importance that some experiments should be made to learn whether the syrup prepared from the juice of frozen cane differs from that prepared from cane not frozen, but in other respects of like quality.

The relative weights of the different kinds of sorghum experimented upon were as follows:—

Early Amber, average of 40 stalks	1·73 lb.
White Liberian, average of 38 stalks	1·80 ,,
Chinese, average of 25 stalks	2·00 ,,
Honduras, average of 16 stalks	3·64 ,,

Since these were all grown side by side, and upon land presumably of equal fertility, it will afford the data for calculating the relative amount of each variety to be grown per acre.

The Early Amber and Liberian closely correspond in their development, being almost identical. While these two varieties attain a content of sugar in their juices equal to the average in the juice of the sugar-cane by the middle of August, the Chinese does not reach this condition until the last of September, and the Honduras not until the middle of October. After having attained approximately the maximum content of sugar, this condition is maintained for a long period, affording ample time to work up the crop.

An average of all the examinations of the four sorghums during the periods when they were suitable for cutting gives the following results:—

Early Amber, from August 13 to October 29 inclusive, gives 14·6 per cent. crystallisable sugar.

Liberian, from August 13 to October 29 inclusive, 13·8 per cent.

Chinese, from September 13 to October 29 inclusive, 13·8 per cent.

Honduras, from October 14 to October 29 inclusive, 14·6 per cent.

Varieties.—The United States Department of Agriculture now have over 30 varieties of sugar-producing sorghums, all of which are valuable to a greater or less degree, according to the varying soil, climate, cultivation, seasons, and process of manufacture. That other useful varieties are to be obtained is beyond doubt. The so-called "Honduras sorghum" is only one of the kinds indigenous to Honduras; and there are probably several varieties growing in Central America, and even as far south as the Rio de la Plata in South America.

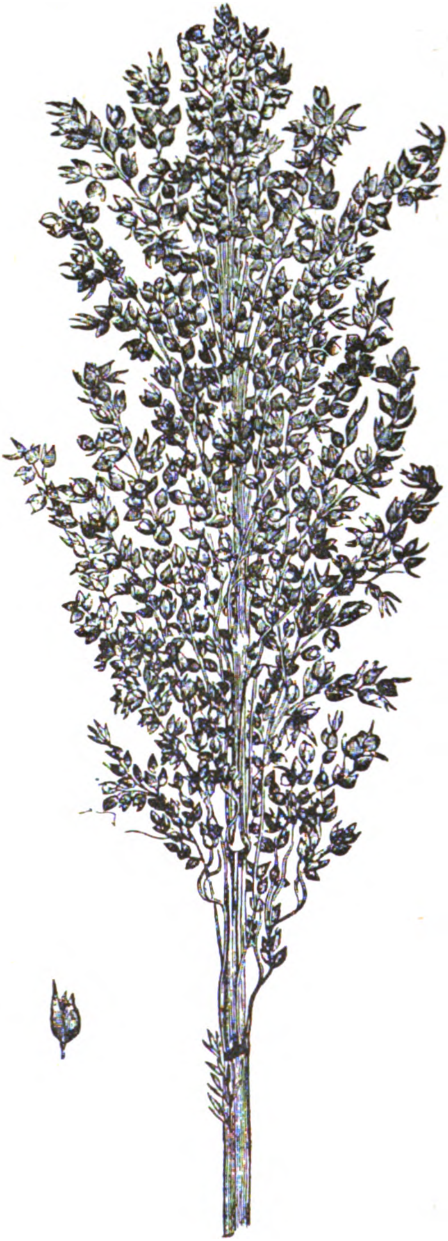
The Early Amber cane is the favourite variety with planters in Minnesota and the North-west. What is now called the Minnesota Early Amber cane is claimed as an improvement upon the Early Amber varieties growing formerly in different parts of Minnesota, by Hon. Seth M. Kenny and C. F. Miller. Acting on the theory that cane in a high latitude will degenerate if grown continuously from its own seed, these gentlemen selected the finest specimens of seed from their own crops and sent them to the southern latitude to be grown. The seed product of this southern growth was returned to Minnesota. By this alternation of seed, and by other intelligent processes of culture, they have succeeded in establishing a new and permanent variety, which they claim to be more productive in weight of cane and to contain a higher percentage of saccharine matter than any other grown in that State. This claim needs to be substantiated by more careful and extended observations before it can be said to be fully established.

Kenny and Miller describe the Early Amber cane as presenting "the characteristics of both sorgo and imphee." By sorgo, they mean the Chinese sorgo, and by imphee, the White Liberian, and its kindred African varieties. The Early Amber receives its name from its early ripening, and from the bright amber colour which characterises its syrup when properly made. It is very rich in saccharine matter. When scientifically treated, its products are destitute of that peculiar "sorghum" taste formerly complained of; the flavour is very similar to that of pure honey. The syrup readily granulates, and yields sugar equal to the best ribbon sugar-cane of Louisiana.

The Early Amber cane on the Department grounds did not grow quite so tall as the White Liberian. Its seed-heads were of moderate fulness and of very dark colour. A head of Early Amber cane is shown in Fig. 153.

The Chinese sorgo cane grown on the Department grounds was about the same height as the Early Amber. Its seed-heads are fuller and more compact, and somewhat resemble

FIG. 153.



Early Amber Cane.

FIG. 154.

Chinese, or Sumach Cane.

a head of sumach; hence the synonym "Sumach cane." It is also known as "Chinese cane." A head of Chinese cane is shown in Fig. 154.

The White Liberian cane is rather taller than the Early Amber. The stalk curves at the top, leaving the head pendent; hence the synonym "Gooseneck." It is also styled a variety of the White Imphee. The seed-heads are shorter, more compact, and of lighter colour than the Early Amber. A head of White Liberian cane is shown in Fig. 155.

The Honduras cane grows about one-half taller than either of the above varieties. Its seed-top is of reddish brown and spreading; hence its synonym "Sprangle Top." It is also called "Mastodon" and "Honey cane." A head of Honduras cane is shown in Fig. 156.

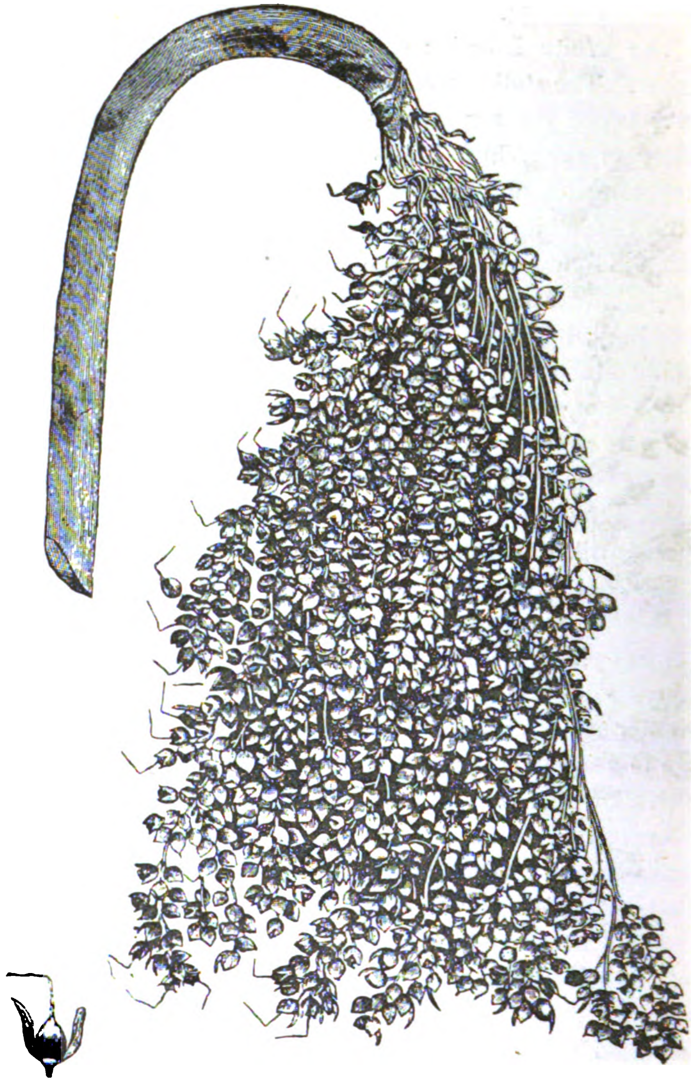
Cultivation.—A convention of the Early Amber cane growers and manufacturers of Minnesota was held at Minneapolis, January 22, 1880. An abstract of the opinions expressed will be interesting.

Soil.—There were some differences of opinion as to the availability of new land, and experiences varied. Some feared that new land would impart a strong flavour to the syrup. Others said that while old land might produce a syrup of brighter colour, it was not at all better in taste. An advantage in using new timber land is found in the small amount of cultivation required. Costly culture on old land will not pay in opposition to cheap culture on new land. New land is comparatively free from foul seed, and consequently less liable to a troublesome growth of weeds.

Some contended that old land required less cultivation and produced better results. It was suggested that, if it were necessary to clear old land of weeds, or to fertilise it with barn-yard manure, a crop of corn should be grown upon it before planting the cane. The general opinion was in favour of a sandy upland soil, well drained, but not freshly manured.

In regard to manuring, facts were alleged to show that it

FIG. 155.



White Liberian Cane.

spoiled the flavour of the syrup. A farmer had selected for his cane patch an old cow-yard. The stalks were tall and

FIG. 156.—Honduras, Mastodon, Sprangle Top, or Honey Cane.

luxuriant, but the syrup would nearly "take off the skin of the mouth."

The great majority of opinion was in favour of the indefinite repetition of this crop on the same soil. The president of the convention mentioned the case of a neighbour who had cultivated the same ground most successfully for seven years without deterioration, his product ranging from 250 to 300 gallons of syrup per acre. Day and Dyer, of Hastings, corroborated this opinion from their own experience. The latter thought that his continued crops improved not only in quantity, but also in quality.

The soil required for the cane is not necessarily very rich. A man planted several knolls, too poor for wheat, in cane, and realised 200 gallons per acre of excellent syrup.

Preparation of the Ground.—The general opinion was in favour of fall ploughing, putting the plough to the beam. This caused all foul seed and especially pigeon grass to germinate in the fall, and to be killed by winter freezing. Another advantage of fall ploughing was that the crop was less liable to injury from droughts in the early season. Bozarth, of Iowa, after twenty-one years' experience in raising cane, was decidedly in favour of fall ploughing. In one case, a portion of his cane patch, reploughed in spring, yielded but half as much syrup as that which had been only fall ploughed. On the other hand, E. A. Chapman, of Wyndham, demonstrated that a very large crop of cane can be raised the first year on the open prairie and at the first breakage. He had broken 2 acres with the La Dow harrow, harrowing it completely, and it produced the best cane out of 5 acres. It was planted June 1, on black, loam soil. He believes that with the La Dow harrow large crops can be raised on new breakings. Those who practised fall ploughing were careful to stir the ground in the spring, in order to destroy the weeds. When the ground becomes sufficiently warm in the spring, some go over it with the Beaver Dam seeder, and then with the drag and roller.

This treatment effectually disposes of the grass, which point was generally considered of first importance.

Time of Planting.—There was some discussion on this point. The majority were of opinion that the cane should be planted as early as it is possible to work the ground properly, avoiding late frost.

The ground should be well warmed before the seed is placed in it. In Minnesota, the average seeding time is in the fore part of May, though several growers had been successful with plantings still earlier. The president of the convention thought that planting should not be quite so early on ground impregnated with grass seed. Wiley advised against planting till the season was warm enough to germinate the seed quickly. He had had later plantings which produced better than some earlier ones. A late spring frost might cut down early plantings, and, before they grew again, the pigeon grass was apt to start up profusely. Wood had seen a field of cane some 8 to 10 inches higher than a neighbouring field. He found that in the former case the seed had lain in the ground all winter, and the latter had been planted early in spring. Experience and discretion were considered requisite to settle for each locality the exact time of planting, as they are in all other cultures.

Seed.—It was suggested that by steeping the seed in warm water for 24 to 48 hours it would become sprouted, and hence would grow more rapidly. But, on the other hand, it was urged that a dry season would kill the sprouted seed, and the crop would be a failure. Nature provides the most opportune moistening.

The weight of opinion was decidedly in favour of seed brought from the latitude of St. Louis. Some cane-growers had sent their seed to Missouri and Kansas to have a crop grown and its seed returned. Among the decisive facts reported, Miller stated that his seed imported from Southern Indiana 11 years before had produced, on its first sowing, stalks 12 to 15 feet high; but by planting the seeds of each crop, its successor showed a declining height of cane, until it grew but 7 or 8 feet high. Wiley had averaged, with seed brought from the south, 273 gallons per acre; the following year, using his own seed, he obtained but 223 gallons, a falling off of 50 gallons. The president of the convention had found, as a general thing, that the deterioration of seed was not very marked till the third year. The Southern seed did not excel so much in an earlier ripening of the crop as in its increased product, the excess, in some cases, amounting to one-third. The sentiment of the convention was expressed in the resolution that Early Amber seed, grown in the latitude of St. Louis, is the best seed for Minnesota for two years.

The seed has a value of its own for consumption on the farm. It was pronounced excellent for feeding hogs, sheep, or poultry. The 5 or 6 tufts growing upon a hill of cane were estimated as equal in feeding value to three average ears of corn. A member of the convention pronounced it equal to oats. Another had found that the seed fed to sheep made the fleece look lively and polished.

Planting.—Plant just deep enough to secure moisture. Hence, earlier plantings should be shallower than late ones. There was some difference of opinion as to the arrangement of the hills. The president of the convention plants in rows 3½ feet each way, and uses 2 lb. of seed per acre, or 6 or 7 seed to the hill; at the second hoeing, he thins them out. Day marks the rows 3 feet each way. Seed should be planted not down in the trough of the marking furrow where a heavy rain is apt to wash it away, but on the edge. Wiley plants at 15 to 18 inches one way and 3 feet the other way, the rows running north and south, thus doubling the number of hills planted by Day. A tract of 4 acres sown broadcast was reported as producing at the rate of 450 gallons per acre.

Miller practised stepping upon the seed as they were placed in the ground. Several planters present sanctioned this practice, urging that the close pressure of the soil round the seed enables it to germinate more rapidly. It was objected that stepping the seed caused the ground to bake, but it was replied that this was the case only with wet clay ground.

Cultivation of the Crop.—The leading point presented in the culture is keeping clear of weeds. This requires prompt action with the hoe, drag, and cultivator. A grain farmer suggested the use of Thomas's harrow, of 90 steel teeth, but the general sentiment was that the cane-plants were too tender for any such treatment. It should be thoroughly hoed, until large enough to cultivate with the plough or cultivator.

Time to Cut the Cane.—Whiting had found the best results from early cuttings, but admitted that in the later cuttings it was the extreme hot weather that had changed the crystallisable to uncrystallisable sugar. The president thought the proper time was when the seed is in the stiff dough, or from August 28 to September 1. It seems to improve for a few days, but afterwards it begins to decline in saccharine matter. The earlier the cutting after the seed has reached the dough stage, the larger the product, and the brighter and cleaner the syrup. The question of suckering was considerably debated, and facts both *pro* and *contra* were alleged, but the convention expressed no collective opinion.

Harvesting.—The question of stripping the leaves elicited considerable discussion. On the one hand, it was urged that if the leaves were put through the mill with the stalk, they would absorb a large portion of the juice. It was replied that this would not be the case with mills of sufficient power. Force enough should be applied to express the whole of the juice. It was complained that cane-growers lost a great deal by purchasing cheap and poor machinery. One gentleman estimated the cost of stripping the leaves before cutting at $15 (3*l.*) per acre. Some advocates of stripping were disposed to admit that it would not pay unless labour were plentiful and cheap. The Commissioner of Agriculture stated that the department experiments showed little or no difference between stripped and unstripped cane, although the department mill was an indifferent one. Several urged that if the leaves were dry they would not in any way affect the quality of the syrup. The convention did not express any general opinion upon this point. It was considered of first importance that the tops be completely removed, as a single top sent through the mill would spoil a large amount of syrup.

The cane should be cut, some say, at 6 or 8 inches from the ground, and others, at the first joint The top should also be cut off from 18 inches to 2 feet; there is no sweetness in either the tops or the roots. Some planters laid the cane in windrows, and others were opposed to the practice, as exposing the leaves, if not the stalks, to mildew. The storing of cane after cutting started discussion. Some insisted that it should be immediately placed under cover to avoid the evaporation by the sun's rays. Others piled in ridges 4 feet high, and covered the mass with marsh hay. To this it was objected that the lack of ventilation would spoil the cane. To obviate this difficulty, some planters were in the habit of laying poles along the piles every 2 feet, in order to admit fresh air. Some would pile it as sugar-cane is sometimes piled in the field, crossing the hills in such a way as to secure ventilation, and to shed the rain. Crops that had been kept in these different ways for several weeks were reported as having produced large and fine syrup returns. One planter produced juice that ranged from 7° to 10° B. from cane that had been stripped and covered with leaves, while other cane of the same lot, that had been ground with leaves on, ranged as high as 12° B. Dr. Goesman, of Massachusetts, was quoted as saying that there was a gain of 3 per cent. by being allowed to lie with the leaves on. One planter had found such a cane to test 11° B., while stripped cane tested only 10°. The higher per cent., however, was by many attributed to the evaporation of the watery part of the syrup, leaving the saccharine matter in larger proportion to the residue. Others had not found the juice to be any sweeter after evaporation.

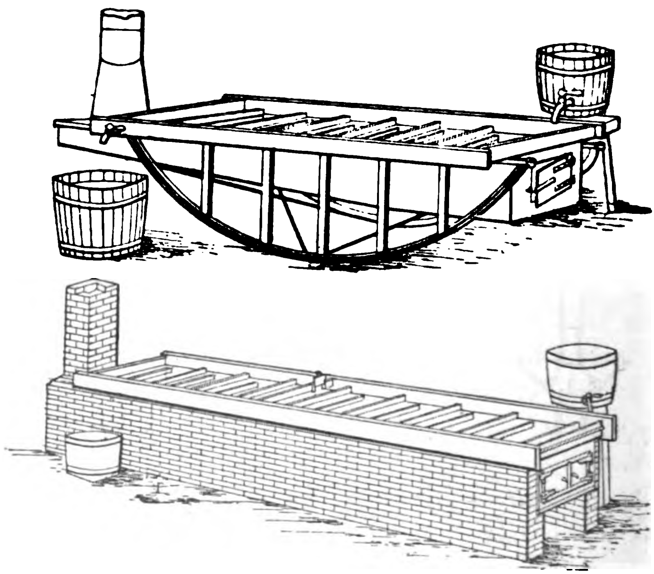
Transport of Cane to the Mill.—Wiley thought it would pay every farmer to have his own mill. The price of the syrup in the market ranged from 36 to 50 cents (18 to 25*d.*) per gallon. The mill owner will charge 15 to 25 cents (7 to 12*d.*) per gallon; if to this be added a charge, say of 10 cents (5*d.*) per gallon, for hauling to a distant mill, it is easily seen that the grower gets but a small proportion for his labour. It is better for the farmer to have the profit of manufacturing the cane, as well as of raising it. In moving the cane from the field, there was a strong expression in favour of bundling it. Some would decapitate it with a broad axe, after binding. Some used a common dump-cart with an elongated box. The points kept in view, both in the transportation and in the storing of the cane, were protection from the weather, and such ventilation through the mass as would prevent mildew.

Manufacture.—The extraction of the juice from sorghum, and its conversion into sugar, is almost an exact repetition of the operations connected with the manufacture of cane sugar. The machinery and apparatus are identical in principle and purpose, but are usually constructed on a much smaller scale, as well as being often of a portable nature.

Crushing Mills.—These resemble those used for sugar canes, but are of lighter construction.

Evaporators.—Figs. 157 and 158 show respectively a portable and stationary Cook evaporator, made by the same firm. The former consists of pans 44 inches wide, and 6 to 9 feet long, ranging in capacity from 40 to 90 gallons a day. When the pans are of galvanised iron, they cost about 13*l.* to 17*l.*; when of copper, 11*l.* to 14*l.* more. Each contains a portable furnace. The whole can be lifted into a wagon by two men, and conveyed thus from field to field. The stationary evaporators are made in 7 sizes, 44 inches wide, and 6 to 15 feet long. With a capacity of 40 to 180 gallons a day, the prices are 6*l.* to 18*l.* for galvanised iron, and 16*l.* to 42*l.* for copper.

FIG. 157 AND FIG. 158.

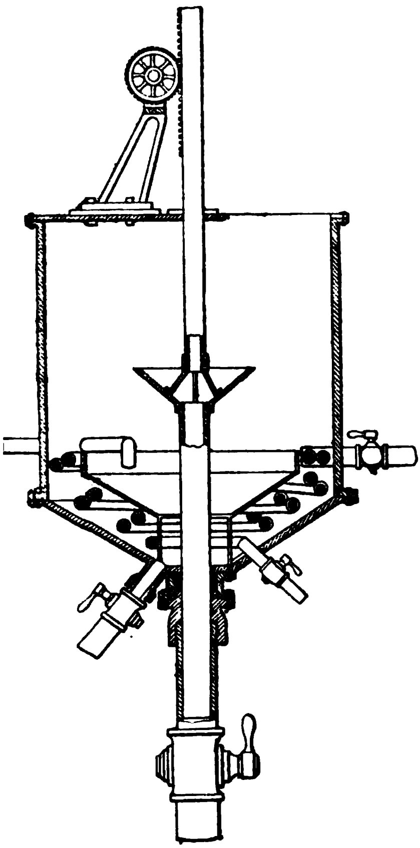


Cook Evaporators.

Fig. 159 shows McDowell's evaporator, 6 feet in diameter and 2 feet deep. It is furnished with steam coils 125 feet long, and a diaphragm directing the currents of evolution over the steam-coils, up the outside, and down the middle axis. In the centre is an adjustable funnel-shaped skimmer, which can be raised or lowered to the level of the boiling juice. It catches the scum, and delivers it by a pipe through the bottom of the evaporator. Two evaporators will reduce 600 gallons of defecated juice by one-half in 1½ hours.

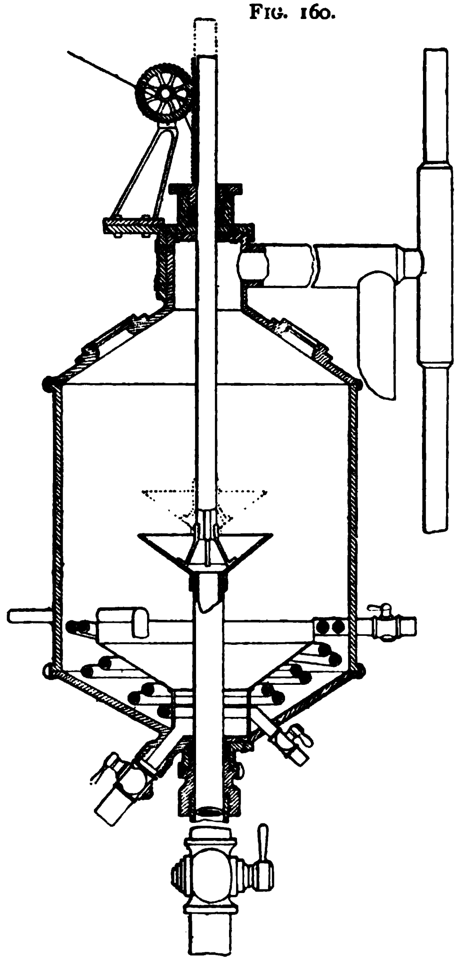
McDowell's concentrator, Fig. 160, differs in having a closed top and a water-jet condenser, producing a vacuum. In this, 600 gallons of evaporator juice are reduced to 200. The product is then "semi-syrup," and can be stored, or shipped to a refinery, or further reduced in a vacuum-pan.

FIG. 159.



M'Dowell's Evaporator.

FIG. 160.

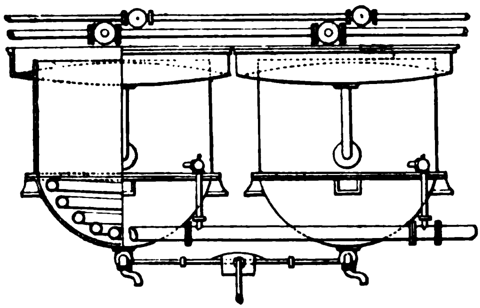


M'Dowell's Concentrator.

Fig. 161 is a direct steam evaporator, which boils clarified juice by means of a steam-coil, the scum passing over into the trough around the upper edge.

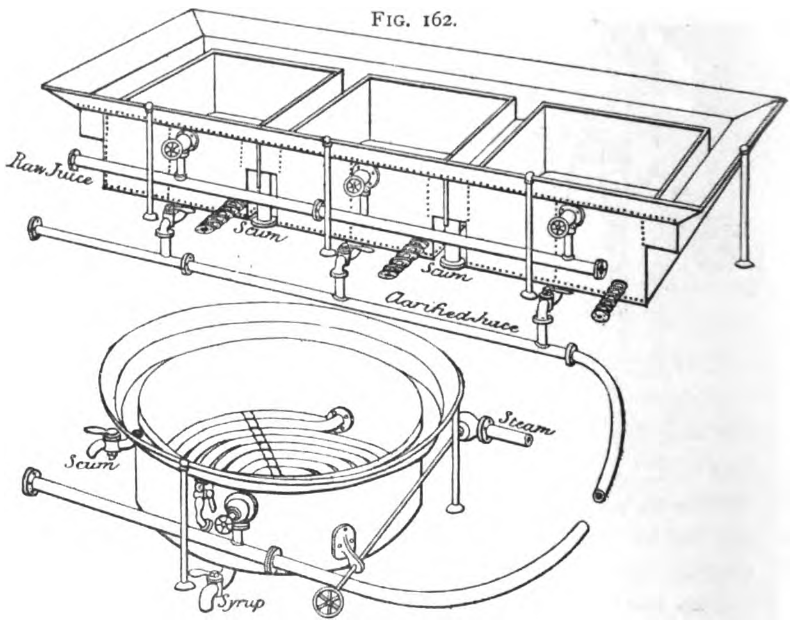
Fig. 162 is a steam train made at the Colwell Iron Works, New York. It consists of 3 clarifiers, and an evaporator, requires little labour, dispenses with pumps and ladles, and finishes the syrup up to the vacuum-pan.

FIG. 161.



Steam Evaporator.

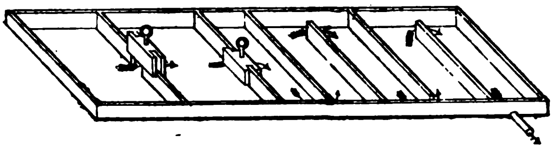
FIG. 162.



Colwell Steam Train.

Fig. 163 is a cheap home-made evaporator, which can be put together by an ordinary mechanic. It is constructed by putting wooden sides and ends upon a galvanised iron or copper tray.

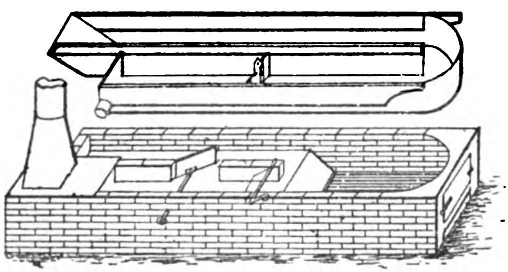
FIG. 163.



Home-made Evaporator.

Fig. 164 shows Stubb's evaporator. The first compartment occupies $\frac{3}{4}$ of the whole pan, leaving $\frac{1}{4}$ for the second. The juice enters the first compartment near the smoke-stack in a regular stream, passing round the semi-circle over the fire-box to cross-partitions, where it thickens to a semi-syrup

FIG. 164.



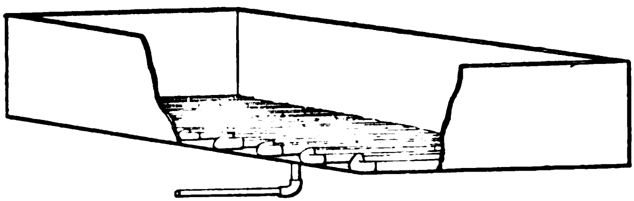
Stubb's Evaporator.

Being over the hottest part of the furnace, it rises to a light foam, which breaks to the lowest point when the cool juice enters, not only keeping back the green scum, but carrying all the scum off 30 feet of surface, where it is scraped off without loss of sugar. The semi-syrup is turned into the second compartment at intervals, to be finished under full control of heat governed by dampers.

Defecators.—Fig. 165 is McDowell's defecating tank, 8 feet long, 5 feet wide, and 2 feet deep. The bottom is covered with a steam-coil, and contains a strainer through which the clear juice can be drawn. Each tankful can be treated in 30 minutes. Two of these tanks suffice to defecate 600 gallons per hour.

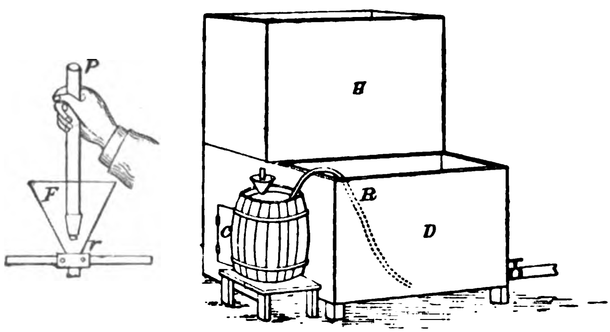
Fig. 166 represents the apparatus required in F. L. Stewart's defecating process. It consists of a heating-tank H, defecating-tank D, a short 10-gallon cask C, a lacquered funnel F with

FIG. 165.



McDowell's Defecating Tank.

FIG. 166.



Stewart's Defecating Apparatus.

indiarubber ring round the neck, a plug *r* for thrusting into the throat of P, and a piece of indiarubber piping R. The directions for its use are as follows :—

"Place the cask on a bench or table so as to be nearly on a level with the tank D. Begin by pouring a gallon of water into the cask. Then pour carefully ½ gallon of sulphuric acid from a carboy into a wooden bucket (noticing that the spigot is closed). In pouring from the carboy, slowly incline it to one side, supporting it by a level held in the hand. Place the bucket carefully upon the cask, with the nozzle of the spigot over the larger hole; open the spigot, and allow the acid to flow into the cask. Avoid letting the acid touch your hands or clothes. When the bucket is emptied, rinse it with water, and set it aside till used again in the same way. Then insert the rubber-covered neck of the funnel tightly into the larger hole in the head of the cask. Compress one end of the long tube slightly, and insert it in the smaller hole. Insert the plug with the rubber ring around it in the throat of the funnel closely, and it will be air-tight. You are then ready to work regularly, as indicated in section 6 below.

"The powder 'B' is dropped quickly, a pound at a time, through the funnel in the cask containing the diluted acid, the plug is quickly inserted, and immediately sulphurous oxide escapes through the tube into the clear juice in the tank D; 1 lb. of 'B' is usually sufficient for 150 gallons of juice when its gas is all discharged. The juice must absorb the gas until it turns blue litmus-paper red.

"In charging the cask with the water and sulphuric acid always *mix the acid with the water in the cask.* Other strong acids may be used in place of the sulphuric, but the latter is reliable and costs but a trifle.

"Never allow the cask to become *more than half full* of the mixture at any time. Otherwise the sulphuric acid, in the form of foam, may be forced into the juice and decompose some of the sugar.

"Lift the end of the rubber tube out of the tank (or loosen the funnel plug) when the gas ceases to flow, or when you have thrown enough of it into the juice at one time. Otherwise some of the juice may be *forced back* into the cask, on account of some reabsorption of it by the acid mixture.

"In large factories, where 1000 gallons of juice are run off into the defecating tank at once, a 40- or 50-gallon cask should be used, instead of the small one as above.

"The sulphuric acid in the cask will be neutralised when about an equal weight of the powder has been dropped into it. Therefore each gallon of acid originally poured into two gallons of water, already in the cask, will eliminate the gas from about 14½ lb. of the powder 'B,' and no more; and charges of greater or less amount in the same proportion. When this proportion has been reached, or when the gas ceases to flow upon the addition of more of the powder, empty the contents of the cask, preserving the fine sediment for use when dry as a fertiliser. It is principally sulphate of lime. Rinse out the cask, replenish with diluted acid, and go on as before.

"It is convenient to use a charge of acid in the cask large enough to last a day's run, or longer."

The complete operations are :—

"1. Heat the freshly expressed juice in a copper or tinned iron vessel to a temperature of 82° C. (180° F.), as shown by a thermometer suspended so that the mercury bulb is immersed in the juice.

"2. After the juice has been thus heated, stir into it gradually milk of lime until the *red* test-paper, dipped into the heated juice, turns *blue;* about 3 pints of milk of lime to 100 gallons of juice is generally needed to procure this effect.

"3. Heat the juice then rapidly to the boiling-point, and when it begins to boil, shut off the heat, or remove the vessel containing the juice from the fire.

"4. As soon as the sediment begins to settle, draw off the clear liquid *from near the top,* by a syphon or swing pipe, into the cooling or defecating tank, until at least $\frac{8}{10}$ of the juice has been removed, leaving a thick muddy sediment at the bottom.

"5. Sweep out this muddy sediment with a broom through a large opening at the bottom of the heater, into a smaller vessel below, and any clear juice that afterwards separates from it should be racked off and added to the contents of the defecating tank.

"6. Into each 150 gallons of this clear and partly cooled juice in the defecating tank (D) introduce as much of the oxide gas as is produced by dropping 1 lb. of the powder 'B' into the small cask, and operating it as described above. For larger or smaller quantities of juice, use more or less of the powder in the same proportion. A charge of 75 gallons will require ½ lb., &c. Test the juice when the gas has ceased to flow, by dipping the *blue* paper into it. If it turns it red, it is all right. If not, drop a little more of the powder into the cask, and let the gas flow in until the colour of the paper changes.

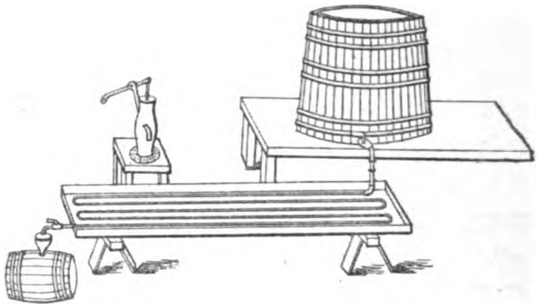
"7. The juice is then ready to be run into the evaporator, where it must be boiled rapidly in as shallow a bed of juice as possible, removing any scum that forms. The syrup should continue to turn the blue test-paper red until the close of the boiling.

"8. Before the syrup has become very dense, it must be passed from the evaporator into the finishing pan. Evaporate rapidly in the finishing pan to a dense syrup, *stirring it constantly at the last*, when a white cloud begins to be seen in it at about 113° C. (235° F.). Turn out into the cooler, and remove to a warm place to crystallise, and when cooled to about 38° C. (100° F.), stir a few grains of sugar into it to hasten it. The syrup before crystallisation is always *golden yellow*—never *red*."

Coolers.—Fig. 167 shows a very convenient arrangement for cooling syrup.

Complete Factory.—Fig. 168 illustrates the arrangement of a complete sorghum-sugar factory. The juice, after running from the crushing-mill into a tank on a lower level, is pumped up into the juice-tank A. B is the defecator; C, settling-tank; D, supply-tank for evaporator E; F, supply-tank for strike-pan G; H, receptacles for scum; I, truck for conveying the syrup to the sugar-room. The cost of such a factory is about 2000*l.* for a small size.

FIG. 167.

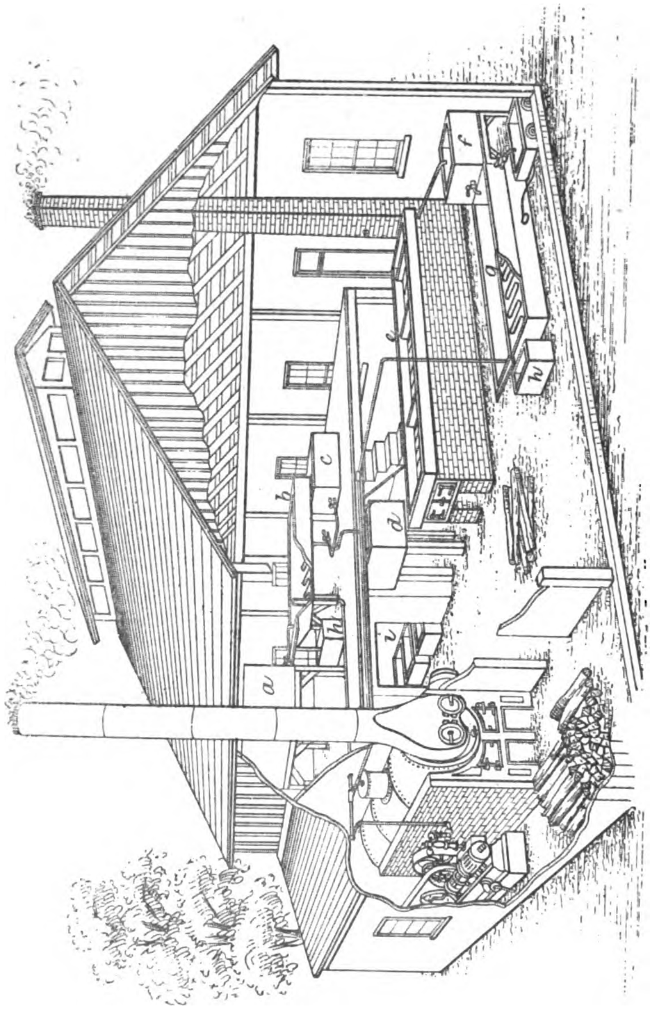


Syrup Cooler.

Diffusion.—According to a recent report by Hayes Sadler, it would seem that the first sorghum factory was built in Illinois in 1881, and in the following year three factories were in operation in Kansas; but, owing to the prices of sugar and syrup falling at that time to a low figure, the industry proved unprofitable, and the factories were closed. It was found that on account of the spongy and loose texture of the cane, it was impossible, with the heaviest and most modern crushers, to extract more than 40 per cent. of juice by the processes adopted, which were similar to those used in the South; and that, while the average amount of juice in the cane was about 90 per cent., half was lost in the first operation, and 10 per cent. of that obtained was lost in the subsequent treating.

The question, therefore, of obtaining a larger percentage of juice was considered all-important, and efforts were made to try the process of diffusion, which had been successfully applied in the production of sugar from beet. As this would demand a considerable outlay, the aid of Congress was solicited, and an appropriation vote was obtained. Encouraged by this assistance, a battery was established in 1884 by the Franklin Sugar Company, at Ottawa, in the State of Kansas, where it was proved—though the appliances were yet imperfect—that by diffusion all the sugar could be extracted from the cane, or fully double that by the system of crushers; but the financial

FIG. 168.



Complete Factory.

results were disastrous, and the company failed. In his report on these trials, Dr. Wiley stated that the difficulties in the application of diffusion were wholly mechanical, though changes were necessary in the apparatus, with a view to the better working of the system. The result having been considered satisfactory, another appropriation was voted by Congress in 1885, and the Parkinson Sugar Company was established at Fort Scott, in Kansas, under an agreement whereby the United States Department of Agriculture should supply the machinery, and the company provide the cane and erect the buildings. The success of the method, consisting of diffusion and carbonation, was further assured; still the experiment failed to prove its commercial practicability. Great difficulty was experienced in inventing a machine to cut the cane, and to elevate and clean the chips, none being found successful; the acids of the cane also, together with the heat necessary for complete diffusion, caused another difficulty, the inversion of the cane sugar, and a large percentage was thus changed into glucose, while the process of carbonation, though securing a maximum yield of sugar, failed to make a marketable molasses from the blackening of the syrup or concentration caused by the small amount of lime remaining in the filtered juice. Dr. Wiley, in his general review of the work in 1885, reported the absolute failure of the experiments to demonstrate the commercial practicability of manufacturing sorghum sugar, caused by the above difficulties. In 1886, $60,000 (12,000*l.*) of the appropriation was expended in experiments. At the close of that year Professor Swenson reported that much had been accomplished, and the continued experiments and suggestions then made appear to have led to the means of overcoming the difficulties, and to the success which has resulted from the season's working in 1887.

All attempts to manufacture sugar from sorghum in Kansas having proved financially disastrous, early last year the State Legislature passed an Act to encourage the industry, and a bounty of 2 cents (1*d.*) per lb. for 5 years was granted on all sugar manufactured from beet, sorghum, or any other plant; and an inspector was appointed for the purpose of determining the percentage, quantity and quality of the sugar produced, as well as to ascertain whether sugar-making in Kansas was a failure or a success. At the close of the year, the Inspector, Professor Cowgill, made his report, in which he shows that 842 packages, containing 234,607 lb. of sugar, were inspected, and branded as provided by law, and that the packages so inspected contained from 92 to 98 per cent. of crystallised sugar respectively. He also states that success has been at last attained, and that the result of the management at the Fort Scott works—the only factory in operation in the State—had been so far favourable as to place sorghum sugar-making on the basis of a profitable business.

The season's work at the Parkinson Factory in 1887, as reported by the manager, shows the value of the product at $34,476·50 (6895*l.* 6*s.*), and the cost at $21,746·93 (4349*l.* 7*s.* 9*d.*), or a profit of $12,729·57 (2545*l.* 18*s.* 3*d.*); but, as the bounty is added in this calculation to the value of the product, the net profit should only amount to 1607*l.* 9*s.* 8*d.* The total product of the season and the total cost are thus stated:—

PRODUCT.

	Dollars.	Dollars.
Sugar, 235,826 lb. at 5¾ c.	13,559·98	
„ State bounty at 2 c.	4,716·52	
		17,276·50
Syrups, 51,000 gallons (estimated) at 20 c.		10,200·00
Seed (estimated)		7,000·00
Value of total product		34,476·50

COST.

	Dollars.	Dollars.
Cane, 3840 tons, at 2 dol.	7,680	
Seed, 967 tons, at 2 dol.	1,934	
		9,614·00
Labour bill, August 15 to October 15, including labour for departmental experiments		5,737·16
Coal, including all experiments		1,395·77
Salaries, &c.		3,500·00
Insurance, sundries, &c.		1,500·00
Total cost		21,746·93

The working season is about 70 days, and the plant at Fort Scott is capable of working 135 tons of chips per day of 22 hours, equal to 170 tons of field cane. The crop contracted for was much less than the capacity of the works, so as to limit danger from loss, and the factory was only operated for three whole days of 22 hours, the remaining part of the season, owing to shortness of cane, being worked at short time; only 3840 tons of cane were bought, produced on about 450 acres of land. As 897 tons of this were used in experiments, and in the production of molasses, only 2943 tons were worked in the production of sugar, and from this must be deducted 333 tons of leaves and blades. The actual cost per ton of cane apart from the cost of experiments, taking an average day when in full operation, is calculated at $1 (4*s.*) for labour and fuel, and $1 (4*s.*) for expenses of management and control. The number of men employed was 38, at from $3 (12*s.*) per day to 12½ c. (6*d.*) per hour. The working expenses might have been relatively less, but for the short supply of cane. To the above costs of $2 (8*s.*), half for labour and fuel and half for management, must be added the cost of the cane reckoned at $2 (8*s.*) per ton, and it is asserted that on this basis, taking the yield of cane and the product, a profitable business has been developed.

The processes of making sugar from sorghum by diffusion at the Parkinson Factory are as follows:—

1. The top cane is delivered at the factory by the farmers who grow it.

2. The cane is cut by a machine into pieces about 1¼ inches long. This is accomplished in the ensilage or feed-cutter, which is provided with three knives, fastened to three spokes of an iron wheel making 250 revolutions per minute, and carrying the knives with a shearing motion past a dead knife. The leaves, and nearly the entire sheaths, are thus freed from the pieces of cane, and the whole are then carried up by an elevator to the second floor.

3. The leaves and sheaths are separated from the cut cane by fanning-mills. The elevator empties into a hopper below, with a series of four or five fans arranged one below the other. The leaves are thus blown away, and finally taken from the building by an exhaust-fan; this separation of the leaves and refuse containing the greater part of colouring and deleterious matter being essential. The pieces of cane are then delivered by a screw-carrier to an elevator, which discharges into the final cutting-machine on the third floor.

4. The cleaned cane is cut into fine bits called chips. This machine consists of an 8-inch cast-iron cylinder, with knives like those of a planing machine, and revolves at the rate of 1200 per minute; the knives, which are inserted in slots, and held in place with set screws, are carried past an iron dead knife, and the pieces are cut into fine chips, which are then taken by an elevator and conveyed to the cells of the diffusion battery.

5. The chips are placed in iron tanks, and the sugar diffused is soaked out with hot water. The diffusion battery consists of twelve iron tanks, arranged in a line, each with a capacity of 75 cubic feet, and holding nearly a ton of chips. These cells are supported near the middle by brackets, which rest on iron joists, and each is provided with a heater, through which the liquid is passed in the operation of the battery. They are also connected with pipes and valves, so that the liquid can be passed to the cells and from cell to cell at pleasure. The bottom of each cell consists of a door, closed on an annular rubber hose, placed in a groove, and filled with water under a greater pressure than the liquids in the cells are subject to, through which exhausted chips are passed into a truck below. The upper part is jug-shaped and secured with a lid held with a screw on rubber-packing. The cells are connected with a water-pipe, a juice-pipe, a compressed air-pipe, and the heaters by suitable valves, and the heaters are connected with a steam-pipe. These cells are filled with chips

and water, turned on in the first till full, when by the process of diffusion the sugar is displaced. The condition under which sugar exists in the cane is one of solution in water, and the walls of the cells in which the sweetish liquid is contained, are porous. In a few minutes there is as much sugar in the liquid outside of the cane cells, as in the juice in these cane cells, i. e. the water and the juice have divided the sugar between them. The liquid, always kept as nearly as possible at the boiling-point, is then passed into another cell full of fresh chips, and by the same process gains in strength, till, after being pressed forward and diffused successively through six cells of fresh chips, it is $\frac{31}{32}$ strength, and is then called juice, and drawn off; from this time forward one cell is emptied for every one filled. The difficulty experienced on account of the inversion of the sugar in the diffusion battery, is now successfully met; at the suggestion of Professor Swenson, a portion of freshly precipitated carbonate of lime is placed with the chips in each cell, which takes up any acid which may exist (producing inversion), and remains inactive should none exist.

6. The juice obtained by diffusion, has its acids nearly or quite neutralised with milk of lime, and is heated and skimmed. The juice drawn off is taken from the measuring tanks into large deep vessels, called defecating tanks or pans, and provided with copper steam coils, for the purpose of heating the juice. Sufficient milk of lime is added to neutralise acids, the test being made with litmus paper. The juice, after being boiled, and as much scum removed as can be taken quickly, is then sent by a pump to the top of the building, when it is boiled and thoroughly reskimmed, all skimmings being returned to the different cells.

7. The defecated or clarified juice is boiled to a semi-syrup in vacuum pans. This is done by double-effect evaporation in two large closed pans provided with copper steam-pipes. The juice has now reached a condition in which it will keep, and is taken to the "strike-pan."

8. The semi-syrup is boiled "to grain" in a high vacuum in the "strike-pan."

This is a large air-tight iron vessel, where the semi-syrup is boiled in vacuo to the crystallising density, air and vapour having been almost exhausted; this operation is delicate and requires much attention. The mixture is then called "melada" or *masse-cuite*, and is either drawn off into iron sugar-wagons and set in the hot room, or emptied direct into the mixer where it is brought to a uniform consistency.

9. The mixture of sugar and molasses from the strike-pan is passed through a mixing-machine into centrifugal machines which throw out the molasses and retain the sugar. The molasses is now driven through the meshes of the wire cloth in the centrifugal machine, and the sugar, when sufficiently dried, is taken out, and is ready for market, unless the further process of refining is required.

From the actual yield at Fort Scott last year and from the experience gained, it is thought safe to assume that an average of 100 lb. of sugar and 12 gallons of molasses can be extracted from one ton of sorghum, and the conclusion come to is that an industry of vast importance has been developed. The diffusion battery is reported to work admirably; the difficulties in cutting, cleaning, and elevating the cane have been overcome, and the loss from inversion remedied, though improvements may yet be made to simplify the machinery and reduce the labour of operating. One great question is to determine the point at which the cane has arrived at such a degree of maturity as to have made its sugar; this must be done by chemical analysis, the manufacturer having no other means of testing the condition required. After being cut, the cane should not be exposed to the atmospheric influences of the earlier part of the season for any considerable time, whereby the sugar might be turned into glucose, great loss being sustained from damaged or injured cane. It should be worked the same day as cut in hot weather, or, if cut in the afternoon before 24 hours have passed, while in cooler weather, later in the season, the same despatch is not necessary. It must be passed rapidly through the different processes till it arrives at a keeping condition, that is, till the juice is reduced to semi-syrup. Analysis is also frequently requisite to observe whether during the work inversion is taking place, when the cause should be at once removed. Little has as yet been done to develop methods of separating the grape sugar, but grape sugar is a valuable content of sorghum, and about 63 lb. are contained in a ton of cane.

As the sweet sap is produced by the natural growth of the plant, and is easily lost through inversion in over-ripe or injured canes, as well as after cutting in warm weather, the farmer's part in the process of sugar-making is the first, and a most important one. It is thought a great deal may be done by experiments to improve the canes, on the same principle as beet for sugar-making purposes has been improved, by careful nursing, producing different hybrids, and preserving seed only from such cane as has been shown by analysis to contain the greatest amount of sugar. It is also thought that the length of the season for working sorghum may be extended by the development of earlier varieties, and by cultivation.

Experiments have been repeatedly made in keeping cane in sheds and in silo, so as to reduce the great cost of sugar operations by keeping the works open beyond the crop season, and from analysis of the "Orange" and "Link's Hybrid" varieties, it is thought that cane can be so kept with little depreciation of its contents of sugar for a greater part of the winter. The distance at which farmers can profitably grow the cane on account of quick delivery at the factory is not greater than three miles, unless railway communication is at hand.

The seed of sorghum is about equal in value with corn for feeding purposes.

Taking seven and a half tons of clean cane as an average yield—and good cultivation can increase the yield to 10 and even 12 tons—an acre of land cultivated in sorghum, will produce 750 lb. of sugar, 1000 lb. of molasses, 900 lb. of seed, 1500 lb. of fodder, and 1500 lb. of exhausted chips (dried); and the total value of the sugar, molasses and seed is about $59 50 c. (11*l.* 18*s.*). For the corresponding gross yield of 10 tons of sorghum at $2 (8*s.*) per ton, the farmer will make $20 (4*l.*) per acre for his crop, or more than double the yield of a crop of wheat or corn; while as a gross product of agriculture and manufacture it is said that six times as much per acre will be realised from this industry as is usually realised from cereals in the State of Kansas.

Local Details.—In New South Wales, sorghum has been found to stand frost better than the sugar-cane proper, and is little affected by floods. It comes to maturity in 5 months, and therefore may be employed as an interval crop, alternating with sugar-cane, and keeping the sugar mills going. In 1868, there were 296 acres planted with sorghum in various districts; but in 1872 this was reduced to 32 acres. Growers expect 1¾ to 2 tons of sugar to the acre. When not grown for sugar, the plant yields abundance of valuable food for cattle, at the rate of 30 to 40 tons of cane per acre.

In France, Vilmorin states that it is capable of yielding on an average, from an acre of land, 26,000 lb. of juice, containing 10 to 13 per cent. of sugar; and that this is more than the average yield of the sugar-beet. It is alleged, however, that the plant is adapted to only a few parts of the south of France.

Wray asserts that some of the varieties which he introduced from Natal gave 30 cwt. of sugar per acre, and that it has yielded from a poor handmill 68 per cent. of juice, containing 15 per cent. of sugar. Where the sugar-cane has yielded 30, sorghum has given 25; but then there is often a second and a third crop to be obtained within the year. Sorghum can in many localities be advantageously utilised for preparing syrup. For this purpose, the sap is expressed at the time of flowers, and simply evaporated; the yield is about 100 gallons from the acre.

Since 1855, its cultivation has steadily increased in many countries. It is grown in France and Algeria for alcohol chiefly; in Italy, for its syrup in wine-making.

In the North-western States of America, where it flourishes, there were in 1864, 366,670 acres under sorghum, and sorghum sugar was selling in Chicago at 4½*d.* per lb. In 1860, nearly 7 million gallons of sorghum syrup were produced in the United States. This had increased in 1870 to 16,050,089 gallons, and 24 hogsheads of sorghum sugar were made.

In the State of Kansas, there were 23,026 acres under sorghum in 1875. The produce was 2,542,512 gallons of syrup.

Sorghum is cultivated to a considerable extent in the Ohio belt of counties, Western Virginia. It is used entirely for the manufacture of syrup for home consumption, where the locality has been more or less denuded of its maple trees. Most persons prefer the syrup prepared from the maple to that from sorghum, as the latter has too commonly an acid taste. The total production for the state of West Virginia was given in 1876 at 780,829 gallons.

The annexed table of the supposed production of sorghum sugar in the United States is given by Lewis S. Ware:—

SUPPOSED YEARLY SORGHUM SUGAR MANUFACTURE IN THE UNITED STATES.

	lb.		lb.
1861	80,400	1870	109,940
1862	137,430	1871	117,525
1863	183,795	1872	172,995
1864	208,300	1873	184,230
1865	280,330	1874	182,050
1866	511,565	1875	108,840
1867	140,658	1876	97,420
1868	200,676	1877	80,760
1869	224,000		

W. Ingram makes the following report of the experimental cultivation of Minnesota Early Amber sorghum on the Duke of Rutland's estate at Belvoir in the season 1880:—

Two sowings were made in April: one within the shelter of a frame, where a growing temperature could be maintained artificially, and one in the open ground. In the latter instance, the seed was scattered in drills, drawn 3 feet apart, and lightly covered with fine soil; the seed-bed was in an excellent state of tilth, and the ground was sufficiently manured; the seed failed to germinate in April, and only a few grains vegetated in May. This was much owing to the cold, dry, ungenial weather which prevailed during that month, which even checked the growth of hardy native plants, showing that the absence of heat was the direct cause of the slow germination of the seed; that its quality was satisfactory, is shown by the fact that the portion which was sown at the same time within the protection of a frame appeared in April, and made a rapid and healthy growth.

The month of June, generally dry and warm, was in all climatic particulars most unfavourable for a tender quick-growing plant like sorghum, requiring heat to quicken it into vitality; an unusual quantity of rain fell and chilled the ground, and the sorghum in this month made little progress, although enough appeared in the rows to promise a fair plant; but ungenial weather still prevailed, and July was even more gloomy and wet than the month preceding. Rain was registered on 26 days, and the land was saturated. Although still advancing, the growth and progress of the cane was in no respect satisfactory, it had the same sickly tinge that marked many of the wheat and barley fields in the neighbourhood. The increased warmth which distinguished the weather in August speedily influenced the plant, which commenced a steady and satisfactory growth that was continued throughout August and September; each set branched and tillered from the bottom, throwing up from 8 to 12 stout stems, which by the first week in October had attained the height of 5 feet.

Retarded in its early growth, it failed to reach that point of maturity indicated by the production of seed, and hardly attained sufficient ripeness to elaborate the saccharine juice in suitable quantity for experiments in the manufacture of sugar. It seemed, however, to promise a valuable supply of nutritious food for stock; offered to horses and cows, it was refused, but pigs devoured it greedily. There was a very perceptible sweetness in the cane when tasted. In the hope that fair weather would be prolonged throughout October, and that the cane would develop seed, the crop was allowed to remain on the ground; but this expectation was frustrated by the occurrence of severe frost, which completely destroyed the crop, thus giving the valuable lesson, that the cane must be harvested before the end of September, or early enough to secure it from the chance of injury from frost, its sensitiveness equalling that of our most tender garden flowers.

An experiment carried on under such unfavourable circumstances of weather, cannot be regarded as conclusive in regard to the suitability of the plant for cultivation in England, and it is in Ingram's opinion very desirable that the experiment of its growth as a profitable farm crop, should be continued in several localities, and for a series of years.

The experience of this season has taught that the seed cannot with safety be sown so early as April, and probably the second or third week in May would be early enough, and the rows need not be more than 2 feet apart. The inherent vitality of the plant may be mentioned as an encouraging fact in connection with its growth. After being checked and injured by the occurrence of 3 months of cold, wet weather, with the arrival of a little genial warmth, it speedily regained health, and made an active and vigorous growth.

In America, the best results in the cultivation of sorghum have been obtained on light loamy soils, resting on porous subsoil; and had circumstances permitted the experiment of its culture on such a soil, doubtless the result would have been more satisfactory. But a cold clay subsoil, and a wet and almost sunless season, militated against the well-doing of the plant and the success of the trial.

The plant will bear removal from its seed-bed remarkably well. Ingram tried the experiment of transplanting a quantity of seedlings, raised in a well-sheltered position, which had reached a height of 6 inches, and although some hundreds were replanted, not one failed to grow.

MILK SUGAR.

CHAPTER XVIII.

MILK sugar, lactin, or lactose, is obtained from milk by precipitating the casein with a few drops of dilute sulphuric acid, and filtering and evaporating the liquid. Crystals are deposited, which are purified by redissolving and treating with animal charcoal. In Switzerland, considerable quantities of milk sugar are prepared by evaporating the whey which remains after the separation of the cheese.

At Marbach, in the Canton of Lucerne, Switzerland, half a dozen refiners are said to make a handsome income from the manufacture of milk sugar.

The raw material used for the recrystallisation comes from the neighbouring Alps, in the cantons of Lucerne, Berne, Schwyz, &c.; a considerable quantity is supplied also by Gruyères. It is the so-called *Schottensand* or *Zuckersand*, the French *déchet de lait*, obtained by simple evaporation of the whey after cheese-making. Notwithstanding a continual rise in the price, consequent upon the demand and the increased cost of labour and fuel, the manufacture continually expands and now amounts to 1800 to 2000 cwt. yearly, corresponding to a gross value of about $60,000 (12,500*l.*), certainly a handsome sum for a small mountain village with but few inhabitants.

The manufacture is only carried on in the higher mountains, because there the material can no longer be used profitably for the fattening of swine, which are found chiefly in the valleys; and the wood required for the evaporating process is cheaper in the highlands.

The crude material is sent to the manufacturer, or refiner, in sacks containing 1 to 2 cwt. It is washed in copper vessels, and dissolved to saturation at the boiling temperature over a fire; the yellow-brown liquor, after straining, is allowed to stand in copper-lined tubs or long troughs to crystallise. The sugar crystals form in clusters on immersed chips of wood; these are the most pure, and therefore of rather greater commercial value than the milk sugar in plates, which is deposited on the sides of the vessels.

In 10 to 14 days, the process of crystallisation has ended, and the milk sugar has finished growing. The crystals are then washed with cold water, afterwards dried in a cauldron over a fire, and packed in casks holding 4 to 5 cwt.

As the *Schottensand* can only be obtained in the summer, the recrystallisation is not carried on in the winter, hence a popular saying that the milk sugar does not grow in the winter. The entire manipulation is carried on in a very primitive manner, it being a matter of astonishment to find a specific-gravity instrument in any place. With a more rational method of working, a whiter and finer quality of sugar could probably be produced. Engling recommends to neutralise the hot whey with chalk, to evaporate to half its volume, and settle. Albumen and calcium phosphate settle out, and the clear whey is drawn off and further evaporated. From a solution thus purified the sugar crystallises in plates and crusts. The mother-liquor on further evaporation yields a second crop. The final viscous mother-liquor can still be worked up for sugar by dialysing. From 100 litres summer whey, 4 kilos. refined milk sugar can thus be obtained. By freezing whey and removing the ice crusts which form, a solution rich in milk sugar can be obtained in a comparatively short time, which is purer than that obtained by evaporation, as fat, albumen, and salts separate, to a great extent, with the ice. With careful work, 10 litres whey yielded by this process 280 grm. snow-white milk sugar. According to Schatzmann, 100 litres whey of the Emmenthal yield 2·5 kilos. milk sugar, or 32 pints give 1 lb. There is a brisk demand for the article as a menstruum for homœopathic medicines, and for infants' food.

STARCH SUGAR AND OTHER GLUCOSES.

CHAPTER XIX.

UNDER this section are included the various factitious sugars, syrups, and brewing compounds, obtained by the artificial conversion of starch into sugar, and recovered from the waste liquors and residues produced in the course of sugar refining.

Formation.—From the theories promulgated by different chemists concerning the formation of dextrine, and the transformation of starch into starch sugar and dextrine, the following conclusions may be deduced :—

(1) That starch torrefied in a temperature not exceeding 180° to 200° C. (356° to 392° F.) is largely transformed into dextrine.

(2) If the starch is heated with diluted acids, it changes in the first place into soluble starch, and then into starch sugar and dextrine. The quantity of the sugar forming depends on the concentration of the acids, and increases considerably during the period of its action, while the amount of the dextrine at the same time decreases.

(3) If the starch is heated with a solution of diastase (extract of malt), it will likewise at first change into soluble starch, of which the larger part is first turned into dextrine and the lesser into sugar. The quantity of the forming starch sugar will depend mainly on the temperature under which the diastase operates. A larger quantity of sugar is formed at a

temperature of 60° to 65° C. (140° to 149° F.); but at increased temperatures, say at 65° to 75° C. (149° to 167° F.), larger quantities of dextrine are formed, until finally, by continued increase of temperature, the diastase itself is destroyed.

(4) The sugar formation increases during the action, by the diminution of the dextrine, especially when the sugar formed is caused to ferment by yeast, and is thereby removed. The quantity of the formed sugar but little exceeds that of the dextrine, even in the most favourable cases.

Principles of Manufacture.—Starch sugar finds no application which common crystallisable sugar could not fulfil, and it must always be considered as merely a substitute. Hence, the manufacture of starch sugar is only advantageous when it can be produced more cheaply than cane or beet sugar. When it is known that the article appearing in commerce as starch sugar is very often far from being pure grape sugar, and contains upwards of 50 per cent. of water and unfermentable substances, it will be seen that starch sugar is used more than is profitable.

The transformation of starch into sugar by means of sulphuric acid and diastase has already been explained. The relative quantity of sulphuric acid used is of importance, as the time needed for conversion is dependent upon it. The transformation occurs, for instance, much more rapidly when 2 than when 1 per cent. of sulphuric acid is added. Boiling under increased pressure also reduces the time of the operation. The sulphuric acid remains unchanged by the process; but a full explanation of its action has not been given. It can be removed from the liquid by carbonate of lime.

According to calculation, every 220 lb. of dry starch should furnish 238 lb. of dry sugar, corresponding to 264 lb. of crystalline starch sugar, if the transformation were perfect. But complete transformation can never occur in practice. Perfect transformation could only occur after the lapse of 36 hours, or even longer, when, by the simultaneous action of the sulphuric acid upon the sugar that had been formed many hours previously, large quantities of other products must accumulate in the solution. The products of decomposition thus formed would be of greater injury for all possible uses of starch sugar than the small quantities of dextrine which might otherwise be retained in the finished article. Too long boiling of the starch with sulphuric acid produces an entirely useless article.

The transformation of starch into starch gum and starch sugar by diastase (malt) occurs most rapidly and completely at the so-called mash temperature of 60° to 65° C. (140° to 149° F.). The formation of soluble starch in this case takes place during a very short period. Starch gum and sugar ensue simultaneously, and the starch gum itself cannot be completely transformed into sugar, even by continual action of the diastase; if, to the solution thus obtained, about 1 per cent. of sulphuric acid is added, and then boiled, an approximately complete transformation of the starch gum into sugar will take place, especially if the boiling is done under pressure.

These general remarks suggest the following rules for practice:—Pure crystalline starch sugar can only be produced by means of sulphuric acid, and only by long-continued boiling. A shorter boiling of the starch in sulphuric acid water produces a glucose which contains considerable quantities of an intermediate product between gum and sugar. The sugar thus obtained is not hard and crystalline, but soft and tough, and becomes moist in the air. From a syrup thus produced, no solid sugar separates, because the starch gum prevents the separation. With a syrup obtained by too long boiling, there ensues a separation of starch sugar in a grainy condition. This is considered as spoiled glucose. Syrup prepared by means of malt alone contains a considerable amount of starch gum. By the application of sulphuric acid, after the use of malt, the gum can be transformed in a great measure into sugar. Starch sugar can be made directly from potatoes, grain, rice, maize, moss, wood, fruits, honey, &c. In the manufacturing industries, it is only made of starch. In the United States, corn starch is with but few exceptions employed; in Europe, potato starch.

Starch sugar appears in commerce in five different forms, (1) starch-syrup; (2) a sticky mass, termed "imponderable syrup" or "glucose"; (3) granulated sugar; (4) common solid sugar; (5) refined solid starch sugar, distinguished by its whiteness and sweet flavour, which are secured by refining.

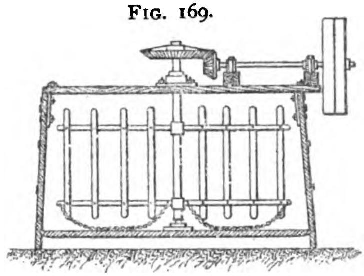
Manufacture.—The manufacture of starch syrup and starch sugar by means of sulphuric acid is divided into the following operations:—(1) Boiling the starch in sulphuric acid water; (2) removal of the sulphuric acid and the sulphate of lime produced from the solution; (3) evaporating and refining the sugar solution.

These are performed in various ways.

Boiling.—The boiling of the starch in water containing sulphuric acid is best performed in a wooden vessel by direct admission of steam, with, however, the disadvantage of introducing much water. Lining the vessel with lead is not necessary, but increases its durability. Formerly the boiling vats were constructed in such a manner that they could be heated under pressure; but they offered very little security, and their bottoms were often blown out. Such vats exist even yet in some old establishments, but are not used in manufactories of recent construction. Their only advantage was that the boiling was shortened; but the starch became somewhat thin and liquid, because the steam entering the mass became condensed, diluting it to 14° or 15° B.

The modern stirring-tub (Fig. 169) has a spiral copper worm, through which steam circulates. By this means, the mass is brought to a boil without being diluted, so as to show 19° to 20° B. when done. There is thus a great saving of fuel. The staves for the vat are of good pine, 2½ inches thick. A vat to boil twice a day 3300 lb. of green starch, should be 8¼ feet high. Its diameter below is 5¾ feet, and above 5½ feet; it is open above, with a cover to be laid on, and a chimney. The chimney is square, and made of ¾-inch pine boards, 10½ inches wide in the clear, and of a height to project above the roof, to carry off the odours. The vat is placed upon a strong framework, so that the boiled starch can run into the neutralising-coops by means of spigots above the bottom.

FIG. 169.



Stirring Tub.

The copper worm has a diameter of ½ inch, so that it may be inserted in the vat without trouble. The rings are fastened with brass clamps. Nothing is made of iron; all screws and nuts must be of copper or brass. The condensed steam escapes at the side through a pipe connected with the copper worm and carried to the steam boiler.

The requisite quantity of water is placed in the vat, and heated to a boil, when the previously diluted sulphuric acid has been added. The starch mixed with lukewarm water to a milky consistency, is gradually run into the vat from the stirring-tub, while the liquid in the boiling-tub is kept at a constant boil. As the starch deposits itself quickly from the starch-milk, it must be constantly stirred. The larger the quantity of the boiling liquid, the less readily it will cease boiling, and the less a paste formation will ensue. If no stirring-vat for the starch-milk is placed over the boiling apparatus, the starch-milk must be poured into the boiling sour water in portions. For each 220 lb. of air-dry starch, about 40 to 55 gallons of water, and generally 4½ lb. of sulphuric acid are used, when syrup is to be produced; for the manufacture of solid sugar, the acid may be increased to 8¾ lb.

The water stated includes that used for stirring the starch. The quantity must at any rate be such that the worm in the converter is covered. As the starch used in glucose factories is generally prepared there, and as the green starch can be well preserved in vats and barrels, it is generally applied in a moist condition; hence, instead of using 440 lb. of dry starch, 660 lb. of green starch are taken, and the water contained in the green starch is allowed for.

When the entire quantity of starch-milk is in, the boiling is continued until the transformation is accomplished. If syrup is to be produced, the boiling is of shorter duration than for solid sugar. During the boiling, especially with potato starch, a very disagreeable, penetrating odour is developed.

At short intervals, the liquid is tested, first with a solution of iodine, and afterwards with alcohol. For the iodine test, a few drops of the sugar liquid are placed in a test-tube, diluted with cold water, and treated with a few drops of the iodine solution. When the liquid is no longer coloured violet or reddish, the transformation into gum and sugar is finished. The alcohol test now begins. To a little of the liquid in a test-tube, an equal or double volume of strong alcohol is added. The stronger the white separation caused thereby, the larger is the quantity of dextrine still present. Even when the precipitation ceases, some dextrine is still unchanged into sugar; a ready means for determining its complete transformation into sugar is not yet known.

Neutralisation and Filtration.—When the transformation is sufficiently attained, the sulphuric acid is removed by the application of carbonate of lime. The acid decomposes the lime, carbonic acid gas escapes, and insoluble sulphate of lime is produced; the liquid loses its acid reaction, and becomes neutral. This operation can be conducted in the boiling apparatus, but, in most cases, is performed in neutralising vats. Such are flat vessels, whose height stands to their width in a proportion of 1 to 3. The most suitable form of carbonate of lime is chalk, but limestone free from clay can be applied. It is indispensable to grind them into fine powder. A handful of this powder is thrown at a time into the hot, acid liquid, constantly stirred and mixed till no further ebullition ensues. Some manufacturers apply the chalk in bags, whereby the settling and refining are simplified. Each 1 lb. of sulphuric acid contained in the liquid requires 1 lb. of pure carbonate of lime; of chalk or limestone, more must be taken, as they are not pure carbonate of lime. An excess should be avoided, so as not to unnecessarily increase the sediment.

As soon as litmus paper shows a perceptible decrease of acid, the liquid is boiled for a short period before more carbonate is added. The cessation of effervescence is the best index of neutralisation. The final additions should be of chalk-milk,—powdered chalk stirred in water to a milk, and used after the coarser parts have settled. Slaked lime is inadmissible, because it destroys the starch sugar.

Neutralisation being complete, the muddy contents of the boiling-tub are run into a wooden depositing-tank of greater height than width, supplied with spigots for drawing off the liquid. In large establishments, adjacent to the boiling apparatus, a reservoir is placed in the ground and lined with brickwork. Into this, the contents of the boiling apparatus are drawn, and afterwards pumped into the depositing-vat. After the lapse of 12 to 24 hours, the sulphate of lime is deposited, so that the saccharine liquid may be drawn off. The sediment still contains a considerable amount of saccharine liquor. For the recovery of this residue, various methods have been applied.

Filtering-barrels consist of vertically placed barrels with sieve bottoms. Above the sieve bottom, a piece of coarse cloth is spread, covered with cut straw or coarse river sand, for the reception of the residue. The liquid runs out by the stop-cock in the lower bottom, pure and clear. The first portion is returned to the filter. Upon the residue, gypsum water is carefully poured, after the upper layer has been made even, and is somewhat loosened. The absorbed sugar liquor is thereby dislodged; or the residue is strained through bags or cloths, the press cakes being again saturated with water and the pressing repeated.

The most general practice is to use bag-filters (described on p. 640), or filter-presses (described on pp. 489–92).

Evaporation and Refining.—The evaporation of the clear sugar liquor is accomplished either over a direct fire or by steam. In the first case, flat pans are used, whose bottoms are only touched by the fire; in the other case, various vacuum-pans. The evaporating cannot be conducted uninterruptedly, since the solution yet contains dissolved gypsum, which begins to separate during the evaporation, by letting the liquid stand. The evaporating, therefore, is divided into two periods: (1) to a thin syrupy consistency, and (2) to a dense syrup after the removal of the gypsum. It does no harm to add sugar liquor to the pan in the same ratio as the contents diminish by evaporation. The scum produced during the process is taken off with a skimmer.

As soon as the separation of gypsum makes it necessary, or when the liquor has reached a concentration of 20° to 30° B., it is transferred into upright barrels, provided with spigots, for depositing and separating the gypsum. When finer cloths are put into a filter-press, the latter may also be used for removing the separated gypsum. When this is accomplished, after the lapse of several days, the clear liquor is drawn off and evaporated in the same pans, or in extra pans, to a dense syrupy consistency (40° to 45° B.). In large factories, vacuum pans are used for this purpose. The deposits of gypsum from the barrels are placed in bag-filters, and then pressed.

Evaporation in open pans does not allow of utilisation of the steam or fuel; besides this, the liquor, while exposed to too high a temperature, receives a dark colour, and, at the finish of the boiling, a strong formation of scum will ensue. Hence closed evaporating apparatus has for some time been used. Many forms of steam- and vacuum-pans have been described in foregoing chapters (see pp. 295–357).

As a brown colour is desired for glucose-syrup, if it is intended to substitute for or mix with cane-sugar syrups, decolorisation by means of bone-black (animal charcoal) is not always demanded. If the syrup is not to be decolorised, it is boiled down in the vacuum-pan to 40° or 42° B. at 60° to 65° C. (140° to 149° F.) and again forced through the filter-press. For this operation, the first filter-press may be used after cleaning; but it is better to set up a second press of smaller dimensions with lighter cloth. The syrup, while passing through the filter-press, must be kept at a temperature of 75° C. (167° F.).

The saccharine liquor is passed through filters of coarsely powdered animal charcoal (as is done in beet- and cane-sugar manufactories), or refined with fine charcoal and blood, to produce an absolutely decolorised syrup, and to improve its flavour.

The filtering through bone-black is best accomplished at 32° B. at 60° to 65° C. (140° to 149° F.). This is done after the gypsum has deposited itself by prolonged rest, the liquor being previously re-heated. If starch syrup is long kept at a temperature near its boiling-point, it assumes a darker colour and becomes sweeter.

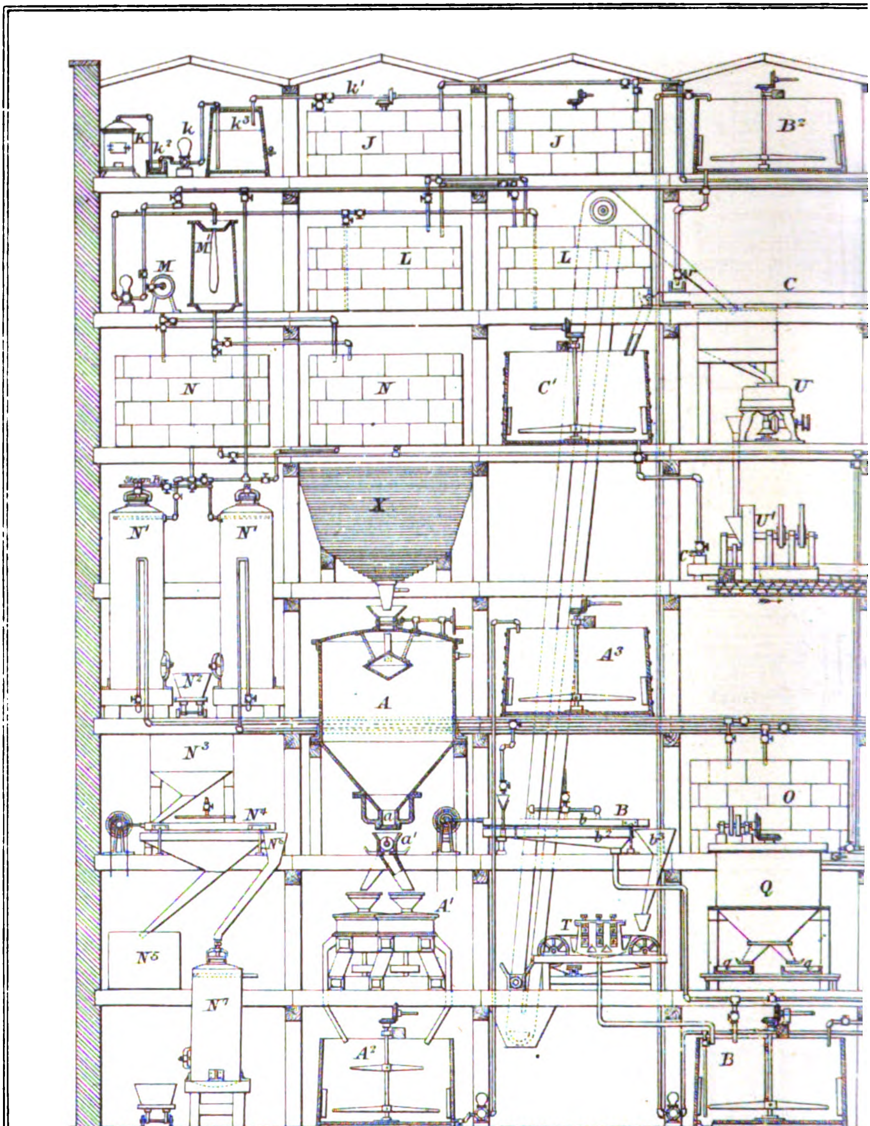
On the manufacture of solid starch sugar, little needs to be added to the preceding remarks. Whether the syrup remains liquid, or in time congeals into solid, grainy sugar, depends less on its concentration than on its quality. If a quantity of dextrine is still present, the syrup will remain liquid even at 45° B. If the starch has been very completely transformed into sugar, the resulting syrup will, by good concentration, gradually congeal entirely to a grainy sugar. Such syrup is permitted to stand in moderately warm rooms, in wooden or earthen vessels, until it congeals. For producing a solid, white sugar, the treatment with bone-black for the purpose of decolorising is indispensable.

Liquid syrup is generally packed in strong casks or tuns of soft wood, and is liable to excessive shrinkage. During hot weather, its transportation is almost impossible, since the syrup absorbs the water contained in the wood, the casks become dry, and the syrup leaks out. In case the boiling process has not been properly attended to, the product will easily ferment and spoil. Hence the article appears in commerce principally in a solid form. If the concentrated syrup, after cooling off, is stirred or beaten, it will coagulate in 8 to 10 hours so perfectly as to assume a soaplike consistency, without altering its quality. In this condition, it can be far better preserved and more easily transported. But liquid glucose which coagulates very quickly is not adapted to form an article of the syrup trade.

The principal grades of starch syrup and starch sugar are:—

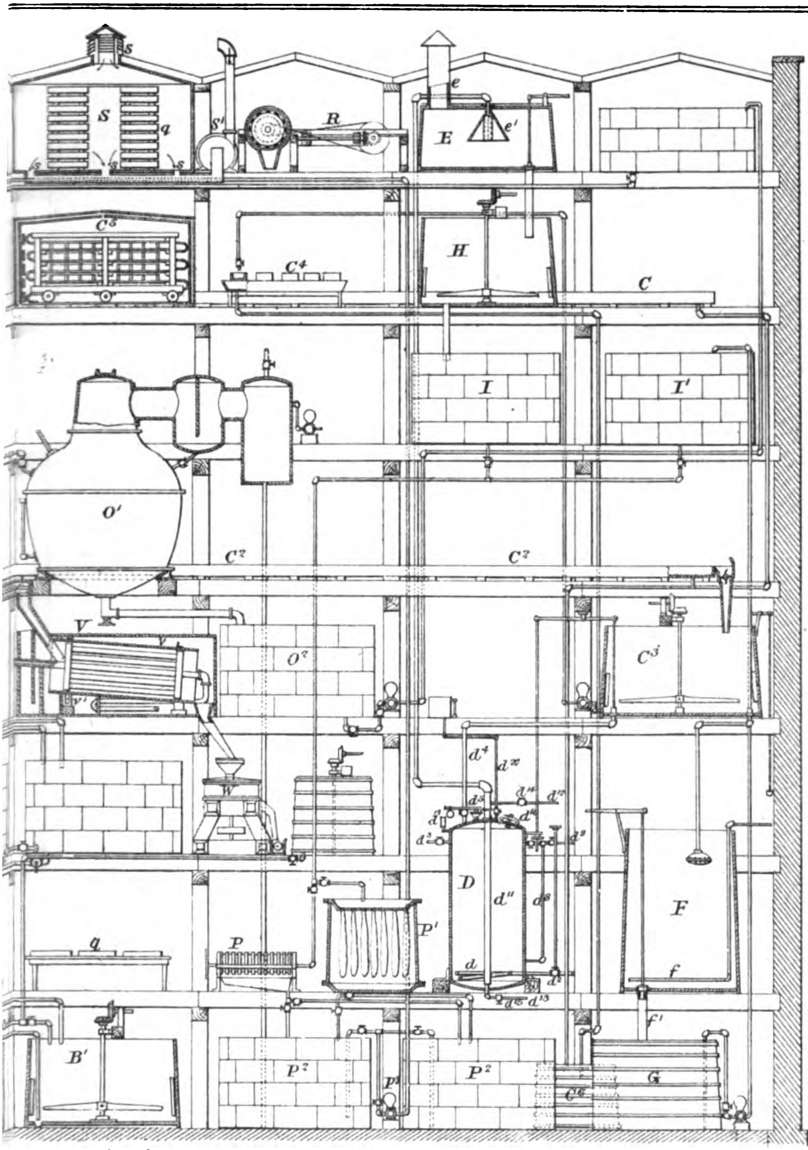
"Starch syrup" or "glucose," an article which remains clear and liquid for a comparatively long time; "common starch sugar," obtained by coagulation of starch syrup, and characterised by containing a relatively large amount of dextrine; "purified" or "refined starch sugar," obtained by repeated refining of the common sugar; "granulated starch sugar," obtained by coagulation, but containing the smallest possible percentage of dextrine.

When the product is to be disposed of as solid sugar, and not as syrup, the liquor is evaporated in flat vessels, to 40° to 42° B., and then placed in crystallising-pans. After the crystallisation has commenced, the sticky liquid is filled into small barrels, where the mass in a short time entirely coagulates, and can be shipped. It may also be allowed to become solid in the pans, and then be ground and packed. Some manufacturers produce a dry and grainy sugar; it is then of



STARCH SUGA

E & F N. Spon, London



AR FACTORY.

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importance that the transformation of the starch into sugar is as complete as possible, since the presence of great quantities of remaining dextrine will hinder granulation.

Common starch sugar is identical with liquid starch syrup; but in general, the composition is so varied that scarcely two samples are exactly alike, as may be seen from the subjoined analyses:—

	Starch Syrup.		Common Starch Sugar.		
	I.	II.	III.	IV.	V.
Water	21·8	20·8	27·8	27·4	26·0
Sugar	42·2	56·0	56·2	58·8	61·5
Dextrine and intermediate products ..	35·4	22·6	15·6	13·3	12·0
Mineral ingredients	0·6	0·6	0·4	0·5	0·5
	100·0	100·0	100·0	100·0	100·0

Johnson's Method.—A process by which large quantities of glucose are made is that patented by S. H. Johnson, of Stratford, which deals with "permeable" grain.

This term "permeable" grain is understood to include grain whole, crushed, bruised or broken, or granular amylaceous substances, being of such form and combined with only so small a proportion of water or liquid that steam can permeate every part of a layer or bed of it with facility, it being an essential feature in this process that complete permeation of the steam should be effected; whole grain is generally preferred, but in some cases it may be more convenient or cheaper to employ broken grain. The grain, however, must not be in the form of flour, as it would then form a paste more or less gelatinous, and so prevent complete permeation by the steam.

Rice or other grain containing starch may be employed, provided it be kept in a permeable condition, so as to allow steam to penetrate and act upon it until the starchy portion of all the grain becomes converted into dextrine. In previous processes the grain operated upon has been treated with so much water as to allow of the starch to become so gelatinous and expand so much as to form a paste more or less impermeable to steam. This inconvenience is avoided by proceeding as follows:—The grain is first macerated in a wooden vat with as much diluted hydrochloric acid, containing about 2 per cent. of real acid, as is necessary to cover the grain completely with the liquid. When the grain has absorbed as much as possible of the dilute acid, the liquid which remains unabsorbed is drawn off from a hole in the bottom of the vat.

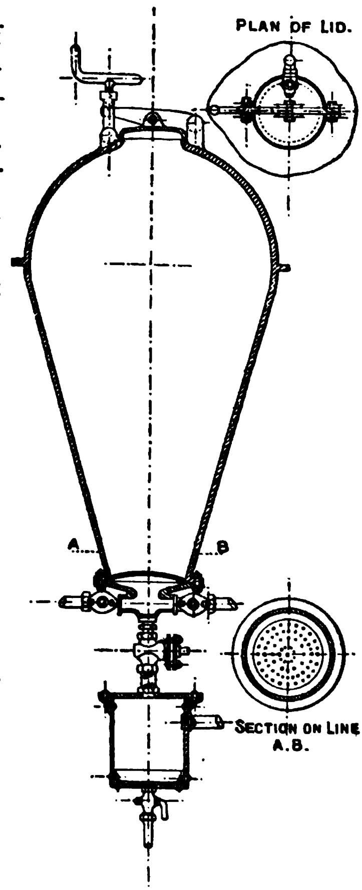
The dilute acid which has been drawn off from the grain will be found to have increased considerably in specific gravity, due to the protein and albuminoid compounds which have become dissolved in it from the grain. It will have also acquired an aromatic odour due to the essential oils removed from the grain by this treatment.

In order the more completely to remove the nitrogenous principles and the essential oils which still remain in the grain, it is macerated with clean water in such a manner that when the grain has become covered with the water the liquid is allowed to flow off at the bottom of the vat through an aperture provided with a filtering diaphragm. The water is supplied at the top at the same rate as the liquid percolates through the grain. This percolation is continued until the liquid running away from the grain no longer gives an acid reaction to litmus paper. When this neutral condition is attained, the grain is allowed to drain, and it is afterwards again macerated for a few hours in dilute hydrochloric acid containing 1 or 2 per cent. of real acid. This maceration is continued until the acid dialyses through the tissues of the grain to such an extent that it will contain enough acid to effect its conversion into glucose when subsequently treated.

The proportion of acid varies according to the nature of the grain, the temperature at which the conversion is effected, and the amount of water present at the time of the conversion. Rice, for example, ordinarily requires about

$\frac{1}{400}$th part of its weight, when dry, of real hydrochloric acid to be present in the grain to effect the conversion under the circumstances and conditions of temperature and moisture that would obtain; but the amount of acid necessary for conversion varies with different grains, and with different samples of the same species of grain. It is therefore necessary when treating a particular lot of grain to ascertain by experiment the least proportion of acid which, under all circumstances, it would be most desirable to employ, and so that during the process of conversion the grain shall not be exposed to the high temperature necessary for such a length of time as would materially affect the colour of the resulting product.

FIG. 170.



Steam Converter.

The grain, when prepared as above described, and well drained, is introduced into a strong wrought-iron vessel lined with lead or with a silicate enamel capable of resisting the action of the acid, as represented in Fig. 170. The vessel should be of such a shape that when steam is introduced through a perforated diaphragm at the bottom it shall be able to pass with facility through every part of the material contained in the vessel. For this purpose, the lower portion of the vessel has the shape of an inverted truncated cone, the whole area of the small truncated portion being covered internally by a perforated diaphragm for the admission of steam. This vessel is further provided with a suitable opening at the top for the introduction of the prepared grain, which opening is capable of being hermetically closed. It is also provided with a steam-pressure gauge and a draw-off cock and sampling cock, connected beneath the perforated diaphragm before mentioned. There is also at the bottom a trap or small box to receive and retain any water which may be brought over by the steam. When the vessel is formed of wrought or cast iron lined with lead, it becomes necessary to perforate the iron at intervals with small holes, so as to prevent the accumulation of steam in case any moisture or dampness existed between the shell and the lead lining. Such accumulation of steam would inevitably occur in the absence of the precaution indicated, and when the contents of the vessel were removed, thus withdrawing the internal pressure, the leaden lining would collapse.

When the prepared grain is introduced into the vessel it still retains its form, and the mass is consequently quite porous, so that the steam introduced beneath the perforated diaphragm at the bottom of the vessel immediately permeates every portion of the material under operation; and, owing to the form of the vessel and the porous condition of the grain, the temperature of the mass is speedily raised without the aid of a mechanical agitator to the point at which the conversion into glucose takes place, the requisite degree of temperature being reached before a sufficient quantity of water has been formed by the condensation of the steam to destroy the porous nature of the grain under operation. When this point is attained, the contents of the vessel become liquid, and are put into a state of violent agitation by the ingoing current of steam. The pressure under which such steam is introduced should not be less than 50 lb. nor more than 100 lb. to the square inch; although lower pressures can be employed, yet it is not at all advantageous to use them. The pressure is varied between these limits according to the nature of the grain employed, or the required character of the resulting product. For example, if it be desired that the product should retain a certain amount of dextrine, then a lower pressure would be employed than that which would be necessary for the complete conversion of the grain into glucose.

The mass may be sampled during the process by means of the sample cock, and after dilution and cooling the samples may be tested for the presence of starch and dextrine by means of an aqueous solution of iodine. When the conversion is completed, which for rice requires from 5 to 15 minutes (provided the steam has been injected with sufficient rapidity), the contents of the vessel are forced out through the draw-off cock into large shallow coolers provided with suitable agitators, or into other suitable apparatus for reducing the temperature with rapidity. In these coolers the material is neutralised with an alkali or alkaline earth, or their carbonates, in the usual way. If the product is required for the purpose of brewing or distilling, then the presence of the extraneous tissue, &c., is of little consequence. In such case, the syrup may be at once boiled down in a vacuum pan to the degree of concentration necessary for its solidification. It is found that glucose so obtained is free from the unpleasant bitter taste of fusel oil, which is eliminated by the hydrochloric acid treatment in the first stage of the process.

Hitherto in order to remove this taste it has been found necessary to filter the glucose through animal charcoal, but such filtration for this purpose is rendered unnecessary by this process. The syrup is also produced in such a degree of concentration as has hitherto been found impracticable.

When it is required to separate the glucose from the insoluble matter accompanying it, it will be necessary to dilute the syrup after neutralisation, and filter it by any convenient method, whether under pressure or otherwise.

If it be desired to produce glucose free from colour, it will be necessary to filter it through animal charcoal; but it will be found that after the treatment described a much smaller proportion of animal charcoal will be required than has hitherto been the case.

For the purpose of removing the fusel oil and nitrogenous substances, some other acids may be employed in lieu of hydrochloric acid, such as nitric and sulphuric acids; but hydrochloric acid answers the purpose best. The hydrochloric acid may be employed in the gaseous state, and may also be replaced by nitric and sulphuric acids for the purpose of conversion; but a solution of hydrochloric acid is the most powerful and convenient, and effects the conversion with the smallest amount of coloration. Where hydrochloric acid is used, the quantity necessary is so small that the common salt produced by neutralisation with carbonate of soda remaining in the glucose is of no material consequence.

Before macerating the grain with dilute hydrochloric acid for the purpose of removing impurities, that treatment is sometimes preceded by maceration in a solution of caustic soda or other alkali for the purpose of more perfectly removing the nitrogenous portion of the grain. The alkali solution should contain ½ to 1 per cent. or more of alkali, according to the amount of nitrogenous substances in the grain.

After macerating a sufficient time (say 5 or 6 hours), the alkaline solution, which has dissolved in it a considerable portion of the gluten of the grain, is removed, and the alkali is washed out in the same manner as described in reference to the acid treatment.

When it is desired to produce glucose or dextrine at the cheapest possible rate for brewing or distilling purposes, or where it is desired to use amylaceous matters, such as sago, tapioca, &c., which have already undergone purification processes for the purpose of freeing the starch from albuminous matter, the purification processes preceding the conversion may be omitted and the following plan may be adopted, viz.:—Treat the grain in a revolving or other suitable vessel which procures the proper mixing of the grain with about 4 per cent. of its weight of dilute hydrochloric acid of specific gravity about 1·060, until the acid is absorbed by the grain. After the acid has been allowed to remain in contact with the grain for the time necessary for the disintegration of the tissues, the mass may then be treated in the converter in the manner hereinbefore described, when it will be found that after expulsion from the converter, neutralising and cooling, the mass will become solid, or nearly so, provided the grain employed for the purpose did not contain an undue amount of water. In such latter case, the excess of water above what is necessary for the conversion should be expelled by heat from the grain before it is employed for the purpose by means of a kiln or other convenient apparatus.

In order to reduce the quantity of water to the smallest possible proportion, it is desirable that the neutralisation of the acid should be effected with dry reagents. For this purpose, in the case of the employment of hydrochloric acid, dry carbonate of soda is good, but when using sulphuric acid, dry carbonate of lime.

When it is desired (for distilling purposes, for instance) that the product shall consist almost entirely of glucose, the conversion is similarly effected, but before removing the material from the converter, a quantity of water or very dilute acid (which by experiment is found to be sufficient for the grain employed), and which has been previously heated under pressure to the temperature of the contents of the converting vessel, is introduced, and maintained at this temperature until the desired result is obtained, which is determined by trial during the progress of the operation. The proportion or description of acid must be varied according to the nature of the grain operated upon, the most convenient proportion having been previously determined by experiment.

Jebb's Method.—The process invented by W. T. Jebb, of Buffalo, comprises the manufacture of starch from maize and other grain, the treatment of starch for the production of solid grape-sugar and liquid glucose, the subsequent treatment of the grape-sugar for preparing it for consumption, and the treatment of the refuse for use as food for animals. Plate XI. is a sectional elevation of a factory containing the necessary train of apparatus.

The grain is introduced from a receiving bin or other suitable receptacle or conduit into a steeping tank or vat A of any suitable and well-known construction, in which the grain is thoroughly steeped or soaked, preferably in warm water, care being taken not to boil the grain.

The steeping tank used by Jebb consists essentially of a closed tank or tub having in its top a central feed opening, which is opened and closed by a suitable valve. In the upper portion of the tub, under the feed-opening, is arranged a spreading device, which distributes the grain in a spray over the entire circumference of the tub. The latter is provided with a conical bottom which terminates in one or more discharge spouts *a*, provided with suitable gates or valves. The tub is provided in its lower portion with an annular chamber having a perforated top, through which the steeping water is admitted to the tub, the water-supply pipe communicating with the chamber. The tub is also provided with a waste pipe, through which the water can be drained from the grain, and with a vapour-escape pipe, leading from the upper portion of the tub out of doors, to conduct the vapour out of the building.

The steeping tub is first filled with water having preferably a temperature of about 140° F. The grain is then introduced into the tub, the spreader operating to distribute the grain, so that the kernels reach the water singly or nearly so. In descending through the water the kernels are washed and freed from the foreign matter, such as dirt, chaff, and the like, which latter float on the surface of the water and pass off through an overflow pipe with which the tub is provided. The temperature of the water is lowered by the introduction of the grain, and is preferably maintained at about 120° F. by renewing the water from time to time.

Maize or other grain is steeped in this manner for from 15 to 20 hours, or until the proper degree of softness is obtained.

When the steeping is completed, the water is drained off, and after the water has been removed, the grain is discharged from the steeping tub through the discharge spout *a*. By this method of steeping, the removal of the foreign matter and the steeping of the grain are accomplished simultaneously, the overheating or boiling of the grain is prevented, and the operation is effected expeditiously and with very little labour.

The steeped grain passes from the discharge spout *a* to grinding, disintegrating, or crushing mills A^1, by which the grain is ground or crushed and mixed with water. When two or more mills are employed, as represented, the grain may be discharged from the spouts *a* into a conveyor trough a^1, which conducts the grain to the several mills. Jebb prefers to employ for the reduction of the steeped grain a pair of millstones, between which the grain is delivered together with a stream of water which enters the eye of the running stone together with the grain. The quantity of water admitted to the mill is preferably so regulated that the material discharged from the mill has a gravity of about 10° B.

The ground grain passes from the mills into agitating vats A^2, which are provided with agitators by which the material is kept in motion. From these agitating vats the material is pumped to other agitating vats A^3.

The material passes next to a separating machine B, whereby the starch water, that is to say, the water holding the particles of starch in suspension, is separated from the bran and other coarse offal.

This separating machine consists essentially of a shaking-sieve *b* covered with bolting-cloth of the requisite degree of fineness, and provided with perforated pipes, whereby sprays of water are delivered upon the bolting surface, so that the material, in passing over the bolting surface, is separated in such manner that the water containing the starch is passed through the meshes of the sieve into a receiving hopper or receptacle b^2 below, while the bran and other coarse offal pass the tail of the sieve into a different receptacle b^3.

The separated starch liquid passes from the separating machine B into settling vats B^1, which are provided with revolving rakes vertically adjustable. The starch liquid is permitted to come to a state of rest in these settling vats, whereby the starch subsides. The supernatant water is then drawn off from above the subsided starch, the settling vats being provided with several draw-off cocks arranged at different heights, so that the water can be drawn off to any desired depth. The water so drawn off may be fed to the mills or sieves, or it may be utilised in the manufacture in any other manner.

After the water has been so drawn off, a solution of alkali is introduced into these settling vats. Jebb employs for this purpose caustic soda in about the proportion of 1 lb. caustic soda to the product derived from 2 bushels of maize. In warm weather the quantity of alkali should be increased, and in cold weather it may be somewhat less. Water is then added in sufficient quantity to work the mixture conveniently, and the quantity of water is so regulated that the gravity of the mixture will be about 10° B. The mixture is now thoroughly agitated so as to incorporate the alkali with the contents of the vats, the alkali operating to render the gluten soluble. The contents of the settling vats are pumped to agitating vats B^2, in which the gravity of the mixture is further reduced, by the addition of water, to the density required for separating the starch from the gluten on starch runs or tables. Jebb adds water for this purpose in such quantity as to reduce the gravity of the liquid to about 3° B. The agitating and settling vats are employed in such numbers that the product coming from the mills and sifting machines can be delivered successively into the several tanks, which latter are successively emptied, so that there are always empty tanks to receive the product, permitting the manufacture to be carried on continuously.

The material passes from the agitating vats B^2 upon slightly inclined starch tables C, upon which the starch is deposited, while the gluten and other light or soluble refuse escape over the ends of the tables. The material escaping over the tables is preferably discharged into a vat in which the heavier valuable portion of the material settles, while the refuse passes off through an overflow pipe into a cistern C^6, from which it is removed to be used as food for cattle.

These starch tables consist essentially of long gutters or troughs, which are slightly inclined in the direction of their length and level in the direction of their width, and upon which the liquid containing the starch is delivered at their heads and caused to flow in a thin stream, from which the starch is deposited in a state of comparative security.

The starch which has been deposited on the tables is placed in a mixing tub C^1, which is provided with a revolving rake, and in which the starch is mixed with water, so as to produce a liquid of about the same gravity which it had when delivered upon the tables C. The liquid is delivered from the agitating tub C^1 upon another set of starch tables C^2, similar in construction, and upon which the starch is again deposited out of the liquid, while the light refuse which may be contained in the liquid runs off, and is collected as above described.

The operation of mixing with water and depositing upon starch tables may be repeated a third time if deemed necessary.

If it is desired to manufacture the various kinds of commercial starch, such for instance as the various grades of laundry starch and culinary starch, the starch is mixed in a tub C^3 with water to a creamy consistency, and is then pumped to boxes C^4, in which the water is permitted to drain off. These boxes are constructed of wood, open at the top and preferably about 7 inches in transverse section and several feet long, and are provided with perforations in their bottoms and sides, through which the water escapes. A lining of cloth is placed in them. The boxes are filled with starch liquid one after another, and placed to drain.

The water escaping from the boxes is conducted to the same receptacle which receives the water from the starch tables. After the starch has become sufficiently hard in these boxes to permit of its being handled, it is taken out of the boxes and placed upon a table, upon which it is cut or broken into blocks having approximately the form of cubes.

The starch is now ready for the dry kiln, which latter consists of a closed chamber C^5 having its walls and doors constructed so as to exclude the exterior air as much as possible from the interior of the kiln, the walls and doors being preferably made hollow and packed with saw-dust or some other non-conducting material.

The kiln is heated preferably by means of steam coils to a temperature of from 120° to 160° F., and is provided with racks, on which the starch to be dried is placed.

The rack is supported upon a carriage running on a track, so that it can be filled with the wet starch outside the kiln. The wet starch is permitted to remain in the kiln for a period of two days, or till comparatively hard and dry.

During this preliminary drying operation, a hard yellow crust forms on the blocks of starch, which crust is now removed by cutting or scraping. The blocks of starch are then wrapped in blue paper, or they are put in wooden boxes each of a size to receive one block, and open at the top, or they are broken up into lumps and covered with a thin layer of an inferior quality of starch to exclude the air.

The starch so prepared is now again placed in the drying kiln and remains there until the operation of drying is completed. The drying operation is carried on slowly and under exclusion of the exterior air, whereby the cracking of the wet starch is prevented.

After the drying operation is completed, the starch is removed from the kiln and either packed into boxes in the condition in which it comes from the kiln, or it is ground or otherwise treated according to the use for which it is intended and the demands of the trade.

When the starch is to be manufactured into grape-sugar or glucose, it is treated in the following manner: When it is desired to convert the starch under pressure for the manufacture of solid grape-sugar, the starch is reduced by an addition of water in the tub C^3 to a gravity of about 12° B.

The closed converter D used in connection with this process is constructed as follows:—

The shell or body of the converter is constructed of cylindrical form, with convex ends or heads, steam-tight, of copper or of iron lined with lead, and of sufficient thickness to withstand the internal pressure to which it is subjected in use. Within the converter and near its bottom a perforated steam-coil d is arranged for injecting steam. Steam is admitted to the coil through a pipe d^1 provided with a suitable valve d^2. The converter may have a diameter of 5 feet and a height of 10 feet. As it is most convenient for the operator to be standing near the top of the converter the latter passes through the floor or platform upon which the operator stands, and the valve d^2 is provided with a long handle extending upwards, and terminating within convenient reach of the operator.

In order that the steam may be permitted to escape from the converter when it is desired that the temperature of the contents should not exceed the boiling point at the atmospheric pressure, the top of the converter is provided with a steam outlet pipe d^3. The upper end of the converter is provided with a pipe d^4, whereby the starch liquid or the diluted acid, or both, are conducted into the converter, and which is fitted with a suitable valve d^5. In order that the contents of the converter may be readily tested, two test cocks d^6 d^7 are provided. The cock d^6 communicates directly with the converter by being screwed into its cylindrical body. The cock d^7 is used for the purpose of testing the contents of the lower portion of the converter, and for this purpose it is connected with the pipe d^8, which is arranged on one side of the converter and connected with the lower end thereof. In order that this pipe may be readily cleansed, it is provided with a steam pipe d^9, having a suitable valve d^{10}, and connecting with the upper end of the test pipe d^8, so that steam may be at any time blown through the test pipe for the purpose of removing its contents and cleansing it, thus enabling a correct sample of the contents of the lower end of the converter to be drawn by closing the steam valve d^{10} and opening the test cock d^7. This improved system for cleansing the test pipe is applicable to open converters as well as to closed converters.

In order that the contents of the closed converter may be discharged free from such heavy solid articles as may be accidentally introduced with the starch liquor, the blow-off pipe d^{11} is provided. This pipe extends centrally through the converter, and has its open lower end a short distance from the bottom. Consequently all the contents of the converter as low down as the lower end of the blow-off pipe, can be readily blown through it, while heavy solid articles, such as nails or pieces of iron, which are sometimes accidentally mixed with the starch, are left deposited in the bottom of the converter, and do not lodge in the blow-off valve. In order that this blow-off pipe may be readily cleansed, two steam pipes d^{12} d^{13} are provided. One of these cleansing steam pipes d^{12} is connected with the blow-off pipe above the upper end of the converter, so that by the introduction of steam, when the blow-off pipe is closed, whatever starch liquor there may be in the blow-off pipe is blown downward, and forced to mix with the starch liquor in the converter. The supply of steam to this upper steam cleansing pipe is controlled by the globe valve d^{14}. The other steam cleansing pipe d^{13} for the blow-off pipe d^{11} is arranged to enter the bottom of the converter and to project upward in the lower end of the blow-off pipe, so that steam can be introduced in an upward direction in the blow-off pipe, for the purposes either of cleansing the same or of assisting the upward flow of the contents through it while they are being discharged from the converter. This lower blow-off pipe d^{13} is fitted with a globe-valve d^{15}.

The converter is further fitted with a man-hole and man-hole plate d^{16}, and with a steam gauge d^{17}, so that the pressure of steam within the converter, and consequently the temperature which corresponds with such pressure, can be readily observed and regulated.

In order that the contents of the converter when discharged may be collected without material loss, the blow-off tank E is provided. This tank is arranged by preference considerably above the converter, so that the contents of the converter can be raised to a high level in the building, whence they can descend by gravitation to have other operations effected upon them. This blow-off tank is closed at the top with the exception of a vent pipe *e*, which is conducted by preference through the roof of the building, and permits the steam to pass off. The discharge end of the blow-off pipe is turned downward into the blow-off tank E, and is perforated so that the liquid is discharged in small jets. The perforated portion of the discharge pipe is surrounded by deflecting plates e^1, which deflect the jets of liquor in a downward direction, and thus obstruct its passage toward the upper part of the discharge tank, and prevent the carrying off of the liquor with the steam escaping through the vent pipe. The liquor collected in the bottom of the blow-off tank E may be drawn off at intervals by means of a pipe and stop-cock, or it may be permitted to flow at once through an open pipe into a tank H arranged below the level of the blow-off pipe. In the latter case the vent pipe *e* should extend into the lower tank to conduct the steam to the exterior of the building.

When the converter is empty and clean, the starch liquor is admitted through the inlet pipe d^4, either mixed with the acid or separately, the acid in the latter case being let in before the starch liquor through a pipe d^{20}. Steam may at the same time be introduced through the perforated steam-coil *d*, so as to heat the starch liquor as it enters. The excess of steam and any air there may be in the converter are permitted to escape during the inlet of starch through the steam outlet d^3.

When the charge of starch liquor and acid is introduced, the starch-inlet valve d^5 is closed, and if the liquor is to be boiled at a temperature not exceeding its boiling-point under the atmospheric pressure, the steam outlet is left open while the steam for heating the contents of the converter continues to be introduced through the steam inlet pipe d^1.

When the contents of the converter are to be heated to a temperature higher than that of boiling under the atmospheric pressure, the steam outlet d^3 is closed or partially closed, and the pressure within the converter is permitted to rise to the desired degree by introducing steam through the inlet pipe d^1, as determined by observing the steam gauge and by regulating the inlet of steam by the steam valve. The condition of the liquor within the converter can at any time be tested by the test cocks d^6 d^7, care being taken to cleanse the test pipe d^8 of the latter cock by the introduction of steam by means of the steam pipe d^9 before each test. The contents of the blow-off pipe d^{11} should also be discharged at intervals in a downward direction by steam admitted through the pipe d^{12}, so that they may become mixed with the mass in the converter.

When the contents have been converted to the desired extent, the valve of the blow-off pipe d^{11} is opened, and the contents of the converter are discharged in an upward direction into the blow-off tank E, to which the blow-off pipe conveys them. After the discharge, the blow-off pipe is thoroughly cleansed by admitting steam into it by means of the lower steam cleansing pipe d^{13}, and, if necessary, steam is admitted through this pipe during the discharge to facilitate the upward movement of the liquor.

In preparing the starch for this conversion, Jebb adds to the liquid starch in the tub C^3 sulphuric acid of a gravity of from 60° to 65° diluted with water in the proportion of about two parts of water to three parts of acid. The quantity of acid is preferably so regulated that 1 lb. of the said acid is employed for every 50 lb. of solid starch contained in the liquid. These proportions may, however, be varied if desired.

If preferred, the acid and the starch liquid can be introduced into the converter separately. In this case a portion of the acid is introduced into the converter through the pipe d^{20} before the starch liquid is supplied, and the rest of the acid is gradually supplied in the same measure as the converter becomes filled with starch liquid. In either case, a small quantity of water is first placed in the converter, so as to cover the steam jets in the bottom of the converter to a sufficient depth to prevent the issuing steam from coming in direct contact with the starch liquid, as it is introduced into the converter.

The water placed in the converter is first heated to the boiling-point, and the starch liquid is then introduced into the converter, preferably in thin streams or sprays. After the charge of starch liquid has been placed in the converter D, the pipe through which the starch liquid is introduced is closed, and the contents of the converter are then boiled until the conversion is completed. This is readily determined by any of the well-known tests. The conversion is usually completed in about 20 minutes.

During the operation of conversion the steam pressure in the converter is maintained at from 40 lb. to 60 lb. to the square inch. When the conversion is completed, the discharge pipe d^{11} of the converter is opened, and the contents of the converter are forced out through the discharge pipe and delivered into the receiving tank E, in which the hot liquor parts with its steam. The steam pressure in the converter is temporarily increased, if necessary, to elevate the hot liquor to the receiving tank E.

When it is desired to convert the starch for the manufacture of solid grape-sugar in an open converter, the starch is reduced in the tank C^3 by the admission of water to a gravity of about 20° B. An open converter, suitable for this purpose, consists essentially of a tank or vat F, open at the top, and provided at or near its bottom with one or more perforated steam pipes *f*, through which fine jets of steam can be injected into the converter, and which has a suitable discharge pipe f^1 at or near its bottom, through which the contents of the converter can be drawn off. The starch liquid is mixed with sulphuric acid in about the proportion stated with reference to the conversion in a closed converter. If preferred a portion of the diluted acid is first placed in the converter and the rest of the acid is introduced into the converter in a small stream, as the starch liquid is delivered. The steam pipes on the bottom of the converter are covered with water to a suitable depth, which water is heated to the boiling-point before the starch liquid is introduced into the converter in several streams or in a spray, and the charge is then boiled until the conversion is completed, which generally requires about 4 hours, and which is easily determined by any of the well-known tests. When the conversion is completed, the contents of the converter are discharged through the pipe f^1 into a neutralising tank G.

When the starch is to be converted in an open converter for the manufacture of liquid glucose, the starch liquid is mixed with water in the agitating tank C^3 to a specific gravity of about 16° or 17° B. Sulphuric acid diluted as before stated is then added to the starch liquid in the proportion of about 1 lb. of acid of a gravity of 60° to 65° to every 75 lb. of solid starch contained in the liquid. If preferred, a portion of the diluted acid can first be placed in the converter, and the rest of the acid introduced in a small stream as the starch liquid is delivered. The starch liquid is then introduced into the converter as before described, and boiled until the proper degree of conversion is reached, when the contents of the converter are discharged through the pipe f^1 into the neutralising vat G.

Instead of sulphuric acid, oxalic acid, muriatic acid, or nitric acid can be used, but Jebb prefers to employ sulphuric acid for converting the starch into solid grape-sugar and oxalic acid for converting starch into liquid glucose.

If it is desired to manufacture solid grape-sugar and liquid glucose at the same time, two mixing tubs C^3 are provided, in one of which the starch liquid is properly prepared for conversion into solid grape-sugar, while in the other tub the starch liquid is prepared for conversion into liquid glucose, and from which tubs the prepared liquid is conducted into separate converters.

If it is desired to manufacture white and hard grape-sugar of a superior quality the material is treated in the following manner:—After the converted starch liquid discharged from the closed converter has parted with its steam in the tank E, it is drawn into a neutralising tank H, where the acid contained in the liquid is neutralised by adding suitable material, such as marble dust, chalk, or the like.

A quantity of pulverised bone-black is introduced at the same time for bleaching the liquid. This neutralising-tank is provided with a revolving rake, whereby the materials are intimately mixed. After this operation is completed, the liquid is drawn from the tank H into a settling-tank I, in which the material is permitted to come to a state of rest, whereby the neutralising agent and bone-black are caused to subside or settle on the bottom of the tank. The supernatant liquid is now filtered through the press-filter P or bag-filter P^1, and the filtrate is collected in tanks P^2. From the latter the filtrate is pumped by a pump P^3 to one or more bleaching-tanks J, in which the liquid is subjected to the action of sulphurous acid gas for bleaching it. This gas is preferably generated by burning sulphur in a suitable furnace K, and is forced by means of a pump *k* through suitable pipes k^1 into the liquid contained in the bleaching-tanks J. The pipe leading from the sulphur furnace to the pump passes through a cooling vessel k^2, containing water and provided with a water inlet and an overflow pipe for supplying the cooling vessel with cold water and removing the warm water. In passing through the pipe in this cooling vessel the gas is cooled before reaching the pump, and the latter is thereby protected against the injurious effects of hot gas. In passing from the pump to the bleaching-tank J the gas is conducted through a closed washing vessel k^3, in which the gas passes through a body of water, and is thereby freed from all condensible and soluble impurities. The pipes k^1 which conduct the gas to the several bleaching-tanks are provided with suitable stop-cocks or valves, whereby the admission of gas to the bleaching-tanks is regulated. Those parts of the pump *k* which come in contact with the gas are constructed of brass, or of iron lined with lead or other suitable metal which resists the action of the gas. A further quantity of powdered bone-black may be added, if desired, to the liquid in the bleaching-tanks J. The liquid is drawn from the said bleaching-tanks into a receiver L, in which the liquid is permitted to come to a state of rest and in which the heavy material settles to the bottom. The supernatant liquid is then pumped to a press-filter or filters M, or bag-filters M^1, or both, and the filtrate is repeatedly passed through these filters until it has reached the desired degree of purity. The filtrate is collected in a receiving tank N, and is passed from the latter through a bone-black filter N^1, such as used for the filtration of the sugar-liquid in the manufacture of sugar from cane or beet. The filter N^1 represented in the drawings, consists of an upright cylindrical case filled with bone-black and provided at its upper end with a perforated pipe, through which the liquor is fed into the filter, and at its bottom with a pipe, through which the filtrate is discharged into a tank O. The filtrate is then drawn into the vacuum-pan O^1, and either entirely or partially concentrated therein. If only partially concentrated, the liquid is drawn from the vacuum-pan into a receiving tank O^2, and again filtered through pressure or bag-filters, or both, and through bone-black filters, and then again returned to the vacuum-pan, where the concentration is completed. If the concentration is completed in one operation, the concentrated liquid is filtered through bag or pressure filters and through bone-black filters after it comes from the vacuum-pan. The material is passed through the filters as many times as may be necessary to bring the material to the desired degree of purity.

When the bone-black with which the filters N^1 are charged requires to be revived, it is removed from the filters through the manholes near their bottoms, and is drawn into a carriage N^2, which is then removed over a hopper N^3, into which the contents of the carriage are dumped. The bone-black is fed from this hopper to a shaking sieve N^4, supplied with water spray pipes, whereby a portion of the foreign matter is separated from the bone-black. The water and the fine bone-black, which pass through the meshes of the sieve N^4, are collected in a box N^5 having suitable perforations through which the water is permitted to drain off, while the bone-black remains behind. The coarse bone-black passes over the tail of the shaking sieve into a spout N^6, which conducts the same to a steam tank N^7, in which the bone-black is subjected to the action of steam, whereby another considerable portion of the impurities is removed. The bone-black is finally placed in a kiln of well-known construction in which it is subjected to heat, whereby the process of reviving is completed.

If the material is designed to be manufactured into solid grape-sugar, and derived from an open converter, it is neutralised in the tank G, and therein mixed with bone-black, and then permitted to partially settle. The liquid is then pumped to a settling tank I^1, in which the heavy material is deposited. The supernatant liquid is then filtered through press filters P or bag filters P^1 into receiving tanks P^2, and the filtrate is pumped from the receiving tanks to the bleaching-tanks J, if it is desired to bleach the material by means of sulphurous acid; the operation of bleaching is then carried on as before described, and the material is filtered through the press filter M, or bag filters M^1, or both, and into a tank N, then concentrated by one or more treatments in the vacuum-pan, and again filtered, if necessary. If the material is not to be bleached by sulphurous acid, it is taken from the receiving tank P^2 directly to the vacuum-pan for concentration, or first to the filters M or M^1 and is treated by filtration and concentration, as may be necessary to produce a product of the desired quality.

In treating material derived from an open converter F, for the manufacture of liquid glucose or syrup, the material is neutralised, settled, and filtered through press or bag filters, bleached, again filtered, and concentrated in the vacuum-pan by one or more treatments, as may be desired. If preferred, the liquid may be taken from the settling vats L directly to the vacuum-pan, and afterwards to the filters M or M^1.

If the liquid is concentrated in the vacuum-pan in more than one operation, it is concentrated by the first treatment to a gravity of about 25° B., and afterwards in the final concentration to about 40° B. In all cases, the finished product obtained from the vacuum-pan is preferably filtered through bag or press filters. The liquid is maintained at a temperature of 145° to 160° F. in the neutralising tanks and in the succeeding steps until it reaches the vacuum-pan. This is accomplished by steam coils arranged in the several tanks. After the liquid has been concentrated to 25° B., its temperature should not exceed 140° F. An additional quantity of sulphurous acid is introduced into the vacuum-pan during concentration, if desired, to further bleach the liquid.

In manufacturing liquid glucose or syrup, the material, after the final concentration and filtration, is taken to a cooling apparatus Q, in which the material is rapidly deprived of its heat.

In the cooling apparatus which Jebb prefers to use, the material is agitated and caused to circulate in contact with coils of pipe through which flows a current of cold water. In this cooling apparatus, the liquid is agitated until cool, and is then drawn into barrels or other receptacles, in which it is disposed of to the trade ; or it may be first mixed with syrup obtained from cane or beet, if preferred.

In manufacturing solid grape-sugar, the material, after final concentration and filtration, is cooled as above described, and then either drawn into barrels or boxes in which it is permitted to harden, or it is drawn from the cooling apparatus into pans or moulds *q* of suitable size, in which the material is permitted to harden, or it is mixed with dry pulverised grape-sugar and then permitted to harden, or mixed with cane or beet sugar either before or after becoming solid.

After scraping, cutting, or pulverising the solid grape sugar, by means of a scraping or cutting machine R, or by means of a grinding, disintegrating, or crushing mill, or both, it may be mixed with granulated or pulverised cane or beet sugar.

Another method consists in mixing a portion of the cane or beet sugar with grape sugar while the latter is in a liquid state, then permitting the liquid to become hard, then scraping or pulverising the compound, and mixing the scraped or pulverised material with an additional quantity of cane or beet sugar reduced to a similar degree of fineness. When the material is delivered from the cooling apparatus into moulds or pans, the latter are preferably placed in a drying chamber S, in or through which air is caused to circulate, by means of a suction fan S^1, or a blast fan, pump, or chimney, and in which the sugar is rapidly deprived of its heat and moisture. Air is admitted to the chamber through registers or openings *s* in its bottom. After the sugar has become sufficiently hard to permit its removal from the pans or moulds, it is taken out of the pans and placed in the drying chamber S, and therein fully exposed on all sides to the drying and cooling action of the air current.

The bran and other coarse offal which is separated from the starch water by the sifting machine B is taken to a squeezing machine T, consisting essentially of one or more pairs of horizontal rollers, arranged one above the other, and an endless apron of wire cloth, or other porous material, which runs over suitable pulleys and passes between the said rollers, and which conducts the wet offal between the said rollers, whereby the water is pressed out of the offal and caused to pass through the meshes of the endless apron, while the solid portions of the offal remain upon the endless apron and are carried off by the same. The rollers of the squeezing machine are covered with rubber, or other elastic material.

The offal is conducted from the squeezing machine to a centrifugal machine U, or to a hydraulic press, in which the offal is again subjected to pressure (preferably a more severe pressure), whereby the remaining moisture is pressed out. If the offal is very much compacted during the operation of compressing, it is taken to a grinding or crushing mill, or a disintegrating machine U^1, whereby it is broken up and disintegrated and prepared for the drier. The offal is next placed in a drying apparatus V, in which it is dried by steam or other heat, and prepared for storage or shipment. The feed is sold in the condition in which it comes from the drier, or it is reground in a grinding, crushing, or disintegrating mill W, and sold in that condition, or after having been so reground it is mixed with corn, meal, or other ground grain in a disintegrating mill or other suitable mixing machine. The addition of corn, meal, or other ground grain to the offal increases the nutritive value of the feed, and renders the same more palatable to the cattle.

The tanks, vats, or vessels in which acid is used are preferably constructed of galvanised iron or lead.

A grain storehouse, containing a number of bins or receptacles arranged side by side, and constructed of planks laid one upon the other, as represented at X, and provided with endless belt and bucket elevators, whereby the grain is elevated to the bins, and with spouts for discharging the grain from the bins, is connected with the manufactory. The engines, shafting, and other machinery for actuating the various machines are not shown.

Payen's method.—The conversion of the starch into sugar is performed in large wooden vats A (Fig. 171), each having a capacity of 350 bushels, and their staves a thickness of about 4 inches. A leaden pipe *b c d* runs into the vat A to the bottom *c d*, the parts *c d* having slits at short distances. The vat is filled to about one-third of its capacity with sulphuric acid water; this is heated by admitting steam from the boiler *i* through the copper pipe *g e b* (fitted with a stop-cock *h*) and the leaden pipe *b c d*. During the boiling, the vat is covered, and the vapours drawn off are immediately conducted into a chimney, or passed through a main pipe into the worm E F, to be utilised for the evaporation. If these vapours escape at once through the chimney, they will create a nuisance; whereas by the cooling off in the worm, the volatile oils become in a great measure condensed with the steam, and thus collect between the pipes F G in the vessels placed below.

In this way, the non-condensed parts escape through the pipe C along with the vapours, and are not noticeable. To entirely destroy the vapours, they may be conducted into the fireplace under the boiler.

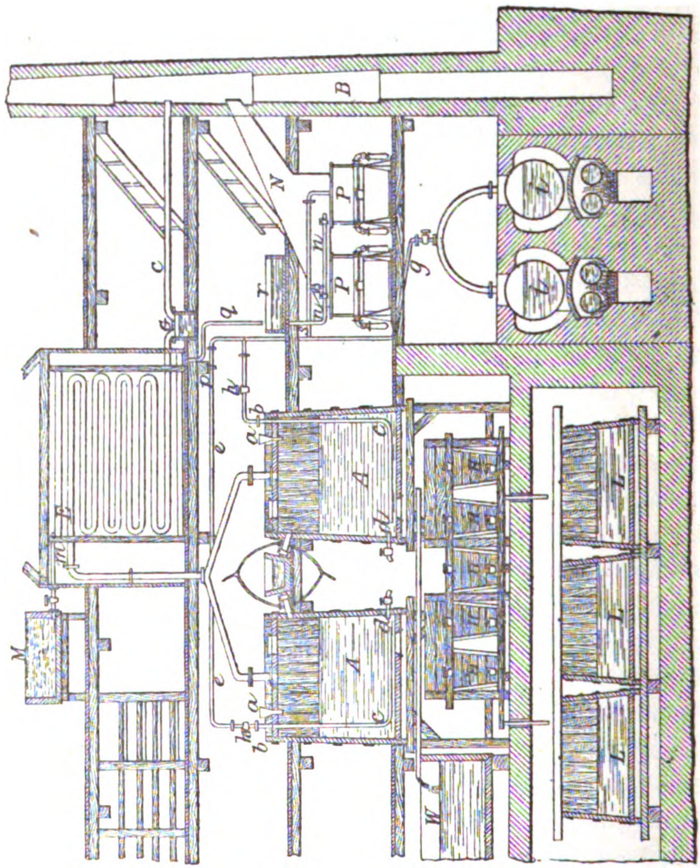


FIG. 171. Payen's Converter.

Into the vat A, is poured about 6600 lb. of water, mixed with half the sulphuric acid necessary for the transformation of the starch, and heated to 100° C. (212° F.). Meantime 6600 lb. of commercial dry starch is placed in a vat of corresponding size set above the boiling-coop. Into this, the other half of the requisite sulphuric acid (in the present instance 66 to 132 lb.) and a corresponding quantity of water have previously been poured, in order to produce starch-milk. This starch-milk is admitted into the boiling-coop by a cock situated in the bottom of the upper vat, and runs in a uniform stream through the funnel *a* into the boiling-vat or "converter." The less the water, in comparison with the amount of starch to be converted, the more care must be taken during the admission of the starch-milk, so that the boiling is not interrupted for a moment. By the gradual admission of the starch-milk, the temperature increases, finally reaching the boiling-point of an equally concentrated sugar solution.

When all the starch-milk has passed into the boiling sulphuric acid water, requiring 1 to 1½ hour, the boiling is continued for 2 to 3 hours, in the case of glucose, and for 4 to 6 in the case of sugar.

When the transformation is finished, the free sulphuric acid is neutralised as usual, and the liquor is allowed to settle for 12 hours. This can be done either in the coop itself, or in the tank W. The clear liquor is drawn off, heated to 60° C. (140° F.), and refined through the charcoal filters H. The gypsum residue is placed over a linen filter, and washed out.

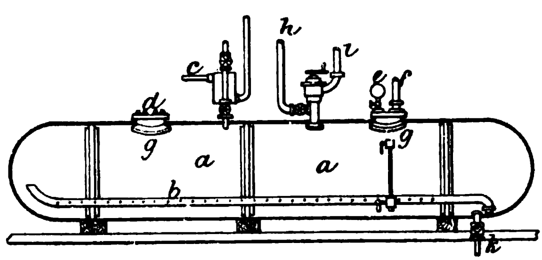
The thin juice filtered through the bone-black, being 15° to 16° B., is collected in the lower reservoirs L, whence it is pumped into the upper reservoir M; thence it flows off into the horizontal chamber *m*, supplied with a number of slits, and runs down through the side slits over the heated worm E F. Under this, the syrup collects in a gutter *p*, and flows through the pipe *q* into the reservoir *r*, where it is finally drawn off as required by the pipe *s* and the spigots *n*, thence to run into the evaporating pans P. Over these pans is a wooden casing N, to conduct the steam into the chimney B. The syrup is evaporated in these vessels to 30° B.; again some gypsum becomes separated, and must be removed by prolonged depositing.

The starch syrup thus obtained is at once serviceable for distillers and brewers. For many applications, however, as baking, cordials, &c., it is, after 24 hours, re-heated to 60° C. (140° F.), filtered through coarse animal charcoal, and immediately barrelled.

This method finds application in but few establishments.

Manbré's method.—The conversion of starch into sugar proceeds much faster when the boiling takes place under pressure: upon this fact rests Manbré's method. The mixture of starch with diluted sulphuric acid is boiled at a high pressure, and at a temperature of 160° C. (320° F.). By this treatment, the action of the acid is increased, the transformation is more perfect, and the volatile oils which impart a disagreeable flavour are distilled off and destroyed. Use is made of a steam-boiler, constructed to withstand a pressure of 99 lb. per square inch (6 atmospheres); it is lined inside with lead, and covered outside with a double casing. The intermediate space between the boiler and the casing is about 4 inches wide, and filled with non-conducting material. In

FIG. 172.



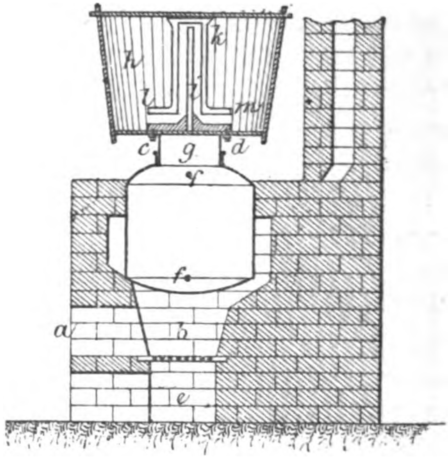
Manbré's Converter.

the boiler *a* (Fig. 172), is placed a perforated leaden steam-pipe *b*. The starch-milk is admitted by the pipe *c*, supplied with a stopcock; the boiler is supplied with safety-valves *d*, test-cock *e*, thermometer *f*, manholes *g*, receiving-pipe *h* for the products of distillation (volatile empyreumatic oils), steam-pipe *i*, liquor-gauge *k*, steam-pipe *l*, outlet-cock *m*, and water-pipe *n*.

The substances are prepared for the boiler as follows:—61½ lb. of sulphuric acid at 60° B. are diluted in 6150 lb. of water. While this mixture is heated in the boiler to 100° C. (212° F.), a further 61½ lb. of sulphuric acid is diluted in 6150 lb. of water in an open wooden tank, supplied with a stirring apparatus. This mixture is heated by steam to 30° C. (86° F.). Into this latter liquid, 2464 lb. of starch are well stirred, and heated to 38° C. (100·4° F.). The starch-milk thus obtained is gradually poured into the boiling diluted sulphuric acid of the boiler by the pipe *c*, and the mixture is kept at a boil. As soon as all the starch is in the boiler, the cock of the conduit-pipe is closed, and steam is admitted until a temperature of 160° C. (320° F.) and a pressure of 6 atmospheres are attained. The cocks *h i* are then opened for the outlet of steam and the products of distillation, while the temperature of the liquid is maintained by steam in the pipe *b* at 160° C. (320° F.), until samples taken out by the cock *k* indicate complete transformation. This is attained, according to the purity of the starch, in 2 to 4 hours. After ceasing to form sugar, the sweet liquor is to be drawn off, for the neutralisation of the sulphuric acid, into an open wooden vessel, supplied with a stirring apparatus and waste-cock, and 185 lb. of purified carbonate of lime are stirred into 550 lb. of water, and gradually added to the liquor. The sulphate of lime thus formed is allowed to deposit, which occupies 2 to 4 hours. The neutral saccharine solution is filtered, evaporated, cleared, and crystallised as usual. The product is entirely pure, and free from any bitter or empyreumatic flavour.

Rössling and Reichardt's process.—Rössling and Reichardt's apparatus for the manufacture of starch sugar on a small scale is shown in Fig. 173. *a* is the furnace opening; *b*, the fireplace; *c d*, the mechanism for supporting the barrel, consisting of a ring-plate and pipe; *e*, the ashpit; *f*, apertures with pipes and cocks; *g*, the neck of the boiler; *h*, the barrel of

FIG. 173.



Rössling and Reichardt's Converter.

white pine, with a bottom at least 1 inch thick; *i*, a tube made of linden or maple, 2 inches thick and ⅞ inch wide; *k*, a pipe with four steam outlets below, two of which are visible at *l m*.

Anthon's method.—Excellent sugar is furnished by the method invented by E. F. Anthon, and patented in many countries. The manipulation is as follows:—

Boiling.—2640 lb. of dry starch are stirred up in 370 gallons of water to a homogeneous milk, and run uniformly into the converter, previously charged with 53 gallons of water and 48 lb. of oil of vitriol, and brought to the boiling-point, so that the mass boils uninterruptedly. During winter, the starch may be stirred with tepid water, but not so warm that it becomes pasty. When the mixture has been kept at a boil for about one hour after the entire mass has been emptied in, the boiling is continued for 4 to 5 hours longer for making hard crystallised sugar, but when syrup is intended, 3 hours' boiling suffices.

Neutralisation.—For this purpose, 66 lb. of good bone-black and 55 to 66 lb. of purified chalk are used. The chalk must previously be mixed in water and strained through a fine sieve. At first, 22 lb. of bone-black are gradually thrown in, and then the chalk-milk is poured in through a leaden pipe reaching down to the lower half of the boiling-vat. But great care must be taken that the seething liquid does not flow over. When the mixture reacts but moderately acid, the adding of chalk is interrupted, and the balance of 44 lb. of bone-black is added. It should be made a rule that one-third of the bone-black is to be added before throwing in the chalk, and two-thirds afterwards.

The finished mixture is boiled gently for about 10 minutes, and passed through a Taylor filter.

Evaporation.—For common coagulated sugar, the syrup is condensed to 33° or 36° B. (hot); but for hard sugar, to about 33° B. (hot). The syrup is passed through a small Taylor filter, cooled, and a few lb. of half-congealed sugar of a former boiling are added and thoroughly stirred in. After 10 to 30 hours, the mass will become so stiff that for common sugar it can be put into barrels and left to harden. For hard sugar, the evaporation is stopped at 33° B., the stirring is not so strong, and is not so often repeated when the partly coagulated sugar is being added. When the body of the sugar has attained a completely stiff consistency, so that it can only be scooped out with difficulty, it is then to be subjected to pressure in a filter-press or centrifugal machine (see pp. 361, 490).

To make loaf-sugar, the press-cakes or sugar taken from the centrifugal are broken up into small pieces and melted, without adding water. This is done in a kettle over a steam-bath, aided by occasional gentle stirring, in a temperature as low as possible, continued until all lumps have crumbled, but not until the fine parts are dissolved. For 880 lb. of sugar, the operation occupies 3 to 4 hours. Complete solution of the sugar must be avoided, since those particles which float in the solution favour crystallisation. When the mass has attained the proper consistency, it is cast into the moulds; in 2 days, it is entirely solid.

The press-syrup can either be mixed with such syrup as contains a large amount of dextrine, and sold as such, or boiled and worked over again so as to make a second product of press-cakes. To this end, it is evaporated to 36° to 37° B. (hot), cooled off and coagulated as usual, and pressed out. The press-cakes thus obtained are inferior, and it is best to dispose of the press-syrups as such.

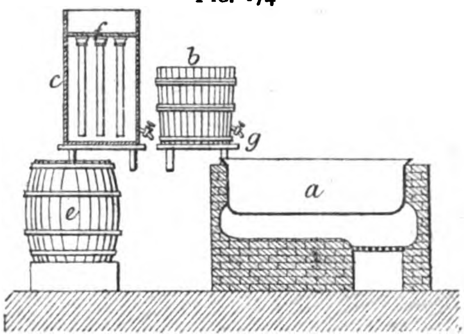
To obtain a product of the whitest possible colour, the application of sulphurous acid is resorted to. After half the chalk has been applied in the neutralisation, 3 to 4 lb. of dry or 11 lb. of liquid sulphate of lime is added, continuing the boiling for 10 minutes, and then adding the rest of the chalk. It is imperative to carry out the process with great cleanliness, and to use no water which contains hygroscopic ingredients, or will be turned brown by sulphuric acid.

In Anthon's method for producing 3 to 4 cwt. of starch sugar per 24 hours, the ingredients for a boiling are:—

370 lb. of air-dry starch.	2·46 to 3·70 lb. of pure burned lime.
11 ,, of sulphuric acid of 66° B.	4·95 lb. of prepared chalk.
3·70 ,, of bone-black.	

The apparatus is very simple, and is represented in Fig. 174: *a* is the pan; *b*, a vat of about 8½ bushels capacity, with a wooden spigot *g* at the bottom: *c*, a Taylor filter in a case 4 feet high and 2 feet wide and deep, arranged for the reception of 9 bags, each about 2½ feet in length, and 6 to 7 inches diameter when filled, and set up so that the thin liquor can be drawn off by a small gutter into *e*. The bags are made of grey linen of prime quality and uniform weft, and are fastened over the funnels *f* with strong cord.

FIG. 174.



Anthon's Apparatus.

Capillair Syrup and Sugar.—Some few establishments have furnished quite recently a water-clear syrup, which, in a very condensed state, is known in the market as "capillair-syrup," and is extensively used by confectioners and others in the United States. The mode of producing it is as follows:—After the usual boiling and neutralisation, the clear, thin liquor of 16° to 20° B. is concentrated in a vacuum-pan to 30° B. (boiling hot). The vacuum-pan is of copper, because by this process the gypsum deposits itself on the copper pipes as firmly as stone, and the pipes have to be frequentl,
by aid of muriatic acid.

If the temperature can be maintained at 57½° to 63¾° C. (145½° to 146¾° F.), the syrup will remain of a lighter colour, as also with rapid evaporation. Since the gypsum never completely separates from this heavy syrup, filter-presses are used. Thus the clarifying is much accelerated, and the thin syrup issues from the filter-presses free from gypsum, and entirely clear. It is directly pumped into the reservoir, thence to the bone-black filter, and is then sucked into the vacuum-pan, and evaporated at 56½° to 62½° C. (133¾° to 144½° F.). If the syrup is for exportation, the concentration is carried to

44° B. at 61° C. (142° F.) The evaporation goes on very quickly, since the syrup already possesses a consistency of from 28° to 30° B. It has to be filled into the casks while yet lukewarm. If it cools off entirely, it will not run out of the vats at all.

The perfectly white and finest quality of starch sugar, which also passes through the bone-black filters, is known as "capillair grape sugar," and is manipulated in a similar way, with this difference, that the syrup at the last stage is condensed to 44° or 45° B., while for the production of sugar, the process of evaporating must be stopped as soon as the syrup has reached the consistency of 40° to 41° B. This sugar has been mostly packed in cases of 1 cwt.; but more recently it is cast into blocks and loaves, which are afterwards grated, and the sugar packed in bags. This method of packing in bags is more practical and advantageous than packing it in boxes, since the sugar adheres to the wood of the boxes, and much of it is lost.

Soxhlet, of Munich, takes the ordinary starch sugar of commerce and mixes with it 70 or 80 per cent. of alcohol of 80° Tralles, or pure wood naphtha (methyl alcohol). Pulverised starch sugar is then added to this syrupy mixture, and the whole is left to solidify at a temperature *above* 30° C. (86° F.), with frequent stirring. The syrup obtained in making starch sugar can also be treated in this way. The mass of crystals thus obtained is pressed and put into a centrifugal machine. The alcohol is recovered by distillation.

For making solid transparent starch sugar (dextrose hydrate, $C_6H_{12}O_6H_2O$) the starch sugar solution is concentrated in a vacuum to 46° B. (taken at 90° C.), and put in moulds to crystallise at a temperature between 35° and 50° C. (95° to 122° F.). At lower temperatures the well-known warty crystals form.

This method depends, it will be observed, upon the removal of uncrystallisable and unfermentable substances from the sugar by means of ethylic or methylic alcohol, in which grape sugar is itself but slightly soluble.

Granulated Starch Sugar.—The manufacture of granulated starch sugar was introduced by Fouchard, at Neuilly, France. The transformation of the starch into sugar is accomplished in the ordinary manner, but at an increased temperature and pressure, as a great amount of dextrine would hinder the granulation of the sugar.

The liquor, saturated with lime, is run through a bone-black filter, to impart to it the colour of a nice clear "covering" sugar. The filtered liquor is evaporated in summer to 30° B. in winter to 28° B. (boiling), and run into capacious clearing-tanks, where the greater part of the gypsum settles; the tanks are in a cool place, or the cooling is accelerated by the use of worms in which cold water circulates, so as to avoid fermentation. After the lapse of 24 to 30 hours the syrup is cool and clear, and is then placed in vertical barrels, left open above, and whose bottoms are perforated with small holes, thus forming a sieve bottom. During the process of crystallisation, these openings are kept closed with small wooden pegs or taps. The barrels stand on a frame-work over a lead-lined gutter.

In 10 to 12 days, crystallisation begins by the formation of small accumulations in the syrup, which gradually increase. As soon as the syrup is about two-thirds filled with crystals, the holes in the bottom of the barrels are opened, draining off the molasses, while the soft crystalline accumulations remain in the barrels.

As soon as the draining appears to be finished, this is perfected by placing the barrels in an inclined position. The molasses thus obtained is again boiled in sulphuric acid water, to transform the dextrine present into sugar. The granulated sugar is then placed on gypsum slabs to the thickness of 4 inches, and dried at 22° to 25° C. (71½° to 77° F.). By increasing the temperature, the crystals would melt and stick together. This lump formation cannot be entirely avoided. If the lower part of the layer begins to become dry and white, it is turned. In 3 or 4 days the sugar becomes perfectly dry, and is then, for the purpose of an even separation, ground through a sieve, while the lumps which do not pass through the sieve are ground between a pair of porcupine rollers. Usually the sugar is again spread on gypsum slabs.

Uses of Starch Sugar, and Glucoses.—These products are used chiefly for the manufacture of table syrups, candies, bee-food, brewing, and artificial honey-making. All soft candies, waxes, and toffies, and a large proportion of stick candies and caramels, are made of starch-sugar syrup. Very often a little cane-sugar is mixed, in order to give a sweeter taste to the candies, but the amount of this is made as small as possible. A very large percentage of all the starch sugar made is used for the manufacture of table syrups. Some kind of cane-sugar syrup is added until the tint reaches a certain standard. The amount of cane-sugar syrup required varies from 3 to 10 per cent., according to circumstances. These syrups are graded A, B, C, &c., the tint growing deeper with each succeeding letter. Small quantities of starch-sugar syrup are used by vinegar-makers, tobacconists, wine-makers, distillers, mucilage-makers, and perhaps in some other industries.

The solid sugar is also used for many of the purposes enumerated, but chiefly for the adulteration of other sugars. When it is reduced to fine powder, it can be mixed with cane sugar in any proportions, without altering its appearance. Since starch sugar costs much less than cane sugar, this adulteration proves immensely profitable.

The cost of manufacture is about ½*d.* a lb. Some 26 to 32 lb. are made from a bushel of corn. It is sold by the manufacturers at 1½*d.* to 2*d.* a lb.

CHAPTER XX.

PROCESSES FOR THE RECOVERY OF SUGAR FROM RESIDUAL SYRUPS OR MOLASSES.

THE following analysis represents the average composition of beet molasses :—

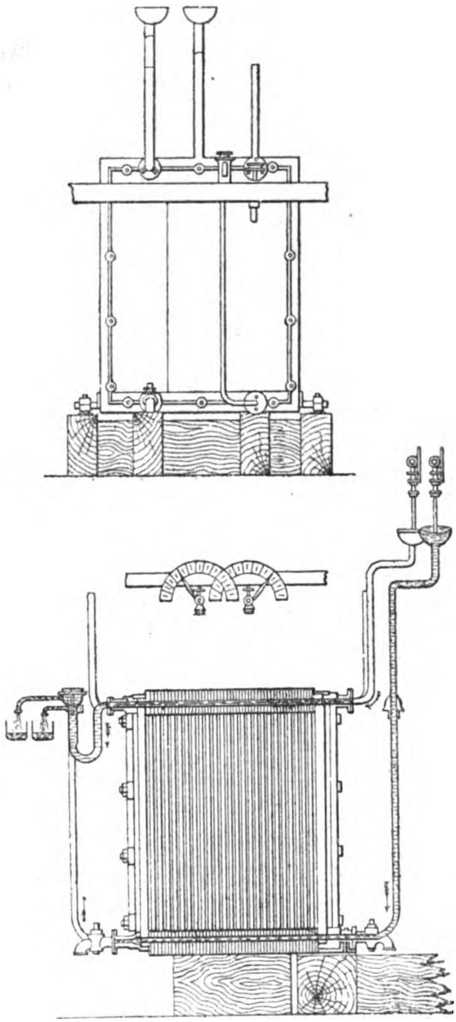
	Per cent.
Sugar	50
Other organic matters	20
Ash (mineral matter)	10
Water	20
	100

All the sugar which can be profitably removed from these molasses by the ordinary process of concentration and crystallisation has been already taken out, the mineral and organic matters preventing the separation of that still remaining. The molasses are very dark in colour and have an exceedingly disagreeable taste and odour, so that they are utterly unfit for consumption as treacle, and therefore usually pass into the hands of the distiller, by whom they are fermented, yielding an inferior kind of spirit, the residue left, after distilling the alcohol, being employed as a manure under the name of "vinasse." The vinasse is often calcined, and a considerable amount of potash salts is obtained in this way. Many attempts of a more or less successful character have been made to recover the sugar from beet molasses, and a short account of the most important of these will now be given.

The Osmose Process of Dubrunfaut.—In the earlier part of this work a description has been given of the principles upon which the "diffusion process" is founded. In describing the action of a porous membrane, when brought into contact on both sides with various liquids and solutions, Professor Graham discovered that many substances could be separated in this manner, and he arranged these in two great classes, viz. "crystalloids" and "colloids." The first class embraces all soluble bodies of a crystalline character, and these pass through the membrane with a considerable amount of facility, whereas the bodies of the second class, colloids (glue-like), are almost entirely arrested by the membrane in question. Even with crystalline substances, there is a considerable difference in the rate at which they pass through such a membrane, thus most salts will pass through much more freely than sugar, and the object of Dubrunfaut's process is to take advantage of this fact. In carrying this into operation, an apparatus is employed termed an "osmogene" (Fig. 175), consisting of two chambers separated by a diaphragm constructed of parchment-paper, or of other suitable material. One chamber contains molasses, and the other water. Each compartment is a wooden frame, which may be of the following dimensions: —39 inches wide, 26 inches deep, and about ½ inch thick. Four wooden stays divide the interior of the frame into five compartments, communicating by means of openings. On each face of the frame are fitted leaves of parchment-paper, held in position by thin cords. The molasses entering at the bottom rise in a serpentine manner into the five compartments of the frame, and escape at the top. A second frame, exactly similar, but filled with water, is placed in juxtaposition to the first, so that the same sheet of parchment-paper serves to separate the two frames, and consequently the two liquids. This constitutes one "element" or couple of the osmogene. Several such placed in rotation form the complete osmogene.

The circulation of the liquids is established by means of channels in the frames, the one at the left, below, communicating only with the molasses frames, the other, above on the right, for the circulation of water. All the frames are screwed together by long bolts. They usually number 50, but sometimes amount to 100. To change the parchment-paper the screws are undone, and the frames

FIG. 175.



Osmogene.

are laid on the table. The molasses enter at a temperature of 60° to 75° C. (140° to 167° F.), and the water at 85° C.

(185° F.); the density of the molasses is reduced from 41° B. to 30° or 25° B. It might be still further lowered, with corresponding cost incurred by the dilution.

A modification of the osmogene has been introduced by Lilpop, Rau, and Löwenstein, of Warsaw, in which it takes the form of Trink's filter-press. The frames, to the number of 51, rest by means of projections upon two horizontal arms, and are screwed together. The discharge of the apparatus and change of liquids is facilitated by arranging the whole to rotate on its axis.

Lime, Baryta, and Strontia Processes.—These processes depend upon the fact that each of the above-named alkaline earths is capable of forming compounds with sugar possessed of only a slight degree of solubility. A compound of this class having been formed by mixing one of the bases in question with molasses, the almost insoluble precipitate obtained is next purified by washing with water, or with alcohol, as in the so-called "elution" processes, and afterwards suspended in water through which a current of carbonic acid is passed. The sugar under these circumstances enters into solution, whilst the base into which it was united is converted into an insoluble carbonate, and may be regenerated by the action of heat. In the case of sucrate of lime, it is sometimes directly added to the raw beet juice, the free acids of which it serves to neutralise, being used for this purpose in place of milk of lime.

Elution Process.—In working this process, the molasses are well mixed with a quarter of their weight of lime, when the sugar is converted into tribasic sucrate of lime, and a solid mass is produced. According to the original method of Lair and Bilange, this crude sucrate of lime was washed with water to remove adhering impurities, but as the sucrate of lime is dissolved to some extent by water, Dr. Scheibler proposed to substitute alcohol, in which the sucrate is insoluble.

Seyferth's Process. — This modification of the elution process was carried out by Seyferth in the following manner: —The molasses employed had a density of 43° to 44° B. at a temperature of 30° to 33° C., and to this was added 30 to 40 per cent. of quicklime, which had previously been made into a very fine powder, and mixed with just enough water to form a sort of cream. The whole was then well mixed, when the heat produced by the combination caused the mass to become solid. This crude sucrate was next reduced to small fragments and placed in a number of vessels called "elutors." It was then washed with alcohol of 35 per cent. in a systematic manner, each fresh lot of sucrate being first washed by the alcohol which had been already partially charged with impurities, and pure dilute alcohol being used for the last washing. By being thus washed five or six times, the impurities were almost entirely removed. Steam was then passed into the "elutor," any alcohol adhering to the sucrate being recovered by distillation, and the sucrate itself being reduced to a paste capable of easy removal, which could be used in the defecation of beet juice, or from which the sugar could be recovered by treatment with carbonic acid gas.

Manoury's Elution Process.—This bears considerable resemblance to the foregoing, and was carried out by Manoury at the fabric of La Capelle, near Dunkirk. The molasses were intimately incorporated with milk of lime, in a specially constructed mixing apparatus, and, by this means, the sucrate of lime was obtained in small granules, which were afterwards lixiviated with alcohol of 40 per cent. in closed elutors.

Steffen Process.—In working this process, the tribasic sucrate of lime is first produced in the following way: Beet molasses are diluted to 6°·6 B., when they contain 7 to 8 per cent. of sugar, and small portions of freshly burned and finely powdered lime are added at frequent intervals, the temperature not being permitted to exceed 59° F. The sugar is thus precipitated in the form of tribasic sucrate of lime, which is but slightly soluble, requiring 200 parts of water to dissolve it. For the precipitation of 100 parts of sugar it is necessary to employ 93·4 parts of lime. The sucrate, which has the appearance of dirty milk of lime, is pumped into a filter-press, which is so made that the sucrate can be washed in situ. The liquor passing through the press is employed as manure, and the sucrate is washed with water, the washings being used to dilute a further amount of molasses. The nearly pure tribasic sucrate of lime remaining in the filter-press may be decomposed by hot water, which dissolves the monobasic sucrate of lime, leaving two-thirds of the lime in the filter-press; the rest of the lime may be thrown down by a current of carbonic-acid gas. On allowing the carbonate of lime to subside, or on separating it by filtration, and evaporating the liquid, the sugar may be obtained. The tribasic sucrate of lime is, however, generally employed in beet sugar fabrics as a substitute for the lime in defecating the raw juice. This process of Steffen is, in some respects, the most successful mode of recovering sugar from beet molasses. It is not, however, adapted for the treatment of syrups in a refinery using cane sugar, as the glucose contained in the syrups is an obstacle to its employment.

Strontia Process.—Dr. Scheibler thus describes the nature of his present modification of this process. If to a 20 or 25 per cent. solution of cane sugar there be added, at 70° to 75° C., with agitation, an equivalent quantity of crystallised strontrium hydrate, a supersaturated solution of strontium monosaccharate is obtained, from which, after a time, either unaltered strontium hydrate may be caused to crystallise out, or the monosaccharate to separate, according as either a crystal of the former or of the latter is introduced. Strontium monosaccharate has the following composition: $C_{12}H_{22}O_{11}$, SrO, when in the anhydrous state, and the same, plus $5H_2O$, when crystallised. It is soluble in cold and more easily in warm water, and is decomposed with formation of the bisaccharate, when a solution is heated above 60° C. One litre of water dissolves the following amounts of the monosaccharate $C_{12}H_{22}O_{11}$, SrO :—

at 0° C.	28·4 grams.	equal to	21·8 grams	of sugar,	
at 58° „	185·1	„	„ 142·1	„	„

In practically carrying out this process, a strong solution of strontium hydrate, in rather more than the theoretical amount, is added to the syrup, the temperature being kept at such a point that there can be no formation of bisaccharate. The mixture, which should remain clear, is then cooled, and a few crystals of monosaccharate are thrown in, when the separation of the same compound commences, and is complete in from twelve to twenty-four hours. The mother-liquor is then separated by a filter press, supersaturated with strontium hydrate, and the whole brought to the boiling point, when a formation of bisaccharate at once takes place. This is removed and mixed with a fresh quantity of syrup in the proportion of 1 molecule of total sugar to 1·25 molecules of strontium oxide. The mixture is cooled, and a second small crop of monosaccharate obtained as before. From the monosaccharate resulting from these two operations, the sugar may be obtained after precipitating the strontia as carbonate by a current of carbonic-acid gas; or better, if a crystal of strontium hydrate is dropped into a saturated solution, the whole being well cooled, a portion of the strontia then separates as hydrate, and the remainder is afterwards precipitated by carbonic acid.

Sucrate of Hydro-carbonate of Lime Process.—This process, invented by Boivin and Loiseau, consists in the purification of saccharine solutions by the use of a compound or mixture called "sucrate of hydro-carbonate of lime," which is produced by passing carbonic-acid gas into a solution of sucrate of lime, so as to partly, but not entirely, decompose the sucrate. The sucrate of hydro-carbonate of lime is sometimes employed directly in the treatment of cane juice. It is also used in refining raw sugars of good quality not containing more than 2 to 3 per cent. of glucose. In this latter case, the sucrate is mixed with a solution of the raw sugar, and the mixture is boiled and filtered. The lime is then removed as carbonate by passing carbonic-acid gas through the filtered liquor. The glucose is destroyed by this process, and it is said without the usual darkening of the liquor which occurs when lime or other alkaline substances are heated with solutions containing glucose. This process is stated to effect a great saving of animal charcoal, whilst the yield of sugar is increased. The residual molasses, however, are only fit for converting into spirit, or to be employed in the manufacture of blacking.

Acetic Acid Process.—By well mixing beet molasses with strong acetic acid, nearly all the impurities may be dissolved out, most of the sugar remaining undissolved. For various reasons, especially the expense of recovering the acetic acid used, this mode of working has not been carried out on the large scale.

Margueritte's Process.—In working this process, sufficient sulphuric acid is mixed with molasses to convert all bases present into sulphates; a considerable quantity of alcohol is then added, and the whole mixture is well stirred, and afterwards allowed to rest, when the bases are almost entirely precipitated as sulphates. The alcohol is recovered by distillation and much of the sugar is left behind, freed to a great extent from its mineral impurities. This process when tried on the large scale was not attended with satisfactory results, there being a considerable loss of alcohol, and also some of the sugar being inverted by the treatment with acid.

Alum Process.—The alum process for removing potash, ammonia, and other impurities from saccharine solutions is the invention of James Duncan, John A. R. Newlands, and Benjamin E. R. Newlands. Beet syrups contain a notably large proportion of potash salts which interfere with the crystallisation of the sugar. The salts in beet molasses, according to Dr. Wallace, are :—

Chloride of potassium	18·70
Sulphate of potash	4·18
Carbonate of potash	53·80
Carbonate of soda	20·81
Carbonate of lime	0·35
Magnesia	0·27
Moisture and loss	1·89
	100·00

A sample of French beet molasses gave 10·86 per cent. of ash, 4·88 being potash.

Out of the 3·40 per cent. of ash from English beet syrup, 1·36 is represented by potash.

Low class cane sugars also contain notable proportions of potash :—

Dutch Bastards, 0·33; Guatemala, 0·40; Low Penang, 0·57; Medium Penang, 0·23; Egyptian, 0·63; Jaggery, 0·49; Clayed Manilla, 0·23; Ilo Ilo Manilla, 0·58 per cent.

The alum process consists of two parts: 1st, precipitation of the potash in the form of alum; and 2nd, neutralisation of the residual acid liquor by means of lime.

1. Precipitation.—This is accomplished by adding to the cold syrup solution of sulphate of alumina, in quantity sufficient to form an alum with the whole of the potash present. It is convenient to work with syrup at a density of 38° B., and solution of sulphate of alumina at 27° B., or thereabouts. If the density of the syrup be much over 38° B. the alum cannot easily settle out. The mixture is well stirred for about fifteen minutes to one hour, and the whole is allowed to repose for one or two hours, until the deposit—which consists of small crystals of alum, technically known as "alum meal"—has completely subsided. The tank in which this operation is performed is provided with mechanical stirring gear, and may be called the "alum-tank."

The three principal points to be attended to in this part of the process, in order to obtain the best results and to prevent the formation of uncrystallisable sugar, are—

(1) To work at the lowest attainable temperature;

(2) To employ solutions as dense as possible;

(3) To perform the whole operation as quickly as is consistent with due separation of the alum.

The amount of potash present in syrups is generally equal to $\frac{2}{5}$ths of the ash. The ash is determined in the usual way by addition of concentrated sulphuric acid, followed by incineration and weighing, $\frac{1}{10}$th being deducted from its weight. It is sufficient for most practical purposes to assume that $\frac{2}{5}$ths of the ash is potash.

Every 1 part of potash requires for conversion into alum about 9½ parts of sulphate of alumina, out of which 2½ parts are required to convert the potash into sulphate, and the remaining 7 to combine with the sulphate of potash, so as to form alum. If the liquor contains any sulphuric acid, either free or combined, or if the solution of sulphate of alumina contains any free sulphuric acid, the 2½ parts of sulphate of alumina required to convert the potash into sulphate may be partly or entirely dispensed with.

For practical purposes it is sufficient to determine the percentage of ash, to assume $\frac{2}{5}$ths of this to be potash, then to multiply the percentage of potash by 9·5, which gives the dry sulphate of alumina, and, lastly, to ascertain the amount of solution corresponding to this.

2. Neutralisation.—The alum-tank is provided with several taps, at different heights, and, when the alum has well settled down, the clear acid liquor is run off, by means of these taps, into another tank placed on a lower level, and also provided with mechanical stirring-gear. This tank is called the "liming-tank." As soon as the acid liquor has been thus decanted into the liming-tank, a little finely-divided chalk, previously made into a paste with water, is added, so as to produce a slight effervescence. Milk of lime is then added at frequent

intervals, until the froth has nearly, but not entirely, disappeared: the gradual abatement of the froth serves to indicate when the neutralisation is nearly complete. This operation takes about one hour. The point at which the neutralisation is pratically complete may be known by three simple observations :—

(1) The absence of any large amount of froth.

(2) The absence of any taste of aluminous compounds.

(3) The liquor should give only a *dull* red tinge to blue litmus paper.

When the neutralisation is thus practically complete, the treated liquor is subjected to the same routine as the ordinary solutions of sugar in a refinery; that is to say, it is heated in the blow-ups to 65° C. (150° F.), but not to a higher temperature, then passed through Taylor filters, and through char, and boiled down in the vacuum-pan.

To wash and dry the precipitated alum, it is convenient to employ a small centrifugal machine. After once machining for a few minutes, a little water being added as usual during the operation, the alum appears white and dry, but still retains a small amount of syrup. It is then mixed up with some cold water, and machined a second time, after which it will be found free from sugar and fit for sale.

The following analyses show the effect of the process on beet syrup, when treated on a large scale :—

	Beet Syrup.	Ditto, after Treatment and before Char.	Ditto, after Treatment and after Char.
Sugar	60·18	40·54	41·60
Ash	3·61	1·33	0·47
Water, &c.	36·21	58·13	57·93
	100·00	100·00	100·00

The advantages of the process are—

(1) The removal of potash and ammonia from syrups without much dilution.

(2) The removal of a great deal of the colouring and albuminous matters.

(3) A considerable improvement both in flavour and odour.

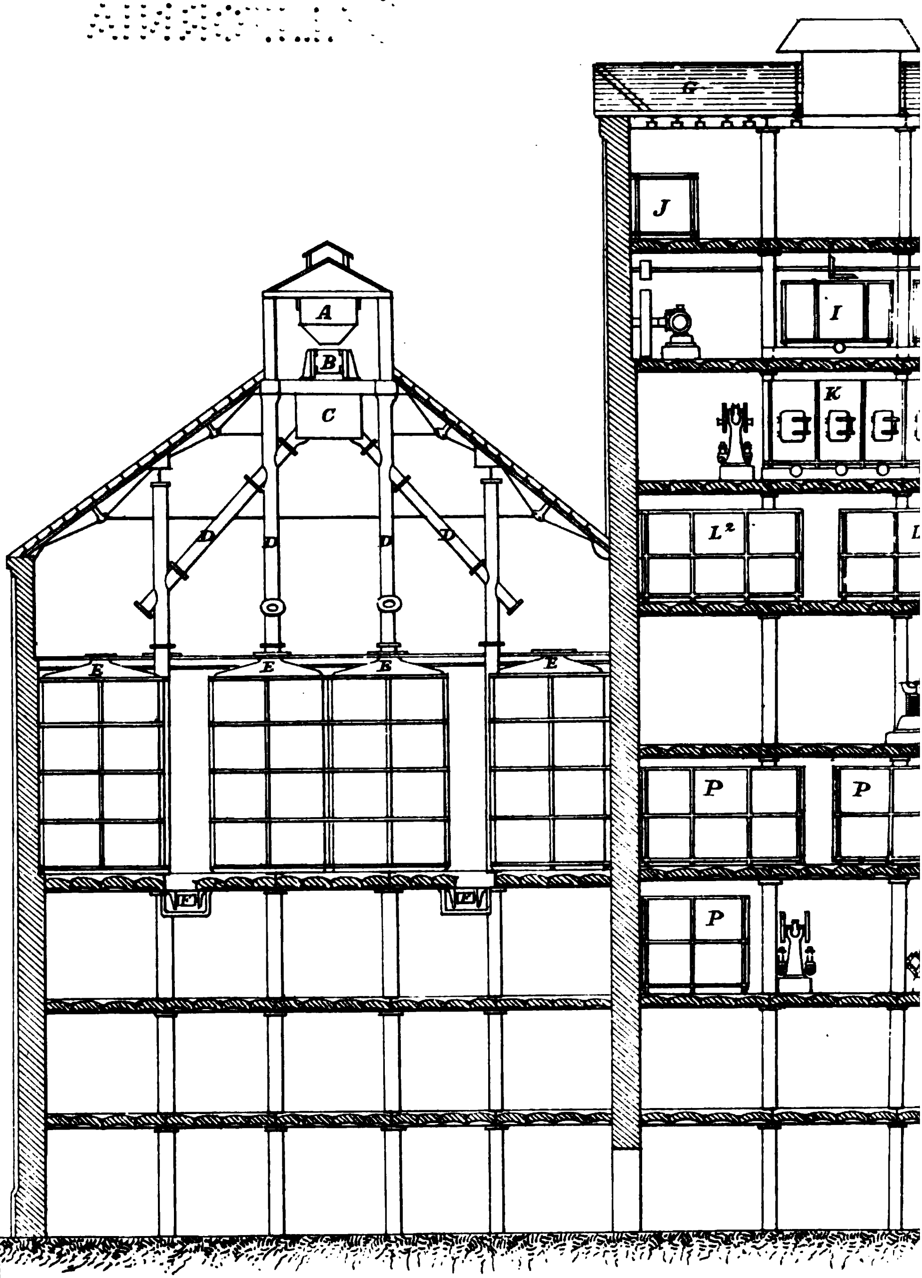
(4) The alum produced is fully equal in value to the sulphate of alumina used, so that the expense of the process is not great.

(5) The plant required is of the simplest description, the cost of labour is small, and the entire process is of a continuous and rapid character.

This process was in constant operation during several years at the sugar refinery of Mr. James Duncan, Clyde Wharf, Victoria Docks, London, where the syrup from many thousands of tons of sugar was treated, several thousand tons of potash alum, of good quality, being, during the same time, produced and sold.

SUGAR R

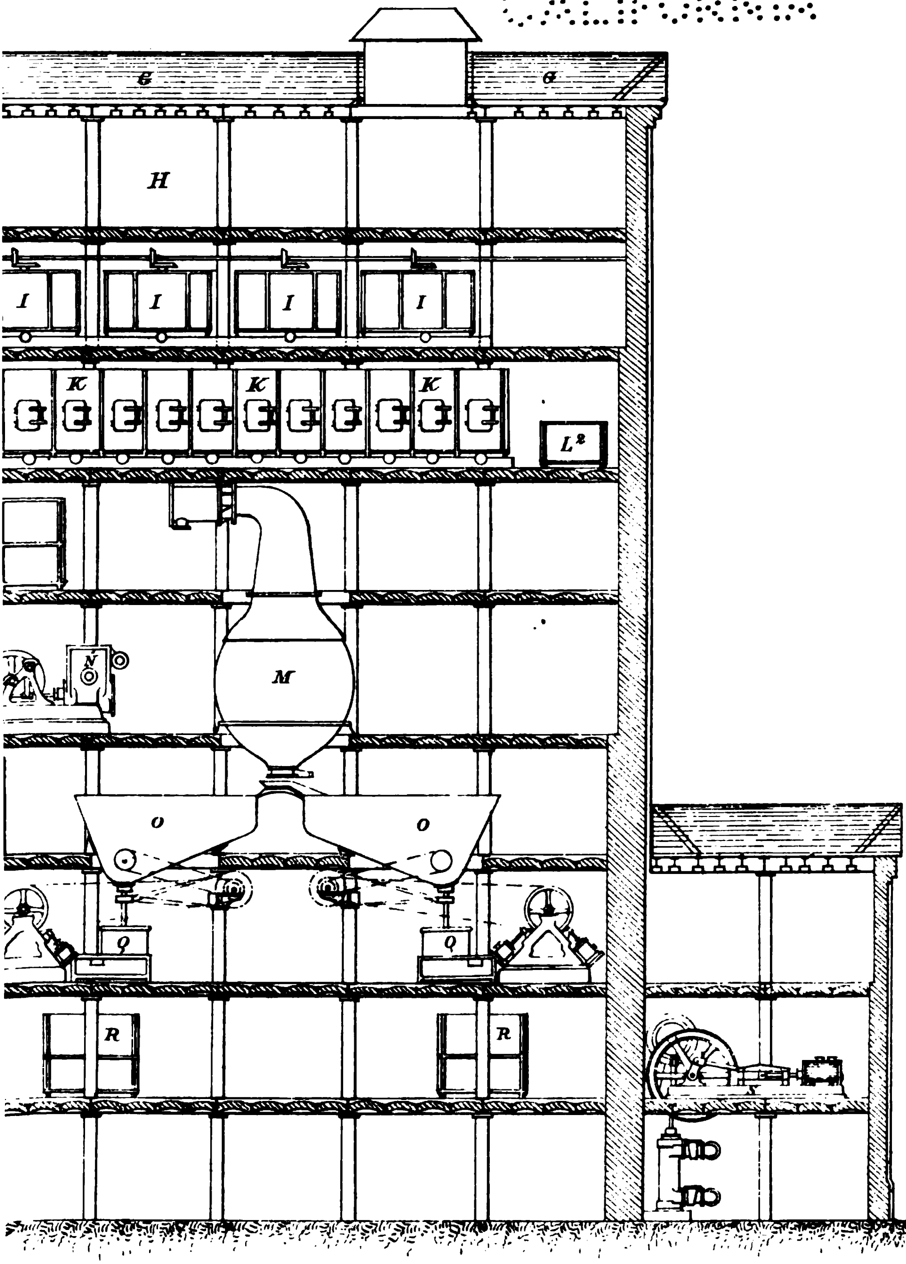
arranged by Dunc



E. &F. N. Spon, Lon

FINERY,

Stewart & Co. Glasgow.



on & New York.

CHAPTER XXI.

SUGAR REFINING.

THE processes described in the preceding part of this book for the manufacture of raw sugar from cane, beet-root, and other sources, yield in some cases sugar more or less fit for direct consumption, such as "Demerara" and "Beet crystals," but, generally speaking, raw sugar contains impurities which are evident in its colour, odour, and taste, and which prevent its use in any highly civilised community, until it has been submitted to a process of refining. To separate these impurities, two modes of treatment are successively made use of: in the first of these various ingredients, such as sand, colouring matters, &c., are removed from the sugar solution by the Taylor filter and by charcoal, and in the second the sugar itself is separated, by crystallisation and machining, from the rest of the impurities which remain in solution.

In some modes of refining, such as the so-called "in and in" system, whilst the insoluble matters and part of the colouring substances are removed, most of the soluble mineral ingredients remain in the lower qualities of sugar turned out, no syrup being produced.

The following are the chief considerations to be borne in mind in selecting the site of a refinery :—The ground should be capable of affording a foundation of a substantial character. There should be an ample supply of water for dissolving the raw sugar, and for washing the charcoal ; soft water is best for these purposes, but if only hard water can be had, it should be softened previous to use by Clarke's process, or some modification of the same. A considerable amount of water, which need not, however, be of such good quality, is needed for the purpose of condensation. The site must be well chosen both for the purchase of raw sugar and the distribution and sale of the refined products, it should therefore have direct access to railways and navigable water. Lastly, fuel should be procurable at a moderate price, and the rate of wages should be low. Refineries are usually seven or eight stories high, and the sugar having been hoisted to the topmost floor, descends by gravitation during the different processes, so that the operation of pumping is, to a great extent, avoided. Sometimes, however, a refinery is constructed with only three or four stories, and then it is necessary to frequently raise the liquor by means of a pump or ***monte-jus***, from one stage of the process to another.

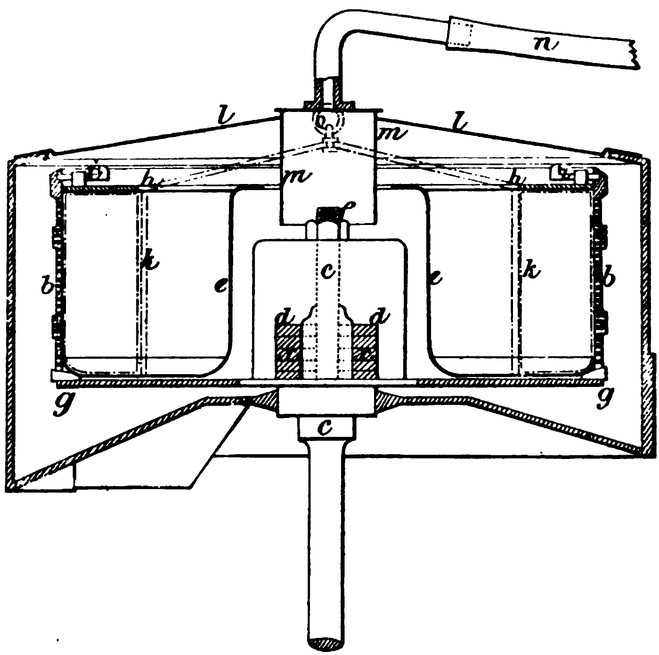
Plate XIII. gives a general idea of a sugar refinery, as designed by Duncan Stewart & Co., Glasgow, to turn out centrifugal sugars; it is useful as showing the relative position of the various apparatus which are described later on in detail. The building is in two parts: one containing the char cisterns, and the other the rest of the refining plant, as may be seen by reference to the following letters:—A, hopper to which the char from the kilns (situated in another building, and not shown in the illustration) is conveyed. B, conveyer delivering the char into C, receiving tank, from which it is delivered to any pipe. D, a short pipe being temporarily attached to the end of these pipes, leading to the cisterns during the filling operation. E, char cisterns. F, wet char bands, delivering char from cisterns to kilns. G, water-tank forming the roof of the refinery. H, garret. I, melting pans or blow-ups. J, steaming tank for washing empty packages. K, Taylor filters. L 1, tanks for washing filter-bags. L 2, raw liquor tanks. M, vacuum pan. N, vacuum pump. O, heaters. P, refined liquor and syrup tanks. Q, centrifugal machines. R, tanks for receiving syrup from centrifugal machine. S, water pump and engine for driving same.

PREPARATORY TREATMENT OF RAW SUGAR.

It is now quite usual, both in this country and on the Continent, to partially purify low grainy raw sugar, particularly beet sugar, by means of steam, water, or syrup, in a centrifugal machine, generally of special construction. In this way the purchase of high-class raw sugar is rended unnecessary, as, by the process of washing, the low raw sugar yields a product containing a large percentage of sugar, which can be employed in the manufacture of any variety of white-refined, and a residual impure syrup, which is either suitable for making pieces or refined syrup. If raw beet sugar be treated in this way, and one or two crops of sugar are boiled from the syrup, the final residue is only fit for distillation. Special centrifugal machines have been devised for washing sugar with steam, &c., by Weinrich, Duncan & Newlands, Walker & Patterson, and by Frémaux, and many others. When the washing is effected by water or syrup without steam, centrifugal machines of any kind are used; but as the use of these purifying agents results in a less yield than in the case of steam, it is not advisable to employ them.

Weinrich Process.—This mode of working is the invention of Moritz Weinrich, an Austrian. By means of his centrifugal machine, beet sugar can be purified by steam to such an extent that it is fit for consumption, and indeed most of the German and Austrian so-called granulated sugar, which finds its way to the English market, is merely beet sugar washed in this way. Crushed loaf-sugar and a soft kind of cube sugar are also produced by a slight variation in the mode of working. Fig. 176 shows the construction of the machine. The basket *b* is provided with a movable ring *h*, which rests in a recess in the top of the framework of the basket, and is held down in its place by a number of bolts *i i*. The vertical shaft *c* passes through a cylindrical closed box *d*, which contains a number of flat iron balance rings *x*. The diameter of the central holes in these rings is larger than the diameter of the shaft, so that they can move freely, and thus by changing the centre of gravity, correct any unequal movement of the basket. The annular guard *e*, which is carried up above the

FIG. 176.



Weinrich Centrifugal.

steam inlet *f*, serves to catch any condensed water and convey it away. The bottom of the annular guard is raised slightly by means of radiating strips of metal or wedges *g g*, so as to provide a space for the egress of the water. The mode of working is as follows :—The ring *h* having been removed, a filling drum *k* is inserted, and the sugar is filled into the annular space surrounding it, and pressed slightly with the hand. The ring is then replaced, the bolts being driven into the bolt holes with a wooden mallet, and the basket is caused slowly to revolve. When, owing to centrifugal force, the sugar leaves the drum, the latter is withdrawn, and the lid *l*, which carries the mouth of the steam-pipe *n*, is shut down. The speed is then increased, and steam of from 1 to 5 lb. pressure is turned on. The steam passes into the guard *e*, which removes any water it may contain, and then flows over the top of the guard into the space behind the sugar, and finally condenses in the latter, passing away as impure syrup. When the sugar is washed sufficiently, the machine is stopped and the steam is turned off. The sugar is then taken out of the basket and melted to produce refined sugar of high quality. If it is desired to produce a white sugar for consumption, the raw sugar is first intimately mixed with a small quantity of ultramarine, and the final product is sifted in the warm state as soon as possible after being machined. To produce hard sugar, the raw sugar is blued as in the case of granulated, and 4 wooden wedges are fixed vertically in the basket at an equal distance apart to facilitate the removal of the sugar. The operation is conducted as before, except that after the steam has been turned off, the basket is allowed to revolve for some minutes to dry the sugar. The wedges are removed by means of an iron rod, which is inserted into rings with which they are provided, and the sugar can then be removed in the form of blocks, which are either sawn into slabs and cut into cubes or reduced in a mill to the state known as crushed sugar. This and similar processes yield with good grainy and raw sugar a product weighing 80 to 90 per cent. and polarising from 99 to 99·75 per cent., and in the case of a low raw sugar, a product weighing from 65 to 70 per cent., and polarising from 97 to 98·5 per cent. The time required for the operation varies with the quality of the raw material and the degree of purity desired in the product, from 10 to 40 minutes. With low sugars deficient in grain, such as China and Jaggery, it is necessary to prepare them for the washing by melting and graining in the vacuum pan, the *masse-cuite* being run into the machine, and the syrup being again evaporated in the vacuum pan, so as to yield a second or even a third crop. In this way about 45 per cent. of the total sugar is obtained from the first *masse-cuite*, 15 to 20 per cent. from the second, and 8 to 10 from the third, the residual molasses being only fit for distillation. The following analyses give an idea of the effect of the Weinrich process when working with grainy beet and cane sugar.

BEET SUGAR.

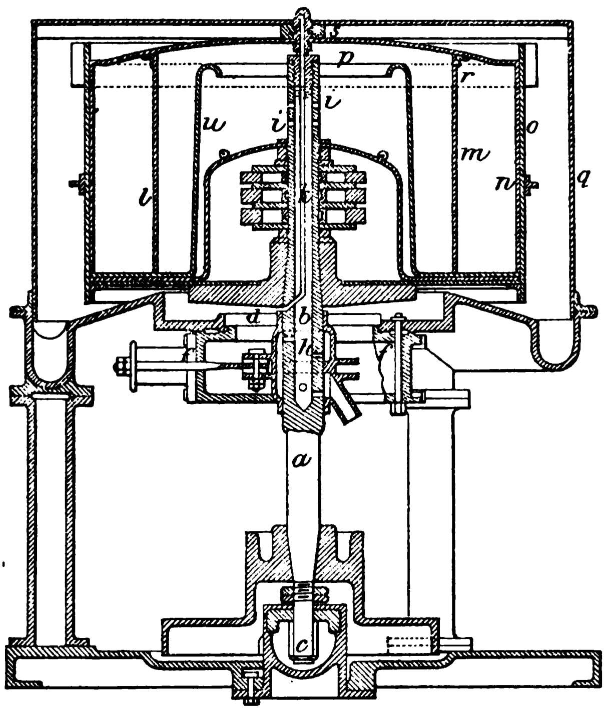
	Before Treatment.	After Treatment.
Sugar	93·30	98·60
Ash	1·58	0·16
Moisture	2·64	0·06
Undetermined substances ..	2·48	1·18
	100·00	100·00
Rendement or available sugar ..	85·40	97·80

CANE SUGAR.

	Before Treatment.	After Treatment.
Sugar	90·70	98·60
Glucose	2·70	0·36
Ash	1·14	0·31
Moisture	3·74	0·12
Undetermined substances ..	1·72	0·61
	100·00	100·00
Rendement or available sugar ..	82·30	96·69

The syrup is generally boiled up to obtain one or two crops of sugar, which are again steamed, the final syrup being sold for distillation. Duncan and Newlands have proposed to dry the raw sugar before steaming it, and in this way a larger yield is obtained, and they have also patented several modifications in the Weinrich centrifugal. They propose to employ a spray produced by the action of a jet of steam, or air, on water, saccharine solutions, or alcohol, in place of steam, and construct their centrifugal, whether arranged to be driven from below or above, with a hollow spindle through which the above purifying agents, or steam

FIG. 177.

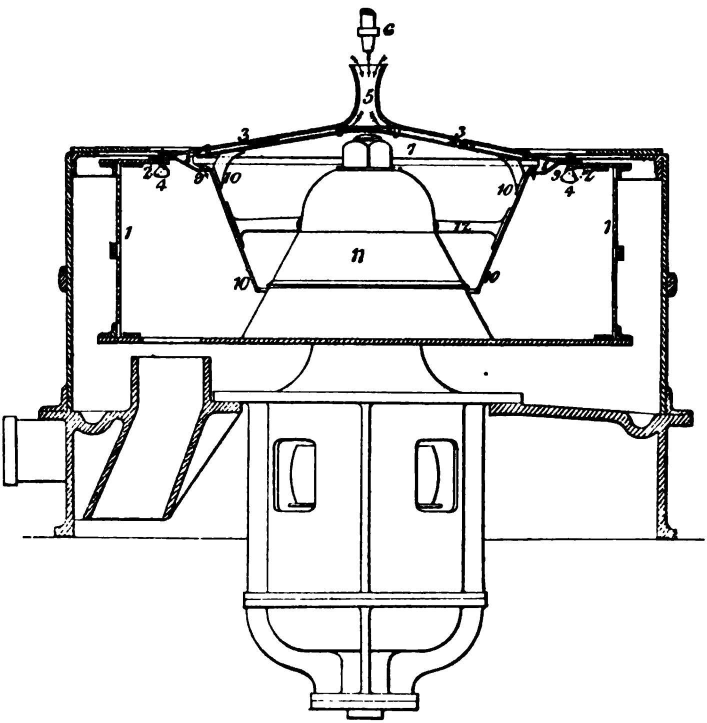


Duncan & Newlands' Centrifugal.

alone, are admitted. Fig. 177 shows a vertical section of the machine. *a* is the hollow spindle with a passage *b* for the introduction of the spray; the spindle is supported at its lower end, and turns in a footstep bearing *c*; it also works in a bearing or collar *d*, carried by a projecting bar *e*, secured to the frame *f* in such a manner to admit of the requisite freedom of movement of the machine, whilst retaining the bearing *d* firmly in position. The interior of this bearing is hollow, so as to form an annular duct *g* for the admission of the spray, which is thence conducted by the passage *b* through apertures *h*, and is discharged into and amongst the sugar contained in the centrifugal machine through other perforations *i*, formed either in the sides of the spindle or in the top. The central pipe *k* is provided for lubricating the bearing *d*. The removable perforated casing *l*, constituting a core around which the sugar is introduced, is retained in the machine during the operation, the spray passing through it into the charge contained in the annular space *m* between it and the interior of the lining *n* of the drum or cage *o*. The lid *p* is attached to the drum *o*, and is provided with an annular rim *r* to encircle the upper end of core *l*, the lid *p* with the core *l* being together retained in position by a nut *s* screwed on to the threaded upper extremity of the spindle *a*.

Walker and Patterson's Process.—The sugar is first mixed with syrup in a cast-iron cylinder about 18 inches in diameter, fitted with a central shaft on which are fixed mixing blades. The apparatus is illustrated in section in Fig. 178. The shaft is made hollow, and through this the syrup to be mixed with the sugar flows to distributing branch pipes which are fixed to the shaft and which thoroughly incorporate the syrup with the sugar. When the mixture of the sugar and syrup is complete, the resulting magma is discharged into a receiver placed over the centrifugal machines. The construction of the machine is shown in the accompanying engraving. The top edge of the basket is constructed in the usual way, with a rim, 2, projecting inwards. The space within the rim is provided with a cover, 3, of sheet iron which rotates with the basket, and after the machine is charged with magma, this cover is placed in position, resting on the inner edge of the annular rim, a tight joint being made by means of a lining of rubber which is fixed to the under edge of the cover. Small weighted holders, 4, hinged loosely to the under side of the cover, are by centrifugal force made to turn

FIG. 178.



Walker & Patterson's Centrifugal.

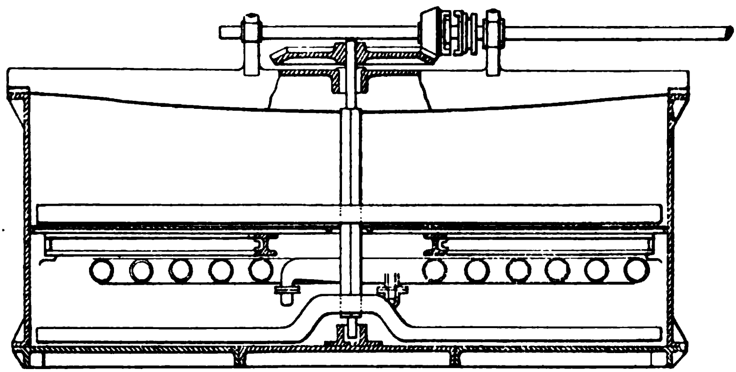
outwards and upwards against the underside of the rim, and so hold the cover firmly down to the rim. These holders have the advantage of requiring no manipulation, as when the basket is not rotating they hang downwards and do not interfere with the placing or removal of the cover. A mouthpiece, 5, is fixed on the centre of the cover, and a nozzle, 6, fixed to a steam pipe is placed so as to direct a jet of steam downwards into the mouth-piece, and cause a quantity of air to enter along with the steam. At a very short distance under the cover, a metal disc, 7, is fixed to the cover, and causes the mixed steam and air to diverge in a disc-like form and spread outwards under the cover. This disc also receives any drops due to condensation, and such drops are by the centrifugal action carried outwards, being thrown from the edge of the disc into an annular pocket, 8, formed by the attachment to the underside of the edge of the cover of an annular curved sheet metal ring 9, having its inner edge below the edge of the disc 7. The water caught in the annular pocket escapes by openings to the outside of the cover and over the rim of the basket, and is thus prevented from reaching the sugar in the basket. The mixture of steam and air passes down round the edge of the disc and between the ring and the upper edge of a conical shell, 10, and so has access to the sugar; whilst some of it may proceed down within the conical shell, and through a narrow annular opening between the bottom of the shell and the central cone, 11. The conical shell serves to collect any drops due to condensation on the central cone, and with the aid of the centrifugal force to lead them up into the annular pocket. This conical shell is fixed to arms, 12, radiating from a ring which rests on the central cone; it is also by preference attached to the cover, to be lifted out therewith when charging the machine, although it may be arranged to be lifted out separately.

In another modification of the machine the steam and air are introduced in the bottom of a hanging machine, such as Weston's, through the shaft which is hollow.

ORDINARY REFINING PROCESSES.—The raw sugar, either after it has been washed in the manner just described, or in its untreated condition, is conveyed to the garret or top floor of the refinery where it is unpacked, the empty casks or hogsheads being steamed, and the bags washed twice or thrice to remove the adhering sugar.

Solution.—The sugar is passed through gratings in the floor of the garret into the blow-up (melting pan) Fig. 179. This is an open cylindrical vessel 4 or 5 feet deep and of varying diameter, capable of holding from 3 to 10 tons of sugar in the

FIG. 179.



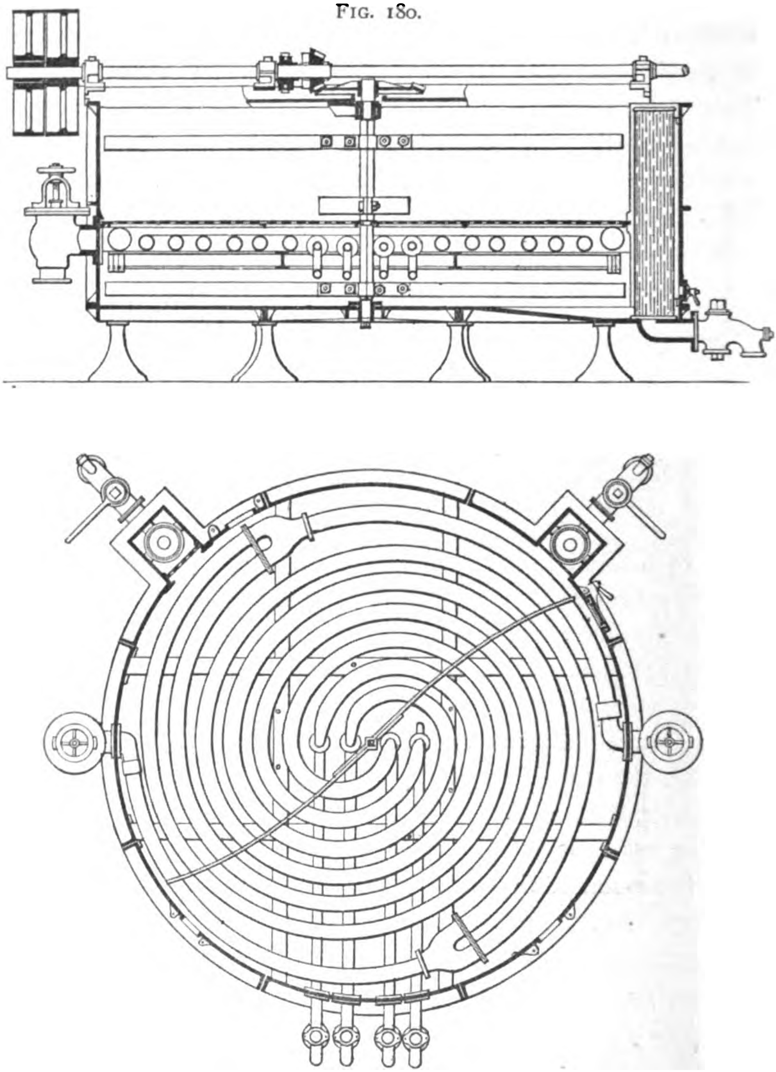
Blow-up.

form of a solution. It is provided with mixing gear and one or two steam worms for heating its contents with close steam, or a perforated pipe for the admission of live steam. These worms are generally protected from damage by a perforated false bottom or grid. There are cocks at the top for the admission of hot water, sweet washings, and syrup.

Fig. 180 represents an improved form of blow-up, designed by Blake, Barclay & Co., of Greenock. This apparatus is similar in most respects to that already described, the principal point of difference being that the liquor is drawn off through strainers extending the whole height of the apparatus, so that the grosser mechanical impurities are prevented from passing on to the Taylor filters. It contains four worms, arranged so as to produce an equal heating over the whole bottom of the blow-up.

Blow-ups have been made with close tops so that the sugar could either be melted in vacuo, in which case they were connected with a condenser or vacuum pump, or they could be employed as *monte-jus*, their contents being forced to a higher

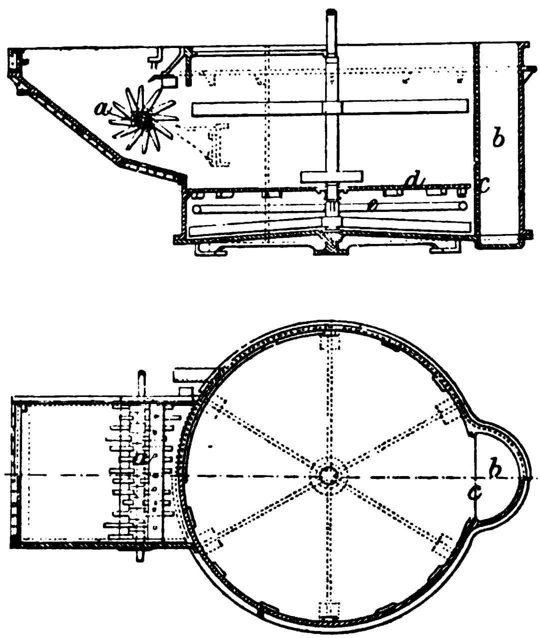
FIG. 180.



Blake, Barclay, & Co.'s Blow-up.

level by air or steam pressure. In the United States the melting is effected on the ground floor of the raw sugar store outside the refinery, the blow-ups being placed in a well below the floor and covered with a grating. The liquor, roughly made up to the required temperature and density, is pumped by means of plunger pumps into a second blow-up on the top floor of the refinery, where the temperature and density, are carefully adjusted. Crushing apparatus is usually fixed above the blow-up, and particularly where low sugars are refined, for the purpose of reducing the large pieces of sugar to such a size as not to injure the stirring gear.

FIG. 181 AND FIG. 182.



Deeley's Blow-up.

Figs. 181 and 182 show a sectional elevation and plan of a blow-up, designed by R. Deeley & Co. of New York, and used in the United States refineries. Attached to this blow-up and directly communicating therewith is a chamber containing a crushing mill, *a*, so arranged that the sugar while being crushed is partially or totally immersed in the liquor, and it has a chamber, *b*, on one side, separated from the blow-up by a perforated metal plate, *c*, through which the liquor runs away when the charge is complete. It has also a perforated false bottom, *d*, placed over the steam worm, *e*, and is provided with suitable stirring gear.

The melting process is carried out as follows:—A sufficient quantity of water or sweet washings to cover the worms, having been run into the blow-up, steam is turned on, and sugar and water are added in such proportions that by the time the charge is complete the density is from 28° to 30° Baumé, and the temperature from 150° to 170° F. Some refiners prefer to raise the temperature higher than indicated in the case of low sugars to help the filtration, but the use of a high temperature is not to be recommended, on account of the resulting injury to colour.

Defecants of various kinds are often employed to aid in the separation of the colouring matters and other impurities, and particularly to facilitate the operation of filtration. The oldest and best known of these defecants is blood or blood albumen, which is added in small quantities to the liquors before the temperature has risen to 160° F., and by elevating the temperature the albumen is coagulated and entangles the impurities, forming a scum which can be skimmed off or removed by filtration. The acid in cane sugar is in some refineries neutralised with lime, and of late years the employment of phosphoric acid in conjunction with lime has come into pretty general use. In the latter case the precipitated phosphate of lime produces a considerable improvement in colour and in the rate of filtration. It is important that the phosphoric acid so employed should be free from arsenic, iron, and other impurities. A. Boake, Roberts & Co., of Stratford, London, are now producing, by a very ingenious process, phosphoric acid in a high state of purity and well adapted for this purpose.

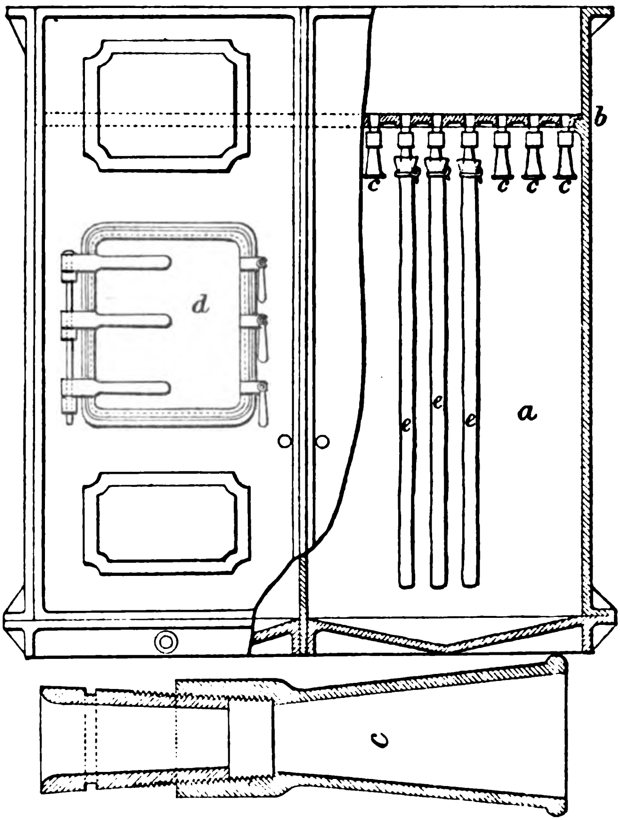
The addition to the liquor in the blow-ups of alumina, sulphate of alumina, or alum with sufficient lime to throw down the alumina, has been employed with similar results. Nearly every substance, mineral or organic, which is capable of being precipitated by the addition of another substance has been patented for this purpose, and the question of the poisonous nature of the materials does not seem to have struck some of the inventors as being a matter of any importance. The addition of many porous and granular insoluble substances has been patented, and to some extent employed with the object of rendering the after process of filtration more rapid.

Sugar is sometimes analysed and mixed before melting so as to ensure an even quality, and this is chiefly done in refineries where loaf or cube sugar is turned out, so as to render the product uniform.

Filtration.—The liquor, on leaving the blow-ups, runs through a perforated metal or wire strainer to remove any coarse mechanical impurities, and is conveyed by metal gutters to the Taylor filters which are placed on the floor below. A pair of these filters is shown, in elevation, in Fig. 183, with the front plate partly removed.

The use of bag filters was introduced by Cleland in 1824, and the apparatus was modified and greatly improved by Taylor in 1830. As at present employed the Taylor filter, Fig. 183, consists of a chamber *a*, made of cast-iron plates, open at the top, and having a horizontal divisional plate *b* about one foot from the top, forming a receiving tank or filter head. This plate is perforated with holes, in rows a short distance apart, these being fitted with gun-metal sockets furnished with screw threads for the reception of gun-metal bells *c*, to which the bags are tied. The filter chamber is provided with a tightly fitting door *d*, and cocks for supplying steam, and the bottom, which is doubly inclined, has a cock for the egress of the liquor. The rows of holes in the divisional plate are sometimes divided by partitions, so that every row of bags may receive its due charge of liquor. The bottom of the

FIG. 183.



Double Taylor Filter.

filter head is usually inclined, its lower end being under the liquor cock, so that each row of filters may be filled in rotation, and the work of the filter be rendered more uniform, thus attaining the same object as is effected by the use of partitions. The bags *e* are made of twilled cotton, and when laid flat are about 6 feet long by 2 to 3 feet wide, and they are either woven without a longitudinal seam or sewn up. These bags are crumpled up and slipped inside of coarsely woven hempen sheaths which are open at both ends, and are about 6 inches longer than the bags, and from 6 to 9 inches wide when laid flat. These serve to restrict the expansion of the bags, thus giving a large filtering surface in a small space. The bell is inserted up to the screw part into the opening of the bag, and the latter, together with the upper end of the sheath, which is brought level with it, is firmly tied on with cotton cord. The bell is then screwed in its place, and on account of its shape causes a tight joint to be made when the bag is weighted with liquor. The number of bags contained in each chamber varies from 100 to 500, or even more in different refineries. The amount of liquor that can be filtered through each bag mainly depends upon the kind of sugar, and also, to some extent, upon the temperature and degree of dilution and use of defecating agents. It is therefore impossible to give precise figures as to this point, but it may be said generally, that in a refinery working with a medium quality of sugar, consisting of half cane and half beetroot, from 10 to 13 bags per ton are required. The mode of conducting the filtration is as follows:—The chambers having been filled with bags, the doors are screwed up, and steam is turned on for a few minutes, so as to thoroughly warm the filters. Any condensed water is then allowed to flow away and the liquor is run on to the filter-heads. As the liquor flows from the filter it is frequently sampled, and should it prove cloudy, owing to the rupture of any of the bags, it is run away into the sweet-water tank. By carefully inspecting the filter-head, the faulty bags can generally be detected by the unusually rapid currents of liquor passing down them, and their nozzles should be immediately closed up. The clear liquor from the filters runs into fine liquor tanks on the floor below. When the bags become dirty and practically cease to allow the liquor to flow through them, the inlet cock is closed and the bags are allowed to drain for some hours. Steam is then turned on and the bags are filled with hot water and left to drain the second time, and this operation is repeated until a sample of the washings, or bag-water, no longer shows any indications of the presence of sugar, when tested by a hydrometer. The bag-water is run into a tank by itself, and is used in place of water for dissolving raw sugar. When the filter is sufficiently cold, the bells are unscrewed and the bags and sheaths are removed from the chamber, and the cords being untied, the sheaths are slipped off the bags, and the latter are then washed. The washing is conducted in a series of three or four tanks containing warm water; the first of these tanks contains the dirtiest water and the last the cleanest. Each bag is turned inside out in the first tank, and by a dexterous movement on the part of the workman it is filled with air, which is imprisoned in it by closing the opening with one hand. The bag is then forced under the water, and the air is driven through its pores, thus removing the adhering impurities, and this operation is repeated in each of the other tanks, and finally the bag is turned with the right side out.

Wringing machines, consisting of a pair of rollers, are sometimes placed between the tanks, and through these the bags are passed, thereby removing the dirty water which is caused to flow into the preceding tank. The mode of washing sugar out of the bags *in situ* is generally employed in the United Kingdom, and, when high-class sugars are used, gives satisfactory results, but, with low sugars, containing a large amount of insoluble impurities (sometimes sufficient to half fill the bags), the muddy deposit always retains a notable proportion of sugar, even after the most careful and repeated washing. The use of steam also tends to injure the fibre of the bags, and some refiners, therefore, instead of washing the bags in the filter chambers, remove them direct to the washing tanks, the operation of washing being conducted in the way just described. The wash-water, however, after the addition of lime, or other defecant, is filtered through a scum or filter-press, and is used for dissolving raw sugar.

James Buchanan & Son, Liverpool, have patented a modification in the construction of the Taylor filter, the top plate being made portable, and fitting into a groove with a rubber joint in the side plates. The top plate is held down by wrought-iron bolts at each corner. When the bags are dirty the plate is removed together with the bags by means of an over-head crane, and replaced by another plate with clean bags attached to it, and the filter can be got in this way to work again in a few minutes. In addition to a saving in time there is also an economy in labour, as the men have no occasion to work in the hot interior of the filter.

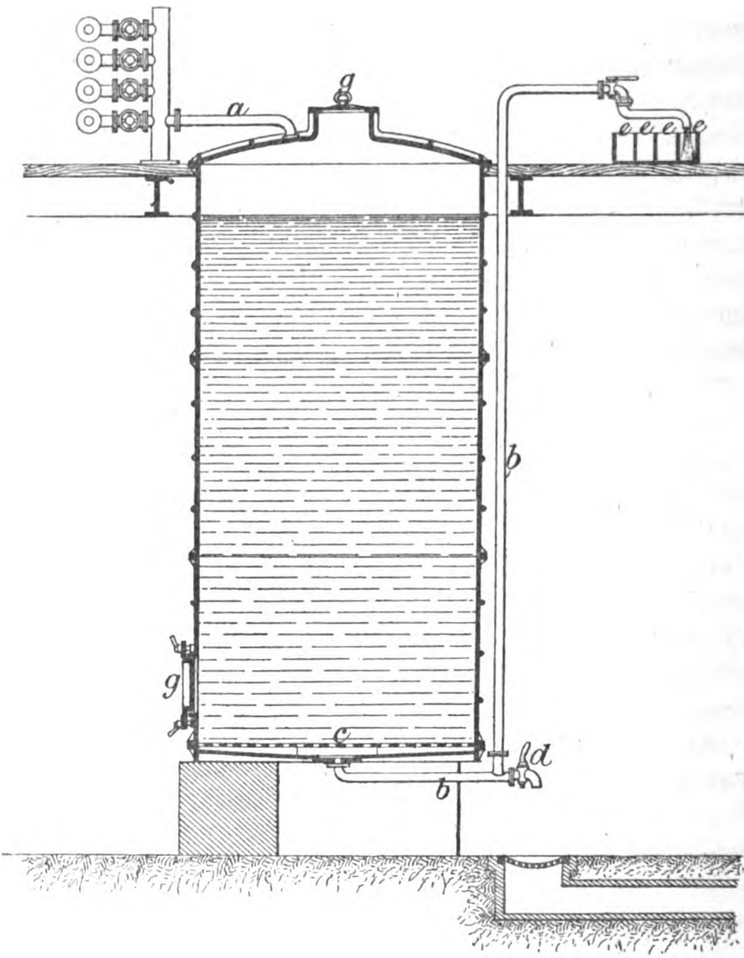
In some refineries, especially on the Continent, where beet-root sugar only is refined, filter presses take the place of Taylor filters, but they do not give satisfactory results with cane sugar. Various proposals have been made to add certain substances to the liquor, with the view of rendering filter presses available for cane sugar; thus, Remmers has patented the use of powdered wood charcoal, Kleeman that of lignite, and Cassamajor that of sawdust, and all of these have been tried on the large scale, but without any decided success.

After being filtered the liquor is decolorised by means of animal charcoal, or "char," as it is technically termed.

Decolorisation.—The apparatus, Fig. 184, employed for this purpose is known by the name of a char cistern. These cisterns consist of large cast- or wrought-iron cylinders, and are usually about 10 feet in diameter, and 20 feet high, but the dimensions preferred by different refiners vary considerably. They are provided with man-holes, *g g*, at the top and side for the introduction and withdrawal of the char.

The raw liquor and water for washing find their way into the cistern through the pipe *a*, which communicates with an upright main connected with various tanks containing a supply of water and of the different liquors.

FIG. 184.



Char Cistern.

The bottom of the char cistern inclines towards its centre so as to cause the liquor to run to the outlet pipe *b*. A short distance above the bottom is a perforated wood or iron false bottom *c*, which, when in use is covered with a blanket or with a flaxen cloth to prevent the passage of any fine char. As shown in the engraving, the outlet pipe *b* is represented as terminating at a level above the top of the cistern head, and this is usually the case, the liquor being forced into the charcoal cistern under pressure. The water, however, is discharged by the cock *d*, at the bottom of the charcoal cistern. The outlet pipe *b* terminates in a pipe having a swivel joint, and thus enables the liquor to be discharged into any one of the four gutters *e e* leading to at least as many storage tanks.

The cistern is filled with reburned char through a jointed pipe, surmounted by a hopper into which the char falls from a band conveyer. As the char descends it is levelled by a man inside the cistern, who also removes the pipe, in lengths, as the filling progresses. Though the char is usually levelled in this manner, the work is both disagreeable and dangerous, and the man is therefore in some refineries replaced by a mechanical leveller. It is questionable whether this levelling is of much consequence, but the prevailing opinion is that less sweet-water is made than when the char is not so levelled.

On the cistern being filled with char to within a short distance of the top, the cover of the upper man-hole is closed, and, the cock at the bottom of the cistern having been opened to allow the air to escape, cold water is passed through the char to reduce its temperature, and this is followed by liquor. The whole of the liquor put upon a char cistern, may be of one quality, but it is usual to begin with a good quality, and to follow on with one or more lower qualities, the last liquor being made from syrups, or char-washings resulting from previous operations. One advantage of this method of working is, that the sweet char-washings, which contain many impurities, are made from a material of low value.

When the liquor commences to come through, the outlet-cock is turned off and the liquor is allowed to rest or "settle" for some time before it is run off.

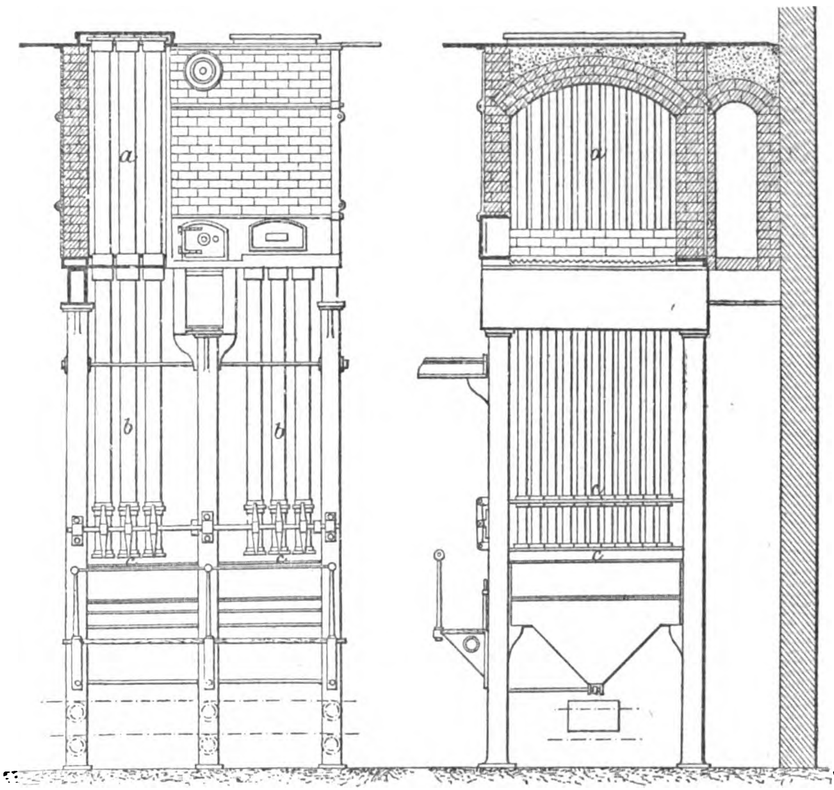
If good raw sugar is being refined, it is not necessary for it to remain in contact with the char for a longer period than the time requisite for its passage through the cistern, which is from 3 to 6 hours, the time varying with the depth and degree of fineness of the char and other circumstances. The liquor is run off in a steady even stream, the speed of the flow being so adjusted as to leave the liquor sufficiently long in contact with the char to utilise its full decolorising effect. As the liquor runs away it is replaced by more raw liquor, until the increasing colour of the refined liquor indicates that it is no longer advisable to run on more. When this point is reached the raw liquor is replaced by water at nearly the boiling point, which forces out the liquor in front of it. The liquor, as it leaves the cistern, is usually divided into different qualities according to its colour and the analysis of the raw sugar from which it is made, and these are employed in the production of white, nearly white, and yellow, refined products. Sometimes, and particularly in refineries where sugar of a uniform high grade is melted, the whole of the liquor is mixed together and boiled into one quality, such as loaves or crystals. The last portion of the liquor running from the char is reduced in gravity, owing to its admixture with water, and becomes cloudy and grey, and on this account has to be kept separate from the liquor, and it is therefore run into a tank by itself. This sweet water, which contains organic and saline impurities derived from the raw sugar, is known as char-water, and is either used for dissolving sugar or is boiled into a low kind of sugar, which is again refined. When, by means of a hydrometer, it is ascertained that the amount of sugar present will no longer pay for recovery, the washings are run to the drain. The washing, however, is continued for many hours longer so as to remove as far as is economically possible the impurities which have been absorbed by the charcoal. The quantity of water employed in the operation of washing may be roughly stated as being from once to twice the weight of the charcoal. The cost of the water, the quality of raw sugar melted, and the degree of fineness of the charcoal, influence the refiner to a considerable extent in deciding upon what is the best quantity to use. If water is dear and charcoal cheap, it is certainly better to replace the latter more frequently, and save the extra cost of doing so by washing less freely. To regulate the washing operation, it is advisable to run a fixed quantity of hot water on each cistern. Oxalate of ammonia, soda, and other reagents capable of precipitating the lime, or iron, which are always present in the washings, are used as rough tests of the efficiency of the washing. If the total solid matter in the last washings is similar to the amount in the water employed, this will indicate that the operation has been carried as far as it can be. Such a result is only practically attainable where water and the fuel for heating it cost little, and one has generally to be content with far less perfect results. The quantity of liquor that can be economically dealt with by the char is usually in this country about twice the weight of the latter, but the amount depends in a great measure upon the quality of the raw sugar from which it is made, and the nature of the after processes of refining adopted. For example, in loaf-sugar refineries the purification is to a considerable extent the result of an after process of washing, or liquoring, so that in some refineries on the Continent only about one third of the quantity of char we have mentioned is required. The use of a large quantity of char, while it results in a gain in the colour of the products, also increases the loss of sugar. Char-cisterns are sometimes worked in sets of two or even three, the liquor in such cases being passed through the cisterns in succession, and when the first one is exhausted, the liquor is turned on the second, and another freshly filled cistern is added to the set. This method of working secures the full decolorising effect of the charcoal, but on account of the length of time necessary for the passage of the liquor through the increased depth, the liquor has a tendency to become sour. The cisterns are also sometimes worked in pairs, both being washed off after the liquor has run through them.

The washing process having terminated the char is removed from the cistern through the lower manhole, and is usually conveyed by means of hanging-trucks travelling on rails, or by conveying bands, to the top of the kilns, the latter being generally placed in a separate building, though in some refineries they are immediately under the charcoal cisterns.

Revivification of Char.—Various processes have been devised at different times for revivifying the char, that is to say, restoring its power of absorbing colouring matters and other impurities, but the only process in general use in refineries is that of carbonisation. This operation is almost universally conducted in what are known as pipe-kilns, of which various modifications are employed. The apparatus shown in Fig. 185, made by Manlove, Alliott, Fryer, & Co., consists of a brick chamber supported by iron columns, and firmly bound together at the corners by angle irons, and which are held together by wrought-iron tie rods.

In the front of the kiln near the bottom are two cast-iron plates, which have eyelet holes with movable lids, through which the internal temperature can be observed, and between the plates is a furnace door. There are two banks or groups of vertical carbonising pipes *a a*, each bank consisting of two rows, or of three as shown in drawing. The pipes are constructed of cast iron, and are of a round, or more often, of an oval section. They are kept in place, at the top, by cast-iron distance plates, which close all the intervals between them, and through which they project an inch or two, the space above the plates being filled up with cement to level the top of the pipes so as to prevent the char from leaking through. The bottoms of the pipes rest on collars cast on the bed plate, and in the centre of each of these collars is a hole which serves to communicate with a sheet-iron cooling pipe, or "cooler" *b* fixed to the bottom of the bed plate. Two slide-valves *c c* at about a foot apart are placed

FIG. 185.



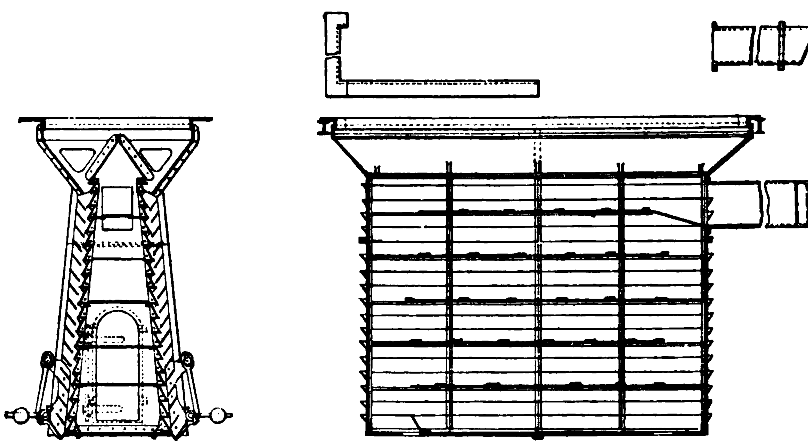
Manlove's Char Kiln.

at the lower end of each row of coolers. The slide-valves are formed of one strip of metal for each row of pipes, and perforated with a number of holes corresponding with that of the pipes. Between the beds of carbonising pipes is a central fire, the heat from which plays around the pipes, the products of combustion passing away to the chimney through flues.

In the United States it is customary to utilise the waste heat of the gases on their way to the chimney for removing the water which the wet char contains previous to its passing into the kiln pipes. The apparatus which is employed for this purpose is placed between two beds of retorts immediately over the fire, and it is raised sufficiently high to allow the char, after being dried, to run on to the mouths of the pipes. There are two forms of this apparatus which are generally used:—

(1) The Colwell Drier.—This consists of a long sheet-iron box extending the whole length of the pipe bed, and containing pipes ranged in rows one above the other, and made in the form of a Gothic arch, with the apex upwards. The heated gases pass through the pipes, and the char which runs down between them is in this way dried, the steam escaping through passages formed underneath the flue pipes by a prolongation of their sides, the removal of the steam being assisted by currents of fresh air.

FIG. 186.



Deeley's Char Dryer.

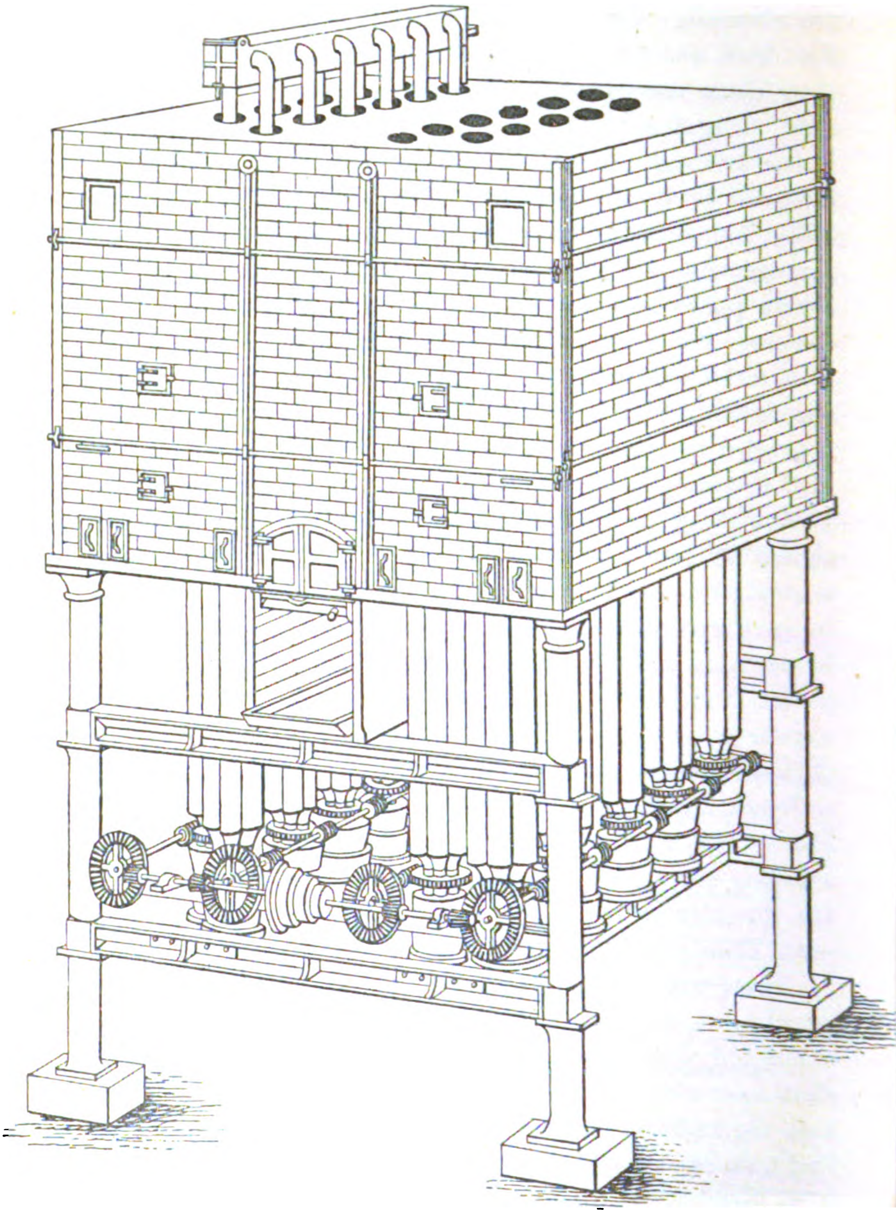
(2) The Farley Drier.—This consists of an A-shaped chamber divided longitudinally so as to cause the gases to

pass backwards and forwards several times before they reach the chimney. The char is placed in a hopper at the top of the drier, and falls through slits extending the length of the drier down the outside of the latter. The char is loosely held up against the sides of the drier by means of an iron louvre arrangement. A successful modification of this drier, designed by R. Deeley & Co., New York, is shown in Fig. 186. The outside plates are made zigzag, and mechanical arrangements are provided for altering the incline of the louvre plates so as to regulate the flow of the char. The drawing shows transverse and longitudinal elevations in section. The construction of the apparatus is explained by the drawing, but it may be mentioned that the gases pass through two openings at the bottom and find their way out at the opening in the side near the top.

Buchanan & Vickess's Kiln (Fig. 187).—This kiln, designed by James Buchanan & Co., of Liverpool, has now, to a great extent, replaced the ordinary pipe kilns, and combines in itself several most important advantages over the latter. It contains 22 pipe retorts, each 12 inches in diameter and 9 feet 6 inches long, and these are provided with internal vapour pipes of a smaller diameter. The vapour pipes are perforated with holes, over each of which is placed a shield or louvre, which serves the double purpose of preventing the char occupying the annular space between the pipes from escaping into the interior pipe, and at the same time alters the direction of the char, thereby giving the whole of it an equal chance of being heated to the same extent.

There are drying-pipes connected with the top of the retort-pipes, and those also have perforated escape-pipes, connected with steam-collecting boxes having outlets and shut-down air-tight valves, with pipes to conduct vapour outside the building, or into a condensing apparatus, or over a fuel furnace as may be arranged. In the latest form of these kilns, two hoppers are placed on the kiln head, holding a large

FIG. 187.



Buchanan & Vickess's Kiln.

quantity of char which runs on to a false top-plate with bevel sides. These plates have an air space underneath to keep them cool, and prevent injury to the char. The char descends by gravitation only through the drying-pipes, then into the retort-pipes, where it is revivified. It then enters the coolers, of which there are 7 or 8 to each retort-pipe, having a large cooling surface. From the coolers the char falls into a conducting box, then into a measuring box, and by the latter measured quantities of char are discharged at regular intervals of time, the speed, which can be varied as required, governing the quantity; this is regulated so as to give the best results in the subsequent clarifying operation. Each set of drying-pipes, retorts, internal pipes, and coolers, are all connected together, and carried by a spindle running in a footstep, revolving on its own axis, the average speed being one revolution in 15 minutes. The revolving of the retort-pipes causes the whole surface to be uniformly exposed to heat, thus giving equally revivified char. The pipes do not bend, as they all expand and elongate to the same extent. The coolers revolve along with the retorts, thus displacing and changing the air surrounding them. The apparatus is automatic in all its operations, and with the latest arrangements for bringing the dirty char to the kiln heads and conveying the revivified char away from the hopper below, works in a satisfactory manner. A very large plant can be worked with little manual labour. The average temperature in the retort chamber required to revivify the char is about 1050° F. The waste gases enter the drying chamber about 750° F., and leave it about 400° F. The quantity of char revivified by one kiln in 24 hours differs with the class of sugar used and other conditions, but in an average refinery it may be taken at 20 tons, although this quantity has been exceeded.

In the engraving one of the steam-collecting boxes is left out in order to show the position of the retort pipes.

Another form of kiln, now but seldom employed, is known as a "revolving kiln." This consists of one or more cast iron cylinders, arranged horizontally at a slight incline, and provided inside with ledges or lifters. Of revolving kilns, perhaps the best is Brinjes', shown in Figs. 188 to 191. Fig. 188, represents a front elevation of the apparatus complete; Fig. 189, a sectional elevation; Fig. 190, a back elevation; and Fig. 191, a sectional plan. In a brick setting, are two horizontal retorts, each of which receives a circular reciprocating or alternating motion of nearly one entire revolution on its longitudinal axis. The upper retort acts as a drying chamber for preparing the charcoal for the recarbonisation which takes place in the lower retort; and it is contained in a separate brick chamber of its own, which is situated immediately above the roof of the furnace, the heat from which, after circulating round the lower retort, enters the upper chamber through openings left for that purpose in the roof of the furnace, and then acts upon the upper retort before passing off to the chimney, through passages furnished with dampers, and leading to the main flue below. The two retorts are provided with a series of internal flanges at intervals of about 6 or 8 inches, and ledges are formed between the flanges for carrying up the charcoal as the retorts reciprocate. An opening is made through each flange, and all these openings are disposed in a line with each other. In order to cause the charcoal to travel continuously along the retorts during the process of recarbonising, an angled projection, somewhat after the form of a three-sided pyramid, is cast inside the cylinder in each of the intervals or spaces between the several internal rings or flanges, and exactly in the centre line of the openings in those flanges. The two opposite sides of these projections present reverse angles, both of which direct the charcoal into the next space on the partial rotation of the retort. The upper retort is driven direct by a mangle-wheel and pinion arrangement; and this motion is transmitted to the lower retort by means of an endless chain, suspended from the rear end of the upper retort, and passing under the corresponding end of the lower retort. Both ends of the retort are supported upon anti-friction pulleys, carried in the transverse framing bolted

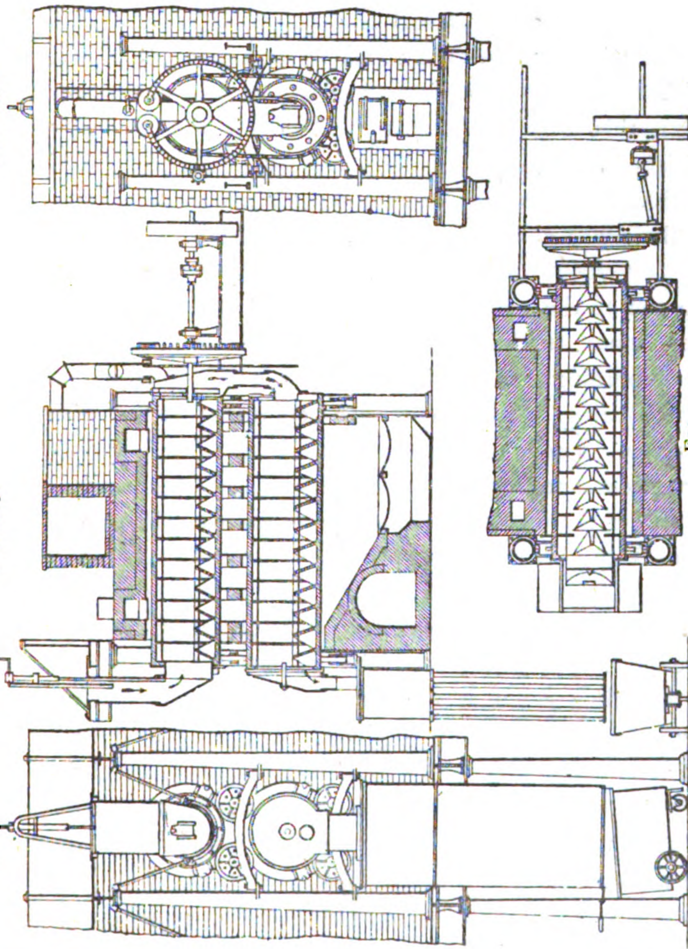


FIG. 190. FIG. 189. FIG. 188. FIG. 191. Brinjes' Kiln.

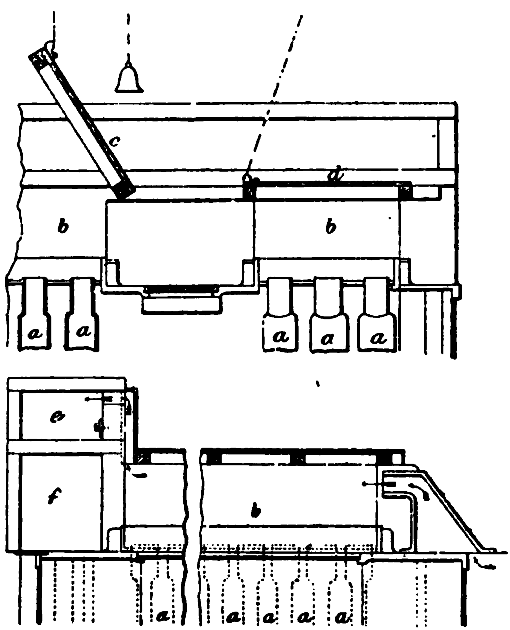
to the main supporting column. The feeding hopper opens to a flue, from which the charcoal is shovelled when being supplied to the retorts, the feed being nicely adjusted by means of the sliding door, worked by a winch handle and screw spindle. A sliding door, covering an opening in the inclined side of the hopper, is for the purpose of inspecting the interior of the retort, a spy-hole being also provided in the stationary front cover of the lower retort, for the same purpose. The upper retort discharges its contents into the conduit which conducts it to the lower retort, after traversing which it is discharged down a pipe into the closed receiver. From this receiver, it passes through the cooler, which consists of a number of long narrow passages, placed side by side, and having intervening air spaces between them for the more effectual cooling. By the time the charcoal has traversed these coolers, it is sufficiently cool to be exposed to the action of the atmosphere, and is discharged into a small truck. The vapours which are evolved during the reburning are carried off by a pipe, provided with a throttle-valve, into a chamber communicating with the chimney. The entire arrangement is supported upon strong iron girders, resting upon columns in the basement.

Under the most favourable circumstances, the vapour that issues from char in process of reburning has usually a sweetish and slightly empyreumatic odour, but it is never overpowering, though sometimes sufficiently pronounced to be very disagreeable. When the used char is permitted to ferment, the acetic acid formed acts upon the sulphides of calcium and iron present, eliminating sulphuretted hydrogen, the odour of which is perceptible, and which is given off when the char is reburned. The nuisance from reburning is capable of being reduced to a minimum. Whatever ill odours may attach to the vapours must depend upon the evolution of sulphuretted hydrogen and the products of decomposition of the organic matters taken out of the raw sugar in its passage through the charcoal purifiers. The remedies obviously consist:—

1. In the thorough washing of the char before reburning, so as to remove from it as much as possible those matters which by their burning give rise to offensive effluvia.

2. Means should be adopted for collecting and disposing inoffensively of the vapours proceeding from the reburning. When Brinjes' reburner is in use, the vapours are collected as a matter of course, being conducted first into a long brick chamber or flue 3 feet square internally, and thence into a chimney shaft at a point below that at which the furnace flue enters; this shaft discharges them at a sufficient elevation to prevent any nuisance, and at other works the vapours are discharged at once into a tall chimney shaft without occasioning nuisance. Should it be thought necessary, a means of condensation might readily be added to this apparatus.

FIG. 192 AND FIG. 193.



Collecting Char Fumes.

There may be some difficulty in collecting the vapours proceeding from pipe kilns, but it is nevertheless practicable.

At Duncan's sugar works, a space *b* (Figs. 192 and 193) above each stack of pipe kilns *a* is boxed in with a wooden cover *c d*; hot air is conducted into this space by means of an appropriate flue at one end and passes out at the other end, through the flue *e*, carrying the vapours with it into a chimney.

Boiling down.—After the liquor leaves the charcoal, the sugar has to be recrystallised out, and this is effected mainly in the vacuum-pan. Several modifications of this important apparatus having been already described, of which some are similar to those in use in refineries, it will simply be necessary to refer the reader to this description. Vacuum-pans are usually worked singly in refineries, though in a few cases a triple effect apparatus, such as that invented by Yaryan or Lillie, is used for the evaporation of liquor to a higher density before it is boiled in the ordinary pan, or for the concentration of char water. The mode of boiling varies considerably with the quality of the liquor and the kind of refined sugar to be produced. In all cases, however, a vacuum is first created in the pan, and a sufficient quantity of liquor is sucked in to at least cover the bottom worm, and steam is then turned on to the latter and the liquor is concentrated and becomes a supersaturated solution. The exact point to which the concentration should be carried is decided by an experienced workman, who, by repeated examination of small portions of the contents of the pan, extracted by means of a proof-stick, can by drawing a drop between his finger and thumb tell the exact degree of viscosity necessary for the immediate production of grain. When this point is reached, a small additional quantity of liquor is run in, which disturbs the equilibrium and causes some of the sugar to crystallise out of the supersaturated solution. More liquor, in successive charges, is then run in, and the crystals gradually grow in size until the pan is full. As the contents of the pan rise above the worms, the steam is turned on to them in succession. In the case of crystals, the boiling, after the production of the grain, is very slow, and the temperature is as high as 190° F., and it is customary when the pan is full, to discharge a large portion of its contents, leaving, however, a quantity behind to be reboiled with fresh liquor into larger crystals; and this operation is repeated three or four times, producing each time larger and larger crystals, until they are as large as needed, when the whole contents of the pan are discharged. Each portion of the contents of the pan so discharged is called a "cutting," and the final pan-full is called the "steam-out," from the fact that the pan is then steamed to remove adhering sugar. The time required for boiling up to the first cutting is usually about six hours, and each succeeding cutting takes about two hours. Small refined or beet crystals are sometimes introduced into the pan with sufficient liquor to cover the worms, and the pan is then boiled in the usual way, except that it is unnecessary to boil down to grain or at so high a temperature. By this mode of working, economy is effected in time, and the crystals resulting from the first cutting are as large as those from the third cutting when boiling from liquor in the ordinary manner.

In boiling crystals great care must be taken to obtain distinct, well-formed grain, otherwise the resulting crystals will have an irregular appearance. If the grain is not well formed, it must be redissolved by the addition of more liquor or water, and boiled out again. Care must be taken after the grain has formed not to destroy it by letting in too large a quantity of liquor at a time. Soft sugars, such as yellow or white pieces, are boiled at a low heat, from 115° to 140°, and in boiling down to form grain a much larger quantity of liquor is taken into the pan so as to form a larger quantity of grain, and the pan is fed with liquor and boiled off more rapidly than in the case of crystals. The time needed for boiling a panful of fairly good quality of pieces does not exceed three hours. In the case of granulated and loaf sugar, the operation is much the same, but the temperature employed is higher, as it is desirable to render the *masse-cuite* as free running as possible. The vacuum is sometimes lowered just before the pan is let go, so as to increase the temperature with the same object.

CURING.

The *masse-cuite* from the vacuum-pan is run into a receiver termed a "heater," because it is sometimes steam-jacketed. This vessel, which is usually provided with stirring gear, is cylindrical with a hemispherical bottom, but in some cases, where over-driven centrifugal machines are employed, it is made in the form of a trough, from the sides of which the baskets of the machines hang.

The *masse-cuite* is next discharged from the heater into a centrifugal machine in which the sugar is separated from the syrup by drainage, and sometimes further purified by washing either with water or liquor.

Centrifugals.—Several kinds of centrifugal machines, capable of being used both in the fabric and the sugar refinery, have been already described under the heads of "Raw sugar," and "Preparatory treatment of raw sugar for refining." It will, therefore, be only necessary to give a detailed description of two forms of centrifugal machines, the Weston and the Hepworth, as owing to the advantages they possess over other machines, they are rapidly displacing the latter.

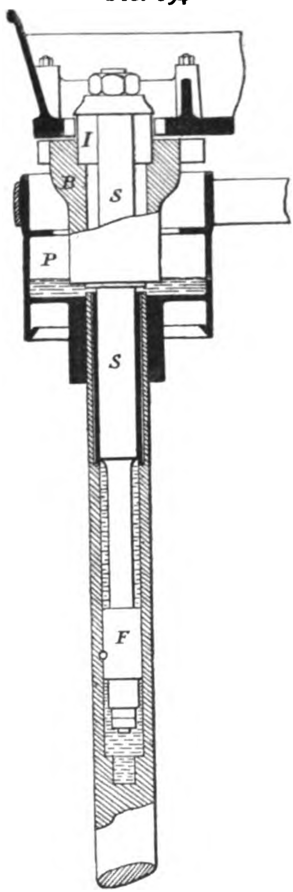
The speed at which a centrifugal machine may be safely driven varies with the diameter of the basket, from about 500 revolutions in the case of a 6-ft. basket to about 1200 with a basket of half that diameter. Large machines are most suitable for drying crystals and high-class sugars, and small machines for dealing with lower qualities. The amount of sugar dried in each operation depends upon the size of the machine (and to some extent, with the quality of the *masse-cuite*) from 2 to 8 cwt. The time required for machining a charge varies from two to three minutes in the case of crystal *masse-cuite* to sometimes as much as half an hour with the lower qualities. With white sugar, such as "crystals" or "granulated," it is usual to wash the sugar from which the syrup has been driven out, whilst it is still being machined, with water or liquor, applied through a rose attached either to a watering can or to a rubber pipe. The sugar is then blued by means of a small quantity of ultramarine suspended in water, or by a soluble blue, to satisfy the fancy of consumers.

The *masse-cuite* is conveyed from the heaters to the machines either by means of small iron trucks, each holding enough for one charge (travelling on an overhanging rail), and which can be easily emptied by a sliding valve, or, as in the Hepworth and Weston machines, which are suspended from a trough-shaped heater, by means of discharge valves, one of which is placed over each machine.

The machines were formerly discharged over the sides, but of late years openings with movable lids have been provided in the bottom of the basket with corresponding openings in the bottom of the outer casing, through which the sugar is emptied on to travelling bands, which convey the sugar to floors where it is mixed previous to being packed.

Various plans have been suggested to enable the centrifugal machine to be worked continuously so as to economise time and labour, but of these the only one which promises to give results of a satisfactory character is the ingenious form of apparatus recently patented by Duncan Stewart & Co., of Glasgow. In this apparatus the basket is made to revolve horizontally, and is provided with an interior drum of smaller diameter attached to an independent shaft, which causes it to slowly revolve in a direction opposite to that of the basket. Around this drum, arranged in the form of a helix and at short distances apart, are fixed flat metal arms, which almost touch the side of the basket. The *masse-cuite* is run into a hopper containing a mixer, from which a screw-conveyer forces it into the annular space between the drum and the basket. The arms attached to the drum then propel the sugar through the machine, discharging it at the outlet in a dry condition.

FIG. 194.

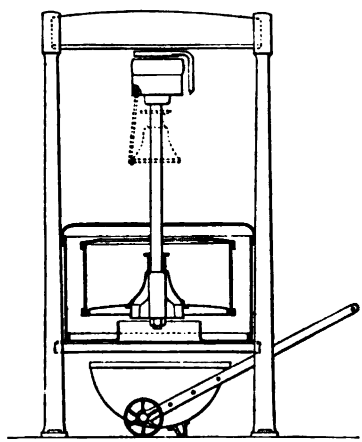


Weston's Centrifugal.

Weston's Centrifugal Machine. —There are two types of this machine, one in which the basket is suspended and over-driven, and the other in which it is under-driven.

The following description relates to the former of these, which has come into general use:—In this machine the basket is allowed a certain freedom of movement by means of the use of elastic bearings, from which the spindle supporting it is hung. When there is an inequality in the load, the basket can swing in an irregular way until the velocity of its revolutions causes the oscillations to become less and less till they finally disappear. The means by which this oscillation is at once permitted and controlled may be explained by reference to Fig. 194, which shows, partly in section, a basket spindle, with its driving pulley, suspending block, &c. B is a strong bracket or block firmly bolted to the overhead beam. It is an elastic buffer resting on the block B, and S is a steel spindle suspended by means of the top nut and washer from the elastic buffer. This spindle is itself stationary, but is fitted at the bottom with a special form of revolving bearing F, and is enclosed by an outer spindle attached in a simple manner to the revolving bearing. The outer spindle has fixed upon it at the top the pulley P, the lower part of which also forms the brake block. The basket is attached to the bottom of the outer spindle. The elastic buffer I permits, and at the same time controls, the oscillation of the basket. Whenever there is an unequal load there is necessarily, in every form of centrifugal, a tendency on the part of the basket to oscillate, and instead of wasting power, and setting up severe strains by trying to restrain this tendency, and to hold the basket to a fixed centre, the basket in the "Weston" machine is allowed entire freedom within the limits required by practice and under the control of the elastic buffer. Vibration in the framing of the machine, or in the floor upon which it rests, is thus prevented by this simple and most efficient expedient.

FIG. 195.



Emptying Weston's Centrifugal.

The hollow portion of the outer spindle constitutes an oil chamber, so that the revolving bearing F, which is the principal bearing of the machine, simply runs in a bath of oil, and is therefore lubricated as long as the bath is maintained.

The provision made for emptying the basket will be readily understood by reference to the illustration (Fig. 195) which is an outline view, partly in section, of a 30-inch suspended machine. It will be seen that the basket bottom is formed with a central opening, which is closed by the conical cover whilst the basket is being charged, so that no syrup or undried material can pass through. When the dried sugar is to be discharged, the conical cover is lifted into the position shown by dotted lines, and suspended by a light rod or chain from the brake pulley. The wall of sugar is then broken down, and easily and quickly swept through the central opening and delivered on to a band or into a handbarrow, as shown in the illustration.

The machine is started by a friction pulley which is placed on the countershaft and drives on to the pulley on the basket spindle. It consists of a pulley which runs loose upon the shaft (and may therefore stand when the shaft is revolving), and a pair of friction arms firmly secured to the shaft, and so constructed that they may expand a little radially when in motion, and thus bind themselves against the inside of the rim of the pulley. When the shaft is revolving, and it is desired to start the pulley, two small wedges are withdrawn by a hand lever. This allows the friction arms to expand by centrifugal action against the inside of the rim of the pulley, and thus to carry the latter gradually round with them as quickly as may be desired, bringing the cage up to full speed without any shifting or slipping of the belt, and without throwing any sudden strain upon it or on any part of the machine.

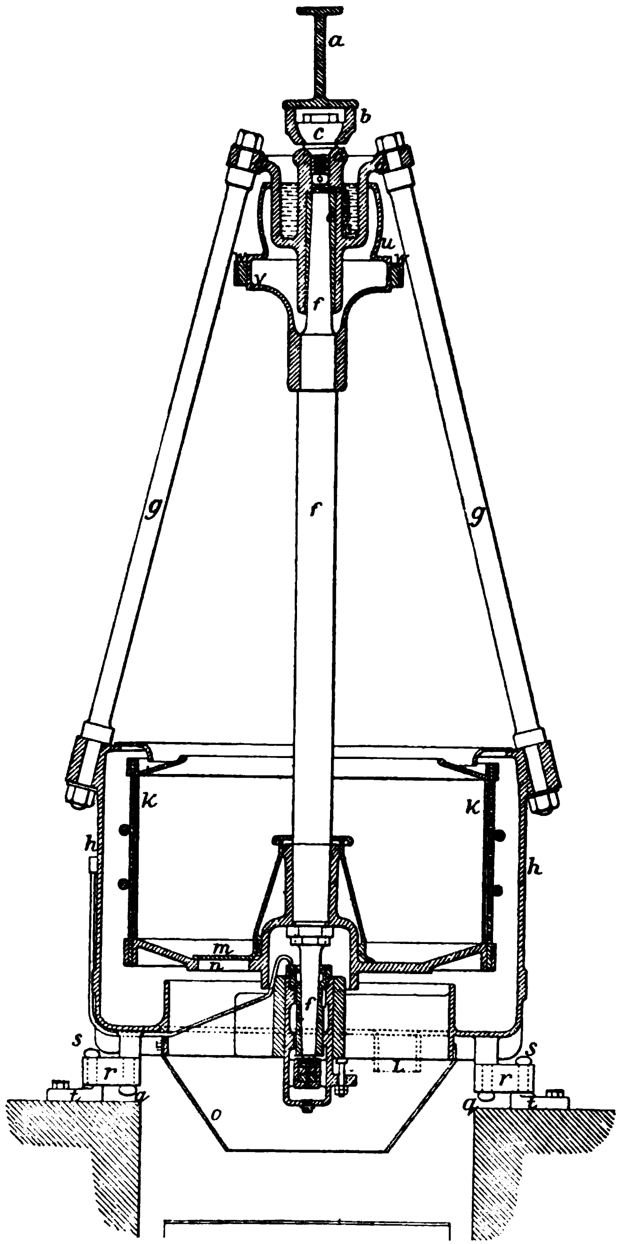
When it is desired to stop the machine the wedges are pushed home, and the power being thus instantly withdrawn, the brake may be applied and the machine brought to rest in a few seconds.

These machines are made in this country by Watson, Laidlaw & Co., of Glasgow.

The Hepworth Suspended Centrifugal Machine.—This machine combines some of the advantages of the ordinary fixed centrifugal machine with those of the suspended type, and is as independent as the latter of heavy foundations, and like them may be suspended from a framework or ceiling. In other suspended machines the revolving basket and its spindle are alone suspended while the casing is fixed, but in the Hepworth machine the casing itself is suspended from a single point, and is only prevented from revolving by indiarubber bands, which, while they restrain it from turning, nevertheless allow it to move freely through a certain distance. The revolving basket and spindle are supported in this suspended casing, and are carried in fixed bearings in it. When power is applied, and the machine is used for purging sugar, any uneven loading of the basket will cause not only the cylinder but also the casing and the framing attached to it to swing, and this they can do without imparting undue vibration to the building or framing holding the machine. As in machines in which the basket alone is suspended, the sugar is generally discharged through the bottom of the basket, and sugar so discharged may be received upon a travelling band running below the machine.

In Fig. 196 *a* represents the iron girder (which may form a part of the flooring of the room above) to which the machine is attached, and from which it is suspended; *b* is a bracket bolted to the girder, and having formed within it the cup or socket of a ball-and-socket joint; *c* is the corresponding ball fitted to work easily in the cup or socket, and firmly secured to the bracket *d*, which forms the upper part of the framework of the centrifugal. This bracket *d* is so formed as to contain the upper bearing *e* of the revolving spindle *f* of the centrifugal, and also a supply of oil or other lubricant. It also holds three side rods *g*, by means of which the upper part *d* of the framework of the centrifugal is secured to the casing *h*, which forms the lower part of the framework of the machine. This casing carries the bottom bearing *i* of the spindle *f*, and is provided with suitable openings for the sugar to fall through as it is discharged through the bottom of the revolving basket *k*, and with a suitable syrup outlet *l*. The basket *k* is securely attached to the spindle *f*, and may be of any usual construction, but is generally made of the form

FIG. 196.



Hepworth Centrifugal.

shown. The valve *m* is arranged to rest upon the bottom of the centrifugal, and to partially revolve upon the spindle, so that in one position it closes the apertures *n*, while, when partially revolved, it leaves them open for the discharge of the sugar. *o* is a light funnel to catch the sugar as it drops through the bottom of the casing, and to guide it on to the travelling band *p*. The projections *q* are secured firmly to the casing *h* of the centrifugal, and the indiarubber bands *r* pass around them, and also around the projections *s* secured firmly in brackets *t*, which are attached to the floor. *u* is the driving pulley of the machine, and is securely keyed to the spindle *f*. *v* is the brake pulley, and *w* the brake. It will be seen that the whole machine swings from the ball-and-socket joint *b* and *c*, and that its swinging is only controlled by its own inertia, and by the indiarubber bands *r* by which it is loosely attached to the brackets *t*, which are secured to the floor.

It is evident that the tendency to vibrate on account of uneven loading will be much less in this machine than in those of ordinary construction, inasmuch as in order to vibrate, the whole weight of the casing and framework of the machine has to be moved as well as the basket itself. It is also manifest that no extent of vibration can cause the revolving basket to come into contact with the casing, as the two vibrate together.

This machine is manufactured by Manlove, Alliott, Fryer, & Co., Nottingham.

Loaf Sugar.—The raw sugar from which loaf sugar is to be made should be of good quality, and the liquor must be boiled into an even small-grained thick *masse-cuite* and run into a steam-jacketed heater. The temperature of the mass is raised to from 180° to 190° F., and it is then filled into conical sheet-iron moulds. These are either painted inside or galvanised and are varnished. The moulds are arranged for filling in rows with their rims touching one another, so as to afford mutual support. Each mould has a small hole at its lower end, and this is stopped up during the filling operation by means of a wooden spigot or a piece of rag. In some refineries the moulds are taken to the heater, to be filled, on iron trucks, but as a rule the *masse-cuite* is carried to the moulds in tin vessels specially designed for the purpose. The operation of filling is usually conducted in the basement of the refinery, or as it is termed, the "fill-house." When the sugar has solidified in the moulds to the thickness of about half an inch or so round the rim, the solid part is cut away by means of a tool known as a brushing-off hook, and is mixed well with the liquid in the centre, this being done for the purpose of preventing the crystals from settling out and so rendering the loaf of unequal texture.

The loaves are now allowed to cool and solidify. This takes 8 to 12 hours according to their size and the temperature of the fill-house; they are then removed, preferably on iron trucks each holding a dozen, to one of the upper floors of the building. These floors are kept at a temperature of from 70° to 90° F. by means of steam pipes, the temperature being varied according to the quality of the raw sugar, fine sugar requiring a lower heat than low sugar. The floors are perforated with rows of holes, for the reception of the tips of the moulds, arranged at such a distance apart that when the moulds are set perfectly upright in them, the rims touch each other so that the moulds are kept in position. Under the floor are inclined trays for catching the syrup, and these discharge into iron gutters communicating with tanks. The filled moulds, having had their spigots removed, are set on end in the holes in the floor, each pan or filling being kept by itself, and the green syrup is allowed to drain off for some hours. If the loaves do not drain in a satisfactory way, it will be necessary to drive a pointed iron rod up through the orifice to make a clear passage some two or three inches deep, but if spigots of this length are employed this is seldom necessary. The surface of the sugar which is soft is then cut away by means of the brushing-off hook to the depth of about an inch. There is in the centre of the face of the loaf a quantity of small-grained sugar, and this must also be cut away or it will impede the passage of the clarifying liquor, and consequently the outside of the loaf will be washed quite clear, while the centre remains brown. In fact the surface of the loaves must in all cases be made slightly concave to make certain that the loaves will be, when finished, of a uniform whiteness. The sugar removed from the face of the loaves is called "brushings," and is sometimes mixed with liquor or water and replaced again on the top of the loaf, thus serving as a means of equalising the flow of the liquor which is employed in washing the sugar, or it can be purified in a centrifugal machine and used for making white liquor. The white liquor, or as it is sometimes called heavy liquor, must be made of pure sugar, the brushings and broken loaves being suitable for the purpose. Beet sugar purified by means of the Weinrich process will do to make up any deficiency. The liquor is made in the ordinary way, care being taken to have a clean blow-up. It should be made of about 2 parts of sugar to 1 part of water. The char through which it is passed must not be too fine, otherwise the liquor will not pass through readily. After the liquor leaves the char it must be cooled to about the temperature of the floor. The loaves are liquored, as it is called, three or four times, the liquor being applied by means of an indiarubber hose. Each time the sugar is liquored the mould is filled up to the brim, and sufficient time is allowed for the mass to drain before it is again liquored. It is easy to decide if the sugar has been sufficiently liquored by knocking out a few of the loaves, and when this is the case the face of the sugar is cleaned by means of the tool mentioned before, care being taken to leave it as even as possible, and to avoid cutting away more of the solid sugar than is absolutely necessary to attain this end. Before the loaves are cleaned or "brushed off" they are loosened from the moulds by giving the rim a slight knock when turned upside down against a wooden block provided for the purpose. The sugar is then liquored again, and after draining for a few hours is placed upon a suction apparatus connected with a vacuum pump, and the last adhering liquor is rapidly removed. The operation of liquoring can be greatly facilitated by the use of a centrifugal machine, and suitable machines for this purpose have been devised by Alb. Fesca & Co., of Berlin, and others. After the sugar has thoroughly drained it is removed from the moulds and placed on racks in a drying stove heated to about 140° F. These stoves usually extend from the top to the bottom of the building and have doors opening on to each floor. They are best heated by a current of warm air which is kept in motion by means of a fan. It is usual to cover the loaves with paper before drying, but in some refineries they are dried naked. After this operation is complete the sugar is ready for sale. It is impossible to state exactly the time that will be required for each operation in the manufacture of loaf sugar, as it much depends upon the quality of the raw sugar and particularly upon the required size of the grain of the finished product, fine-grained sugars such as are sold on the Continent taking a much longer time to manufacture than the large-grained sugar which finds favour in this country. It may generally be stated, however, that the time occupied by the process, from beginning to end, is from 8 days to a fortnight, and that about half of this time is needed for stoving the sugar and about half for cooling and liquoring.

Moulded Cube Sugar.—This kind of sugar is made in the form of slabs or sticks, which are afterwards cut into cubes or tablets. The inventions for this purpose are too numerous to admit of individual detailed description, but as the processes of Langen; Tietz, Selwig & Lange; Duncan & Newlands, and Walker & Patterson, are in operation upon a manufacturing scale, they are selected for special notice.

Langen Process.—As at present carried on this process is a combination of the work of several inventors. The construction of Langen's mould is clearly shown in Figs. 197 and 198. It is oblong in shape, is open at the top and bottom, and tapers somewhat from the top to the bottom. Thin divisional plates are inserted in recesses provided in the sides for their reception, and these divide the contents of the mould into slabs of the thickness of the cube sugar. The moulds are placed one on another as shown in Fig. 198. Thin perforated

FIG. 197.

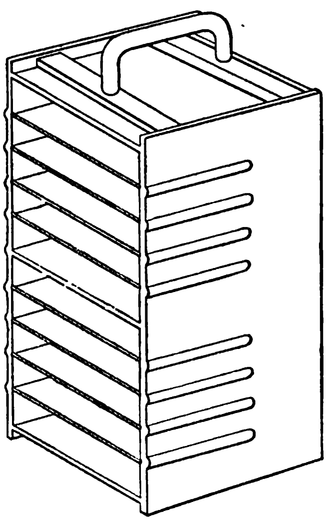
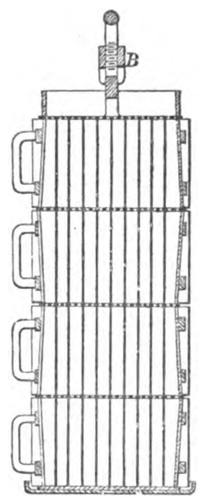


FIG. 198.

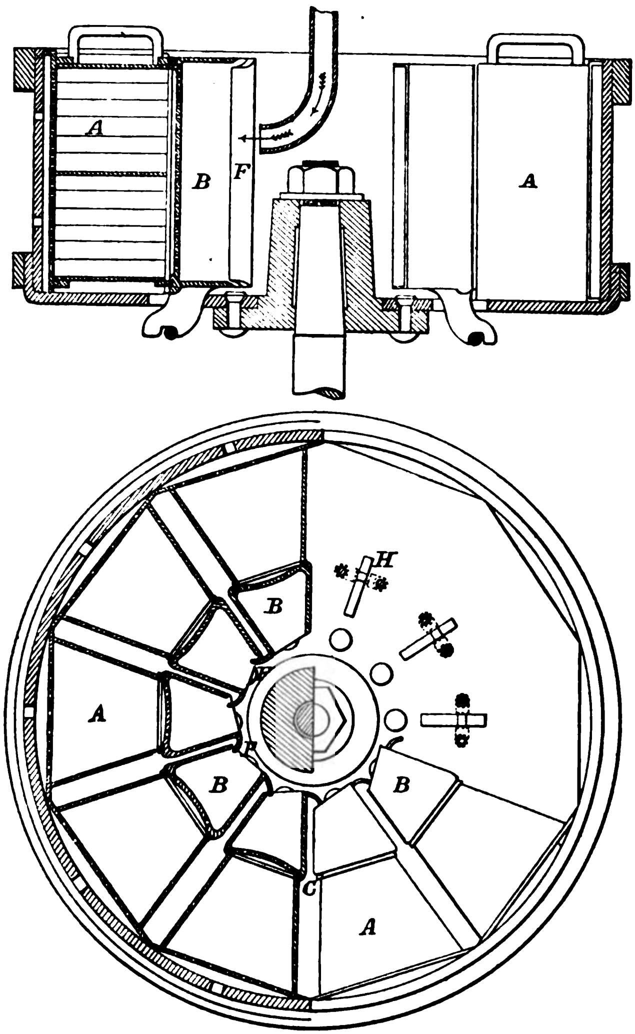


Langen's Moulds.

iron plates with their edges covered with a soft material to form a tight joint are inserted between the moulds, and sets of 4 or 6 arranged in this way are placed in rows on an iron truck to which they are tightly attached by means of iron bolts B. The moulds are then filled with *masse-cuite* and allowed to stand till their contents have set. This mode of filling the moulds is the invention of Matthiessen (English Patent 1439, 1875). The moulds are then separated and they are placed in a centrifugal machine in which the green syrup is driven out. The sugar is next liquored in the machine. Many plans of liquoring have been suggested, and one of the most successful is the invention of Elmenhorst (English Patent 4695, 1878), who uses a centrifugal basket having a central liquor chamber connected with a number of rectangular spouts or receptacles, these being hinged at their lower ends so that they can fall back towards the centre of the basket when the latter is at rest, and thus allow of the free admission or withdrawal of the moulds. When the machine is revolving each of the spouts presses against the edges of the mould opposite to it, and the liquor from the central chamber runs through it on to the face of each mould. Langen has patented a similar apparatus (English Patent 3488, 1879) as shown in Figs. 199 and 200. A A are moulds containing sugar. B B are spouts or receptacles through which the clarifying liquor flows into the moulds. Each receptacle has a lip F on one side which overhangs the side of the next receptacle and so prevents any escape of liquor between the moulds. After the sugar has been thoroughly liquored the moulds are removed, the blocks of sugar are pushed out, and the slabs are placed vertically side by side in iron trays which have small projections at the sides to keep the slabs of sugar upright and apart from each other. The bottoms of the trays are perforated to facilitate the drying operation. The trays are carried on a moving frame through a current of heated air. This mode of drying is also the invention of Langen. After the sugar is dried it has only to be cut across in two directions to form cubes.

Tietz, Selwig, and Lange's Process.—By this process the sugar is formed into slabs, which are washed in vessels of special construction, centrifugal machines being employed to remove the clarifying liquor. The *masse-cuite* is run into large rectangular oblong moulds, *a* and *b* Fig. 202, which are divided by 7 thin cross vertical divisions at a distance apart corresponding with the length of the slabs. Between these cross divisions and supported by them, are small longitudinal

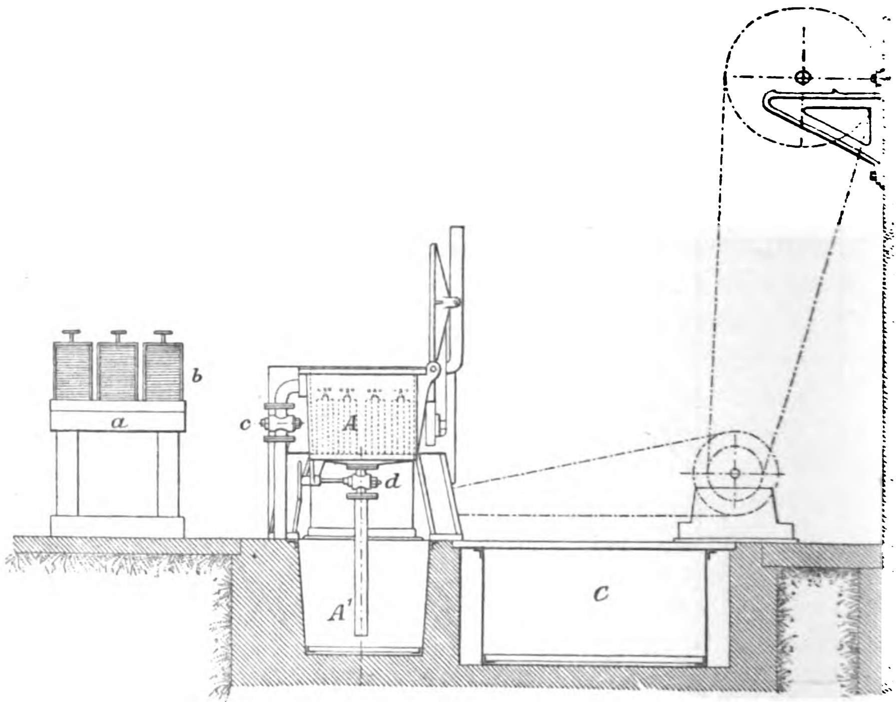
FIGS. 199 AND 200.



Langen's Moulds.

plates, having a space between them equal to the thickness of the slab to be produced. Each mould when filled with *masse-cuite* is allowed to stand for 24 hours, and is then carefully turned upside down upon a table, and the mould is removed, leaving the solidified mass which is divided by the cross plates into 8 easily separable sets of slabs *a a*, Fig. 202. The sets of

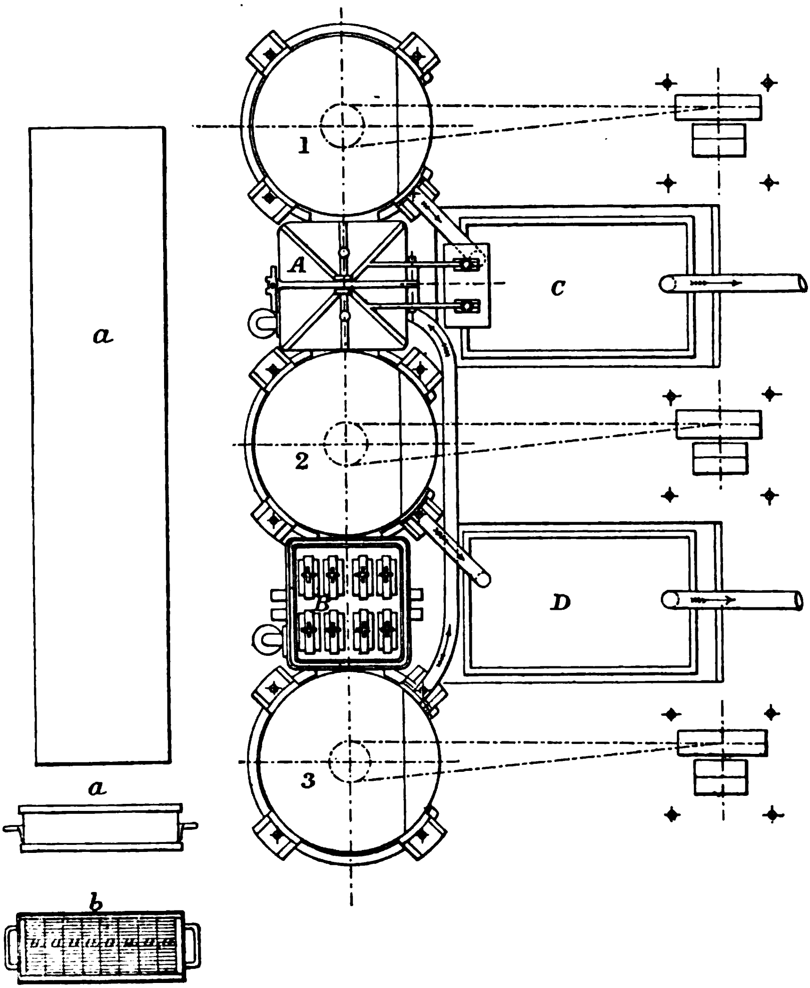
FIG. 201.



Tietz, Selwig and Lange's Cube Sugar Apparatus.

slabs are then arranged horizontally in iron frames, *b* Fig. 201, and are taken to a centrifugal machine 1, Fig. 202, the basket of which is fitted with 8 perforated plates, against each of which is placed a set of slabs. After being revolved for a short time, the green syrup is expelled, and the sets of slabs are then placed in the vessel *a*, known as an "impregnator." This vessel, which is sufficiently large to hold 8 frames, i. e. the contents of one mould or the charge of a centrifugal machine, has an air-tight lid which is closed upon the charge being put in. A vacuum is then produced by opening the tap *c* which

FIG. 202.



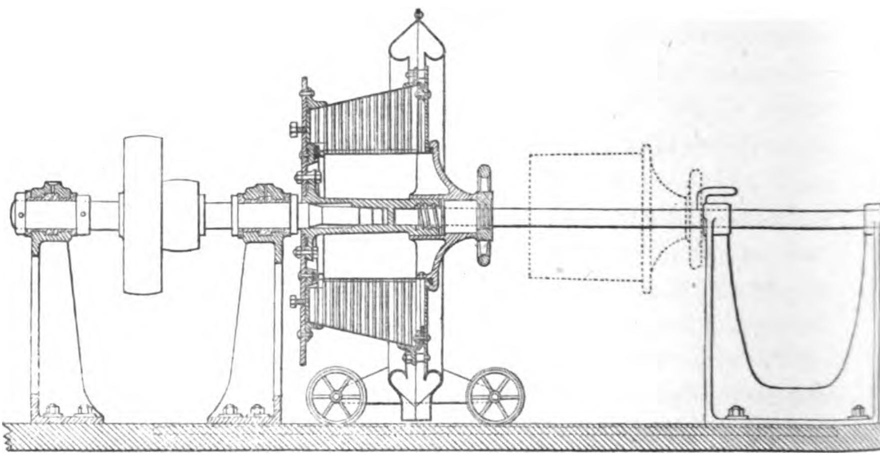
Tietz, Selwig and Lange's Cube Sugar Apparatus.

communicates with an air pump, and sufficient clarifying liquor to cover the sugar is introduced by the tap *d* from the tank A 1. The taps *c* and *d* are then closed, and air is admitted by another tap, when the pressure of the atmosphere drives the clarifying liquor into the interior of the plates of sugar. The lid is next opened, and the excess of clarifying liquor not absorbed by the sugar is allowed to run back into the tank A 1. The frames are then transferred to centrifugal machine 2, by means of which the liquor is removed, and this process of alternately absorbing and discharging the clarifying liquor is repeated once or twice more, till the desired degree of whiteness is attained. On leaving the last centrifugal machine the frames are removed, and the sugar is dried in a stove and cut into cubes. The tanks C and D shown in the drawing are for the clarifying liquor which has been used and the green syrup respectively. The arrangement of the plant as shown in the drawing is from a design by Cail & Co., of Paris.

Duncan & Newlands' Process.—In this process an oblong mould is used. The mould is open at the top and bottom, and has also a movable side. The two ends of the movable side plate are turned over in such a way as to hold a strip of indiarubber, which enables a tight joint to be made when the plate is fixed in its place by means of lugs and screws. The interior of the mould is filled with serrated divisional plates an inch shorter than the walls of the mould, by means of which the contents are divided into sticks. The mode of working is as follows. The serrated plates are inserted in the mould, and the side plate is attached. The mould is then placed on a surface of indiarubber or cotton cloth, which is laid upon a stage or iron truck, to which it is held down by iron bolts. *Masse-cuite* is then run in, and the filled mould is allowed to remain in a cool place for a sufficient time for its contents to set. It is then placed in a centrifugal machine, the basket of which has an inner lining composed of four perforated flat plates, against each of which two of the moulds are set on their sides, one on another, and the green syrup is removed by centrifugal force. When this is accomplished, the sugar is either liquored or steamed in the machine, and when thoroughly purified, is taken out of the mould, dried in a stove, and cut into cubes. By this plan of working, raw sugar can be converted into cubes in less than two days from the time of melting.

Walker & Patterson's Cube-sugar Process.—In carrying out this process a mould of a truncated conical form is employed, and a series of flat annular plates are placed in it and retained by a removable cover. The *masse-cuite* is led into the mould while it is rotating at a moderate velocity, and the centrifugal force causes it to flow in a uniform manner, into the spaces between the annular plates. When the mould is full, a tapered or slightly coned inner shell is moved in to close the ends of the spaces between the plates. When this shell has been fixed in position, the mould is removed from its shaft and placed with its axis vertical in order that its contents may set, when it is again fixed on the shaft for the refining operations. The inner shell is then withdrawn, and the mould is made to rotate at a sufficient velocity to carry off the green syrup. The outer conical shell of the mould is not perforated, so that the syrup cannot pass through it as in an ordinary centrifugal basket, but an outlet is provided for the syrup at its widest end. When the sugar is being drained, the syrup in each space between the annular plates first passes rapidly to the shell of the mould, and then in consequence of the conical form of the shell, which form is given for the purpose, flows along the shell to its larger end, and passes out at the outlet provided at that part into a suitable movable receptacle which is placed on wheels. When the syrup has been thrown off, the operation of liquoring is commenced. A saturated solution of pure sugar is used for liquoring, and may be applied in various ways. Thus it may be poured into the mould while it rotates at full speed, or it may be supplied in separate successive charges, the mould rotating at a moderate speed while receiving each charge, and subsequently being driven at full speed. The application of liquor is repeated as often as may be necessary. Finally the mould is driven at full speed during a time sufficient to completely drain the sugar, and then the mould is taken off the shaft, the annular cover is removed, and the mould is inverted to empty out the sugar and annular plates. The cakes or blocks are then easily separated from the annular plates and dried in the usual manner. The machine is shown in Fig. 203.

FIG. 203.



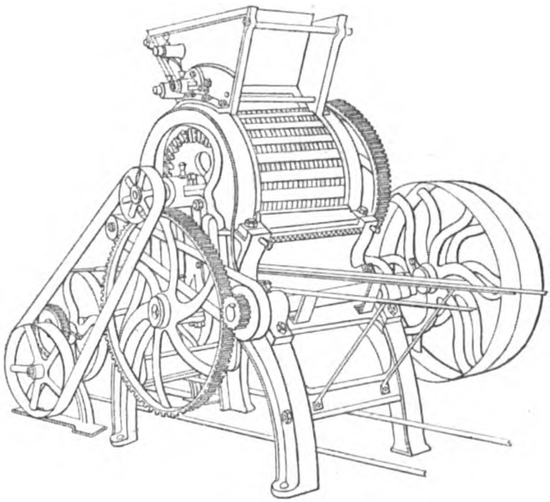
Walker & Patterson's Cube Sugar Machine.

Pressed Cube Sugar.—An inferior sort of cube sugar is sometimes made from centrifugal granular sugar by pressing it in small moulds of the same shape as the cubes, or in the form of sticks, which are cut into cubes. Hersey's and Jasper & Boushey's machines are largely employed for this purpose in the United States, and turn out cubes direct; Pzillas's machine is used in Europe for the production of sticks.

As these machines are almost the only ones in use, they will be shortly described.

Hersey's Cube-sugar Machine.—In this machine (Fig. 204) moist white sugar can be converted into cubes. The sugar is first liquored and blued in the centrifugal machine; it is then passed through a set of small rolls, on leaving which white liquor is sprinkled over it, and by means of a revolving screw,

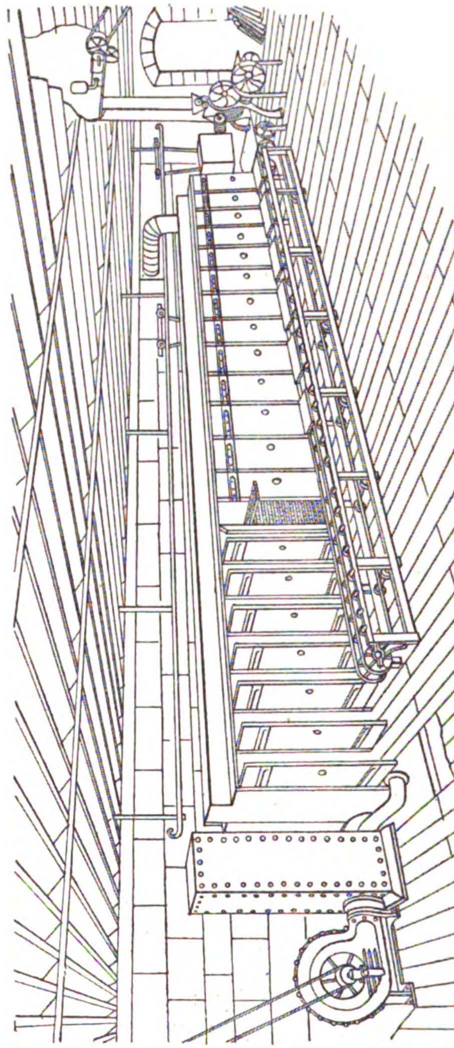
FIG. 204.



Hersey's Cube Sugar Machine.

thoroughly incorporated with it. After this treatment the damp sugar is fed into the hopper of the machine, in which are shafts provided with mixing arms and an inclined packing plate. The bottom of the hopper is formed of the upper surface of the moulding drum. In the periphery of this drum are a number of rows of moulds, each of the size to form one cube. These moulds are open at the top, but are closed at the bottom by means of movable plungers, the position of which is determined by the movement of iron bars, to one of which each row is attached. The bars are caused to advance and retreat radially by means of cams. When a row of moulds is at the top and directly under the hopper, the plungers are withdrawn to their full extent, and the sugar is caused by means of the mixing arms and packing plate to fill the moulds. The row of filled moulds then passes behind a strong iron plate curved so as to fit closely to the drum and extending about half way round it. The plungers gradually

FIG. 205.



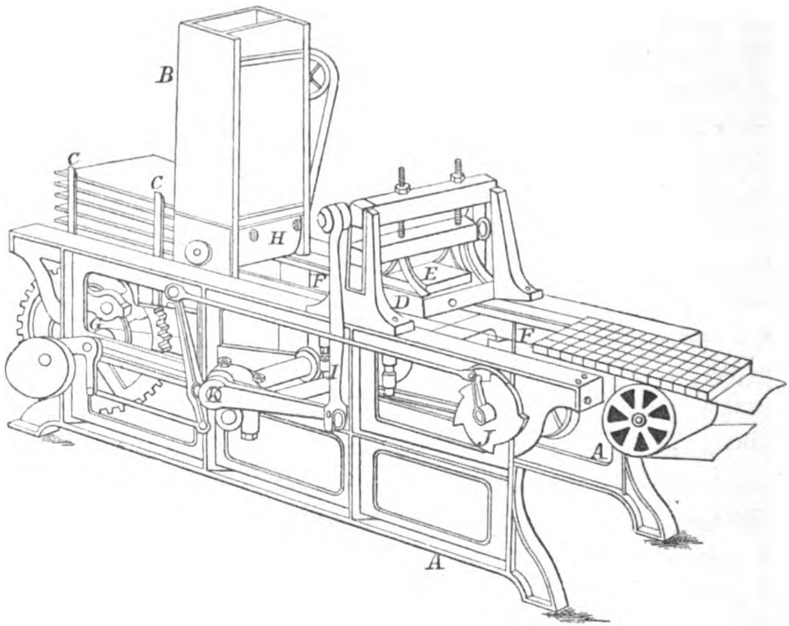
DRYING STOVES HERSEYS CUBE SUGAR PROCESS.

press the sugar more and more as it passes behind the plate, until nearly the bottom of it is reached, when the plungers are slightly withdrawn to remove the pressure. After the moulds have passed the plate, the plungers advance to their full extent and push out the pressed cubes, which fall on to metal perforated trays, on which they are arranged in regular rows by a rake, which also at the same time detaches any cubes which may adhere to the moulds. The trays containing the cubes ride on two endless bands to the doors of the stoves (Fig. 205), and when they arrive opposite the stove which has to be filled they are taken off and placed one above the other in racks. The doors of the stove are then closed and hot air is passed through the stove, the sugar being dried in from three to four hours, when it is ready for the market. One machine will press about 28 tons per day. Five men attend to the whole operation from the introduction of the sugar into the hopper to its removal from the stoves. The machine is largely employed in the United States and elsewhere, and when suitable sugar is pressed the cubes leave little to be desired in point of brilliancy and appearance. The machine is manufactured by Hersey Brothers, South Boston, U.S.A.

Jasper & Boushey's Process.—The apparatus employed in this process consists of a machine by means of which the moist sugar is distributed in the form of a slab of uniform thickness, on a tray or plate, and is then cut and at the same time pressed into cubes, which are afterwards conveyed by a belt, on which they are dried by means of hot air before being handled. Fig. 206 shows a perspective view of the apparatus, and Fig. 207 a sectional elevation.

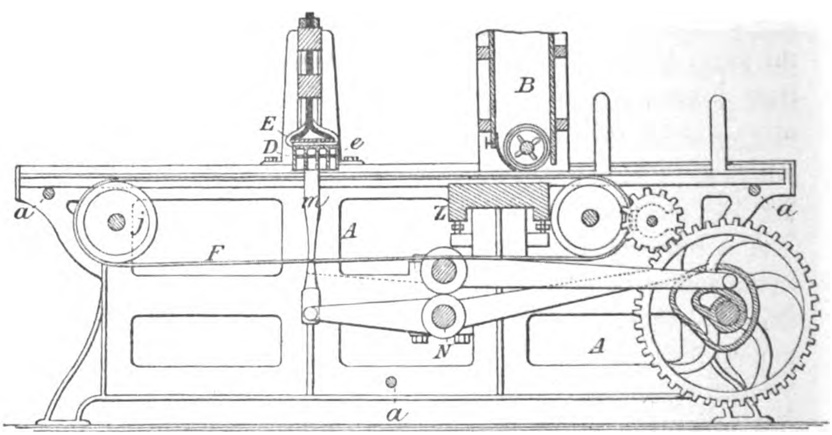
A A represent the side frames of the machine, in which the shafts and working parts are held; and *a a* the rods that bind and hold them together. B is the feed-box or hopper containing the moist sugar; C, plates or trays which are fed along beneath the hopper to receive the sugar and carry it to the cutting apparatus; D is the cutter-plate, E is the press-plate, and F the endless belt or apron for conveying the trays

FIG. 206.



Jasper & Boushey's Cube Sugar Press.

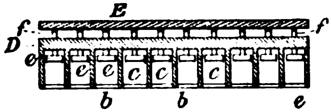
FIG. 207.



Jasper & Boushey's Cube Sugar Press.

or plates from the feed-box to the cube-forming mechanism, and carrying the finished cubes out of the machine. The mould-plate (Fig. 208) is formed of two sets of blades *b b* crossing each other at right angles so as to include a series of rectangular spaces of the size required for the cubes. The height of these spaces *c c* is made somewhat greater than the width of the cubes to afford room for a series of press-plates *e e*, and to allow also for the compression of the sugar. Each space or mould is provided with a press-plate attached to the end of a short vertical rod *f* which passes through a hole in the centre of the top of the mould and is fixed to the plate E.

FIG. 208.



Mould Plate.

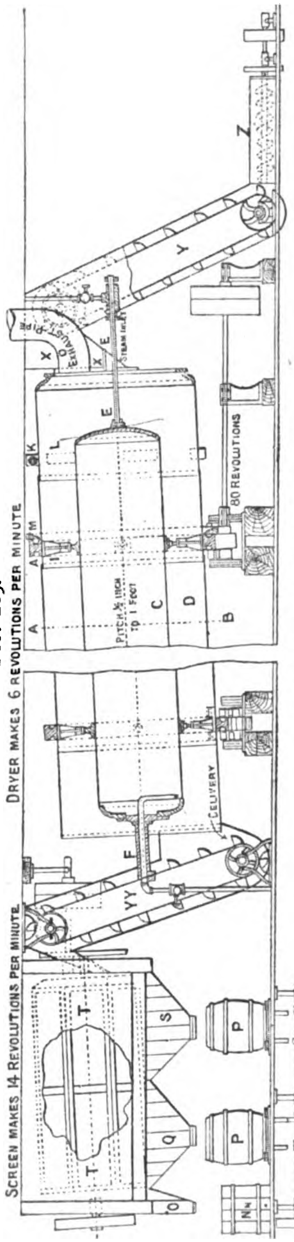
The mode of working is as follows:—The trays C are carried in a continuous line under the hopper D, where they are covered with an even layer of sugar, and then on the table Z under the mould-plate D. In the operation of moulding the blades *b b* pass through the layer of sugar till they come in contact with the surface of the trays, and the press-plates then move down and compress the enclosed sugar to the required extent. The blades are then moved upwards and at the same time the press-plates are held down to keep the sugar on the tray and prevent the first upward movement from disturbing it while it is in its moist state. A continued upward movement causes the top of the moulds finally to strike against the plate E, to which the press-plates are fixed, when they both are lifted together above the sugar, and the tray containing the cubes is moved forward a sufficient distance to admit of a repetition of the operation with another trayful. The sugar after being pressed is dried on the plates and packed.

Pzillas's Cube Process.—This is somewhat similar to Hersey's. The machine is formed of a revolving metal drum, about $\frac{7}{8}$ of an inch thick, with 18 slots or moulds cut longitudinally through it at equal distances apart. A temporary bottom is formed by an inner half drum which does not move. The moulds are filled as in the case of Hersey's machine, and the outer drum as it revolves brings the filled moulds opposite a stamp which compresses the sugar against the inner drum, and the pressed sticks when they reach the bottom are forced out of the moulds by another stamp (acting from the inside) on to boards placed beneath to receive them. The sticks are dried on these boards in a stove, and then cut into cubes by passing them through a pair of cutting knives which are caused to advance towards each other and recede by a suitable mechanical arrangement.

Granulated Sugar.—This form of sugar is already the leading article in the United States, and its consumption is rapidly increasing in this country. It well deserves its popularity, for in addition to being practically free from moisture and other impurities, it is easily dissolved, and does not lose weight or become discoloured by keeping. Many machines have been devised for producing granulated sugar, the most important being those invented by Hersey, Newhall, and Gibbs. The sugar dried in these machines must not be confounded with the so-called German or Austrian granulated, which is generally raw beet sugar which has been washed with steam by the Weinrich or a similar process. Real granulated is refined in the ordinary way, and is boiled to a small sharp grain like that of loaf sugar, and then washed in an ordinary centrifugal machine with water or liquor. As it leaves the machine it contains from 1 to 1½ per cent. of moisture, nearly the whole of which is removed in its passage through the granulator.

Hersey's Granulator.—Figs. 209 and 210 illustrate this machine, the description of which is as follows:—The heating cylinder *c*, which is fastened inside of the conveyer cylinder D, and revolves with it, is filled with steam through the pipe E in one end, and the water of condensation is delivered from the opposite end through the pipe shown at F. The damp sugar as it comes from the centrifugals is delivered into the hopper Z. The hopper contains an adjustable device by which the sugar is fed at any desired speed into the elevator Y, and thence through the spout X into the granulator. By means of the lifting shelves H on the inside of the outer cylinder it is carried up and dropped in a continuous shower upon the heating cylinder, and rolls off by the rotation of the machine, to be again carried up, working forward to the opposite end by the inclination of the apparatus, and is there delivered by means of the elevator Y into the screen T. The finer grade of sugar falls through the shoot S into the barrel R, the coarser through the shoot Q into the barrel P, while the lumps pass out at the end of the screen through the shoot O into the barrel N *n*. The barrels stand upon iron shaking-tables operated by the cams M *m*, which give them a constant rocking motion, by which the sugar is effectually packed. The heater cylinder is

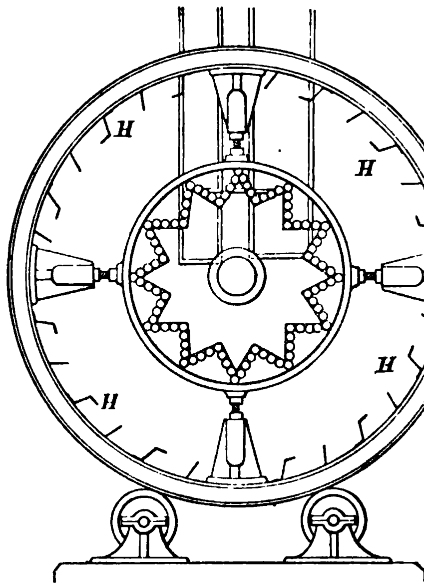
FIG. 209.



Hersey's Granulator.

fixed centrally within the conveyer cylinder, and is adjusted and secured by means of the adjustable screws I. The conveyer cylinder is made of iron, and the heater is constructed of steel plate. The conveyer cylinder is 23 feet long and

FIG. 210.



Hersey's Granulator.

6 feet in diameter, and the heater cylinder 20 feet long and 3 feet in diameter, and they make 6 revolutions per minute. The striker shown at K is for the purpose of removing any sugar that may adhere to the cylinder when first entering the machine, and is caused to move by the cams L L. The machine is rotated by means of gear M upon the outside of the conveyer cylinder, driven by a pinion on the shaft N. The current of air, which is sometimes previously heated, constantly passes through the machine, carrying off the moisture from the sugar through the pipe O. The machine will granulate 6000 lb. per hour. Being automatic, but little labour is

required in attending to it; the sugar being thrown into the hopper, passes through the dryer and then through the sifter or screen into barrels ready for the market. In a refinery, if room permits, it is advisable to place the hopper Z on a floor above the granulator, and the screens on a floor below, so as to avoid the use of elevators.

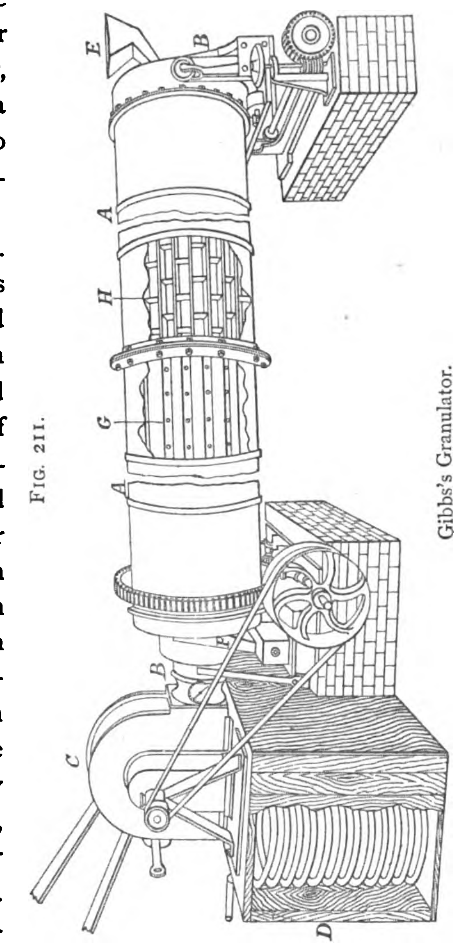


FIG. 211.

Gibbs's Granulator.

Gibbs's Granulator.—This machine has been recently adopted by sugar refiners both in this country and abroad. It consists of an inclined cylinder provided with shelves and cross-cells on its interior circumference, and with elevating gear by which the degree of inclination can be altered and adjusted. Running through the whole length of the cylinder is a stationary air-duct of a D section, perforated with three or more lines of holes. Over each line protecting louvres are fixed in such a manner that, whilst allowing free exit for the air, no sugar can enter the air-duct. A large volume of warmed air is driven by a fan into this air-duct, and emerges in thin streams from under the louvres. The cylinder as it rotates lifts up the charge of sugar (which is fed continuously at one end), and lets it fall in showers on to the flat face of the D-shaped duct, so that in its downward passage it has to pass through three distinct streams of warmed air, thus getting its full share of the drying action in its transit from end to end. The air is warmed by passing through pipes heated by steam or fire or over steam coils (as shown in Fig. 211), and its temperature is regulated by valves in the neck of the fan. It is a recognised fact that air is far more effective as a drying agent than any mere contact with transmitted heat from the surface of metals, and one advantage of this system is that by the way in which the air is distributed, very large volumes of it can be used without blowing the sugar out of the cylinder, another advantage being that the air is delivered into the falling showers of sugar equally dry and effective all along the lines of the duct. If the same volume of air were either driven into or drawn from one end of the cylinder, it would become damp at its first contact with the moist product, and for the whole remaining length of its passage would be damping rather than drying in its action.

Utilisation of the last Syrups of the Refinery.—After as much sugar has been extracted as is economically desirable, the residual syrup is either manufactured into treacle (the finer sort of which is known as golden syrup), or invert sugar, or when of very low quality is sold to the distiller.

Treacle and Golden Syrup.—With the syrup resulting from raw cane sugar it is generally only necessary to reduce it to liquor with hot water, to a density of 28° to 29° B., to raise it to a temperature of 160° F., and then pass it through char, and boil down in a vacuum-pan to the required density. If, however, the syrup results from the refining of beet sugar, or a mixture of beet and cane, or even in some cases from cane sugar only, it is necessary to partially invert the sugar it contains, so as to prevent the gradual crystallisation of the sugar, which would otherwise occur and render the product unsaleable. The inversion may be carried out in the following manner:—The syrup is placed in a wooden or iron cylindrical vessel lined with lead, fitted with stirring gear, and it is then diluted with hot water to from 25° to 28° B. From 2 to 5 per cent. of sulphuric acid in a dilute state is next added, and the mixture is heated to nearly the boiling point with open steam, until on being tested it is found that the amount of invert sugar is about equal to that of the crystallisable sugar contained in it. The acid is then neutralised with milk of lime or carbonate of lime, and the liquor is filtered to remove the sulphate of lime, and after being passed through char is concentrated in a vacuum-pan. The percentage of sulphuric acid required for inversion depends, to a great extent, upon the amount and nature of the saline ingredients.

Invert Sugar, commonly known as Saccharum.—The process by which saccharum is produced is similar to that for making treacle as already described, except that the acid is not neutralised until the whole of the crystallisable sugar has undergone inversion, and also that, after leaving the vacuum-pan, the saccharum is stirred while cooling to promote crystallisation, and is then run into casks or pails, in which it solidifies to a honey-like consistency. If it is not agitated by stirring, the saccharum may remain liquid for some days, and it is sometimes sold in this state.

CHAPTER XXII.

ANIMAL CHARCOAL OR BONE BLACK, COMMONLY CALLED "CHAR."

In consideration of the important part which animal charcoal plays in sugar refining, it is advisable to collect as much information as possible regarding its nature and properties. Many of these particulars could not be conveniently incorporated in the description of sugar refining, and accordingly they have been made the subject of this special chapter.

Animal charcoal should be made from well-selected clean bones of compact structure. These are first boiled or treated with a solvent such as benzene to remove the fat they contain, and they are then carbonised in vertical or horizontal cast-iron retorts, the whole carbonising apparatus being similar to a small gas-works. The volatile products pass up ascension pipes and then through a hydraulic main to scrubbers and washers, in which the bone-tar and ammonia-liquor collect, the residual gases finally finding their way to a gas-holder. The passage of the volatile matters is assisted by an exhaust-fan. After being heated to a red heat for from 8 to 10 hours, the char is withdrawn from the retorts and cooled in iron canisters, which immediately on being filled are covered by lids and luted with water or charcoal paste round the edge to exclude the air. When the char is quite cold it is crushed in a suitable mill into different sizes of grist. Before crushing, any pieces of iron which may be mixed with the bones are removed by means of electro-magnets. Dried blood, leather, horns and other animal matters, yield, on being carbonised, a char possessing great decolorising power, and though, on account of its friability, such char is not suitable for sugar refining, it is employed to some extent in bleaching oils, fats, glycerine, &c.

In new char the carbon should range from 9 to 11·5 per cent., the siliceous matters should not exceed 0·5 per cent., the peroxide of iron 0·15 per cent., and the sulphate of lime 0·2 per cent. A cubic foot should not weigh more than 52 lb. When incinerated, the ash ought to be of a uniform white or cream colour. The grain or grist should be even and the colour black or dark brown. It should be hard, but at the same time porous in structure, adhering strongly to the tongue. These are the principal characteristics of a good sample of char.

Char manufactured in this country is generally of good quality, but the same cannot be said of that made on the Continent. The foreign manufacturers often combine the manufacture of gelatine with that of charcoal, making the latter from the partially degelatinised bones, and there is reason to believe, occasionally supplying the resulting deficiency of carbon by a judicious admixture of spent or exhausted char containing a superabundance of that element. This adulteration can be easily detected by calcining a small quantity, when the ash will be found to present a speckled appearance. The ash of spent char is either grey or red. Even if the foreign char is honestly manufactured, the small grist which finds its way here is generally the softer portion resulting from the production of the large hard grist required by the beet-sugar manufacturers.

It would not be right, however, to condemn all foreign char, as some continental manufacturers make a perfectly good article. It is important that char should be hard, otherwise considerable inconvenience and loss will be experienced from the production of dust. Even with good char, however carefully it may be handled, it is impossible to avoid the destruction of a certain amount by the attrition to which it is subjected in its journeyings in the refinery, and the small char being evidently softer than the large, is destroyed to a greater extent.

When the percentage of dust in the working char reaches a certain point, especially when the dust is very fine, it is a source of considerable trouble in various ways, and it is usual therefore to reduce its amount by passing the char over a fine screen, or by means of a current of air. Mumford and Moodie's newly invented separator acts in the latter way, and gives good results. The size of grist which it is most suitable to employ depends upon the purpose for which the char is to be used. If the solution of sugar to be purified is of high specific gravity, then large grist should be selected, but fine grist is more suitable in the case of ordinary liquor of 28° to 30° B. At present most refiners prefer small-grained char, and as fine char removes more colour than coarse, they are justified in so doing; but as the difficulty of washing, and also the amount of sweet washings increase with the degree of fineness, this preference may be carried to too great an extent. The reason that fine char is more active than larger grist may be due to the fact that the larger grist retains the liquor to a greater extent and so prevents its circulation.

The temperature of the liquor has a considerable influence in aiding or retarding the action of the char. The time during which the solution to be decolorised is kept in contact with the char is also of importance.

After the time is reached at which the best results are obtained, any further contact is attended by loss of colour, owing to the action of heat producing more colour than the char can, under the same conditions, remove. It has been proved by various experiments that cane sugar is more easily deprived of its colour than beet. This may be due, to a great extent, to the fact that cane sugar is almost always acid, and beet sugar alkaline, and also that the easily removable colouring matter of the latter has been removed by the greater care taken in its manufacture. Before employing new char for refining it should be carefully washed with hot water until the washings give with nitrate of silver and nitric acid no more indication of chlorine than is due to the washing water.

The peculiar action of char appears to entirely depend upon the carbon it contains, which exists in an exceedingly fine and porous state, the only useful purpose of the mineral matter, so far as decolorising action is concerned, being to act as a framework to support the carbon. If the mineral matter be removed, the residual carbon will decolorise more effectively than the original char. Thus it has been experimentally found that the decolorising effect of the carbon from 1000 grams of old char was greater than that of the entire weight of the char from which it was obtained.

Unfortunately, however, the carbon of animal char, when freed from its accompanying mineral matter, is in too soft a condition to admit of its use for refining purposes, on account of the impossibility of passing liquor through a cistern containing it, and even if it were stirred up with the liquor, its separation therefrom would involve the expense and trouble of filter presses. Lastly, there is no known apparatus in which such carbon can be re-burned satisfactorily so as to enable it to be used over again. For these and other reasons the sugar refiner is content to avail himself of the more lasting, though less effective results, which can be produced by the use of char in its ordinary condition.

From the foregoing experiment it is evident that the decolorising action of char is dependent upon the carbon contained in it, and a further proof of this statement is afforded by the fact that if char be calcined so as to remove the carbon therefrom, it no longer possesses any decolorising power whatever. Whilst all authorities admit the above facts, they by no means agree as to the interpretation to be put upon them, and, accordingly, numerous theories have been from time to time propounded to account for the action which char, or the carbon it contains, is capable of exerting upon so many and such diverse substances.

Char possesses, as is well known, the power of absorbing many times its volume of various gases, such as oxygen, nitrogen, carbonic acid, and ammonia, and different investigators have given the credit of the work done to one or more of these gases; but as it has been demonstrated that char from which the absorbed gas has been driven out by heat, and which has then been allowed to cool in various gases and in a vacuum, has in all cases the same effect, it is evident that the gases play at most a very unimportant part in the action.

It has been stated by P. Degener and Lack that peroxide of hydrogen is generated when char is exposed in the damp state to air, and that this is the reason to some extent why colour is removed ; but this cannot be the case, for peroxide of hydrogen would undoubtedly destroy the organic colouring matter, or modify it to such an extent that it could not be recovered. In the case of char, however, the whole of the absorbed colour can be dissolved out with a suitable solvent, such as a solution of ammonia, potash, or soda.

Char seems to act by means of a surface attraction, merely withdrawing the colouring matters, &c., from the liquid passed through it, much in the same way as peat, earth, and many other substances do to a less degree.

In addition to its action on colouring matters, char removes many mineral and organic bodies, and particularly in the case of sugar solutions, the lime salts, gum, and albumen. New char is most suitable for low sugars, as it produces a golden-coloured liquor, which cannot be obtained from char which has been in use for some time. This may be partly due to the fact that new char gives off a large amount of ammonia, which renders the liquor alkaline, and colours it if any glucose be present. If white liquor is desired, it is necessary to employ char which has been in use for some time, and from which the alkalies have been practically removed by repeated washing. It has been found that new char gives off a liquor containing ferric salts, and old char ferrous salts, when liquor containing iron is passed through it. This is probably due to the new char containing more oxygen than the old.

Char which has been freshly burned and cooled in a vessel from which air is excluded gives out a considerable amount of heat on being exposed to the air, owing to absorption of the latter.

Washing used char by an upward current of water has been patented and often tried. But it is obvious that the solution of sugar, however weak it may be, is heavier than water, and will have a downward tendency, and so by continually mixing with the water will greatly increase the sweet washings and loss of sugar.

Elwes suggested (Eng. Patent, No. 2189, 1875) passing the liquor in an upward direction, introducing fresh char continuously at the top of the cistern, and removing the used char also continuously at the bottom, and quite recently several very ingenious patents connected with a similar mode of working have been taken out by Matthiessen and also by Quimby.

Espeut, De Castro, and others have patented emptying and filling the cisterns by means of a current of water under pressure, and this method, so far as emptying is concerned, answers well enough if the char has only to pass through short straight pipes; but if the pipes are long, and especially if there are bends in them, they are certain to stop up and give much trouble. If this plan of emptying be used, the bottoms of the cisterns should taper towards the centre to the extent of the angle of repose of wet char, otherwise a considerable portion of their contents will have to be removed by hand.

In re-burning char, a high temperature, besides being a waste of fuel, causes serious injury to the char by contracting its pores, and so rendering it, in the course of time, less active.

Working char heated in an oil-bath to 550° F. for one hour had the same decolorising power as when re-burned in a pipe-kiln, and the same char heated in a bath of melted lead to a temperature of about 617° F. for one hour gave rather more decolorising power than similar char re-burned in the kiln. It has been shown by these and many other experiments that a very short and intimate contact with heat not exceeding 700° F. is all that is necessary to obtain good results. It is impossible to work at so low a heat in a pipe-kiln even of the best design and with the most careful management. The pipes in the kiln, even if they revolve, are sure to be unequally heated, the row nearest to the fire having to be heated to a much greater extent than the others, to make certain that the latter are raised to the required temperature. Owing to the difficulty experienced in evenly re-burning char, many plans have been suggested and patented for improving the mode of working. The use of superheated steam and various gases have been much recommended, and in some cases employed on a large scale. This method of applying heat possesses the advantage of equally heating the char; on the other hand, there is a danger, if the temperature is high, of a destruction of carbon by the action of the steam or gas. However, with care, the loss from this cause may be reduced to an insignificant amount.

As a rough means of ascertaining whether char leaving a kiln has been sufficiently re-burned, it is usual to boil a small portion with a solution of soda, which turns brown if, owing to the presence of organic matter, the carbonisation is not complete. Some refiners also employ a solution of acetate of lead in addition to soda, when, if a blackening takes place owing to the presence of a sulphide, they regard this as an indication of over-burning. The odour given off by insufficiently burned char as it leaves the coolers is also characteristic.

Improvement of working Char.—Under certain circumstances the carbonate of lime, carbon, iron, and other constituents, increase to such an extent during long use, as to render their reduction a matter of importance, and various means have been devised to attain this end. The treatment with dilute hydrochloric acid to convert the carbonate of lime into chloride of calcium is the ordinary mode adopted on the Continent in the beet-sugar factories, but this plan is open to the objection that a certain quantity of phosphate of lime is sure also to be decomposed, and that the framework of the char will consequently be injured. To obviate this to some extent, it has been proposed to exhaust the air previous to the introduction of the acid, so as to bring the latter instantaneously in contact with every particle of the char, and in this way equalise its action. To further overcome the difficulty, Beans used dry hydrochloric acid gas, which is said to have no action on phosphate of lime. Stenhouse and Duncan proposed to use dilute nitric acid in place of hydrochloric acid, and there is but little doubt that it possesses advantages over the latter. Cook has suggested treating the char with a solution of chloride of ammonium and then re-burning so as to produce carbonate of ammonia, which goes off, and chloride of calcium, which is afterwards dissolved out. Cook also patented the use of phosphoric acid to decompose the carbonate of lime. Patrick, Beans, and others have proposed to dissolve out the carbonate of lime by means of a saturated solution of carbonic acid. In English refineries the carbonate of lime in all cases, so far as can be ascertained, decreases during use, and this appears to be due to the employment of cane sugar, which is generally slightly acid. It has been proposed to reduce the carbon by re-burning the char after it has been saturated with a solution of nitrate of ammonia, but this does not appear to have been carried out on a large scale.

In those refineries where the carbon in the char is kept as nearly as possible at the same percentage as when new, or even less than this, the result is obtained in part by liberal washing, but it is chiefly due to the accidental introduction of air into the kiln pipes. This is evident from the fact that as there is a constant production of carbon going on from the carbonisation of the absorbed organic impurities which cannot be washed out, the total carbon must, of necessity, increase in the absence of atmospheric oxidation. The carbon destroyed in the kilns is partly derived from the char and partly from the organic impurities contained in it. Of the two evils it would seem that the loss of carbon is certainly more detrimental than the slight gradual increase which usually occurs when the washing is properly performed and the kilns are in good order. Instead of revivifying by carbonisation, it has been proposed (and, to some extent, carried into effect) by Eisfeld, and also by Phillips, to digest the char after use, in a solution of ammonia, potash, or soda, in water or alcohol, the ammonia and alcohol being recovered by distillation. In this way the colouring matters and a large portion of other organic and mineral matters taken up from the sugar can be removed. This process has been worked on the Continent, but only experimentally in this country.

Removal of iron.—Magnets have been used to remove the iron existing in the metallic state or as magnetic oxide, and a considerable amount can be withdrawn in this way. The plan of souring the char, as it is generally called, is often used as a means of improving the quality of old char. The method of working is as follows:—A cistern of char, from which the sugar is nearly removed by washing, is allowed to stand for some days to ferment, when the sugar is converted into acetic and other organic acids, which act upon the carbonate of lime and sulphide of calcium, and to some extent dissolve the iron also. The resulting soluble lime and iron salts are removed by washing, and the char on being re-burned, generally shows a marked improvement.

In revivifying char, a curious deposit or scale forms inside the kiln-pipes; this consists of sulphide of iron. The sulphur possibly is derived from the sulphurous acid in the flue gases which finds its way through the porous red-hot cast iron, and, meeting with the reducing gases given off from the charcoal, is reduced to sulphur, which combines with the iron in the interior surface of the pipe, the temperature of which is somewhat lower; or, as has been suggested, it may be formed from the sulphur existing as sulphide of calcium in the char.

CHAPTER XXIII.

SUGAR ANALYSIS.

THE complete analysis of raw sugar, or of cane or beet juice, is a problem of considerable difficulty, on account of the number of organic matters present, consisting of inverted sugar, colouring matters, waxy substances, and nitrogenous impurities, the accurate separation of which is all but impossible.

A large number of organic acids have been reported to be found in combination with the bases in raw sugars, molasses, &c. The principal of these, named in alphabetical order, are :—acetic, aspartic, apoglucic, butyric, citric, formic, glucic, humic, lactic, malic, melassic, metapectic, oxalic, pectic, succinic, tartaric, and ulmic. There are also certain alkaloids, especially betaine, peculiar to beet sugar ; certain nitrogenous matters, mainly albumen, legumin and ferments ; and certain non-nitrogenous organic matters, such as pectose, pectin, mannite, starch, colouring material, caramel, cellulose, gum, fat, and wax.

The salts present in raw sugar, molasses, &c., consist chiefly of potash and lime salts, and smaller proportions of the salts of soda, magnesia, and oxides of iron.

These bases may be present as salts of some of the organic acids already mentioned, but they also frequently occur in the form of sulphates, nitrates, phosphates, chlorides, carbonates, and silicates. The process of analysing a sample of cane or beet sugar, either raw or refined, will now be described, with one preliminary remark. The discrepancies which sometimes occur in the analysis of samples of sugar are due more to imperfect sampling than to errors in analysis. This is especially the case with low sugars of the jagghery class, which sometimes contain 10 per cent. of fragments of pottery and stones, and in many cases 7 to 10 per cent. of moisture. Great care must be taken to ensure thorough admixture of the sample before weighing out the quantities for analysis; it is also essential to keep the samples in well-closed bottles to prevent loss of moisture.

In analysing a sample of raw sugar it is usual to make direct determinations of the amount of each of the following constituents:—

1. Sugar, sometimes spoken of as cane sugar or crystallisable sugar.

2. Uncrystallisable sugar, including invert sugar and other bodies capable of acting upon the copper test, which are often put down under the name of "glucose."

3. Mineral matter, or ash. This again is sometimes divided into soluble and insoluble ash.

4. Moisture, or water.

The remaining constituents are usually classed together as "undetermined" or "unknown organic matters," and include various organic substances, such as organic acids, albuminous and colouring matters, &c. These are difficult to determine, and their correct determination is not considered of importance in valuing a sugar, so their amount is made up by difference, i. e. the percentage of sugar, glucose, ash, and moisture having been ascertained, whatever is wanting to make up the 100 is put down as "undetermined organic matters."

A simple mode will now be given for determining the amount of each of the important constituents in a sample of sugar.

Determination of Sugar.—Weigh 26·048 grams of sugar, and transfer it by means of a funnel and a little water, hot water by preference, to a 100 cc. flask. Enough water is next added to thoroughly dissolve the sugar, and then the flask is dipped into cold water, so as to bring its contents to the ordinary temperature of 60° F. On adding one or more cc. of solution of basic acetate of lead, many colouring matters and other impurities are precipitated. If the solution of raw sugar is light in colour, very little acetate of lead is required, but a good deal must be used to remove the colour from dark solutions. The correct amount can be easily hit upon after a little practice, and it is advisable to avoid an excess, or on subsequent filtration some of the oxide of lead remaining in solution may be precipitated as carbonate of lead by the action of the carbonic acid in the air, and the solution rendered turbid. It is sometimes desirable to add a little solution of sulphate of soda to remove any lead which would otherwise remain in solution. With raw beet sugars it is advisable to add very little basic acetate of lead, which may be advantageously followed by a drop or two of a solution of tannin. The addition of a small amount of well-washed hydrate of alumina will be found to improve the subsequent filtration. The contents of the flask are when cold made up to 100 cc. Should there be any froth on the surface, it may be removed by adding a few drops of alcohol just before making up to the mark on the neck of the flask. The contents of the flask, after having been well shaken, should be filtered through a dry filter into a glass cylinder or beaker, the first part passing through being returned to the filter. The 200 mm. tube of the polariscope is next taken, and thoroughly cleaned and dried. The screw-cap and glass plate having been removed from one end of the tube, the latter is next filled with the decolorised sugar solution. The glass plate and screw-cap should now be replaced, being careful not to screw down too much, which would strain the glass plate and affect the optical results. Instead of drying the tube, it may be rinsed out two two or three times with the solution to be tested. When a light is observed, by looking through the eye-piece of a polariscope, a circular disc is seen, divided vertically into two halves, which should have exactly the same tint when the zero on the fixed part of the scale coincides with that on the movable part. If a tube containing sugar or any other optically active substance be introduced into the polariscope, the equality of tint is disturbed, but by turning a small handle or milled head, placed below the front of the instrument, the two semi-discs may be made to assume one and the same tint. The percentage of sugar should then be read off on the scale, and by the aid of the vernier this can be easily done to a tenth of a per cent.

Determination of Glucose.—The glucose is estimated by Fehling's solution, which may conveniently be made in the following manner:—Some pure crystallised sulphate of copper, previously powdered and dried by pressing it between folds of filter paper, is got ready, and of this 34·639 grams are dissolved in 200 cc. of water. In a separate vessel 173 grams of pure crystallised Rochelle salt are dissolved in 480 cc. of a solution of pure hydrate of soda, having a specific gravity of 1·14. The first solution should now be gradually added to the second, which is previously placed in a litre flask, and the mixture should be agitated after each addition, sufficient water being finally added to make up to 1000 cc. The solution should then be well mixed and kept in a dark-blue stoppered bottle. This solution will not keep long, and on this account it is especially desirable that it should not be exposed to the light or air; but if the two solutions of which it is made up are kept separate, and mixed in the proper proportions shortly before use, they may be depended upon to remain unchanged for a considerable time. To standardise this copper test, take 2·375 grams of pure sugar, dissolve in water, and add a few drops of sulphuric acid, afterwards heating to 60° C. for a few minutes. The solution, when cold, should be neutralised with carbonate of soda, and lastly made up to 500 cc. 10 cc. of this solution contain 0·05 gram of invert sugar, and ought to entirely reduce an equal volume of the copper test. The amount of raw sugar to be taken in the determination of glucose may vary from 0·5 to 20 grams in 100 cc. The better plan is to make a comparatively rough preliminary trial with a moderately strong solution, and afterwards a more careful and exact test with a dilute solution. To get sharp results, it is desirable to use not less than 10 cc. or more than 50 cc. of sugar solution to decolorise 10 cc. of the copper test. It is of great importance that the sugar solution should be as colourless as possible, and then the exact point at which the blue colour of the copper test has been entirely removed is not difficult to ascertain. The copper test is measured out by a 10 cc. pipette, graduated into tenths of a cc. The sugar solution is placed in a 50 cc. burette, divided into tenths of a cc. In carrying out the process it is usual to measure 10 cc. of the copper test into a flask capable of holding about 200 cc., and then bring it to the boiling point, when, if the copper test be in good condition, there should be no red deposit formed. The flask is then removed for the moment from the source of heat, and 3 or 4 cc. of the sugar solution having been run in from the burette, the contents of the flask are made to boil. If any blue colour is left, more sugar solution must be added, a few cc. at a time, boiling after each addition, until at length the blue colour has quite vanished. The number of cc. used must then be read off, and from it the percentage of glucose may be found by a simple calculation. Thus, if 50 cc. of a solution containing 1 gram of sugar in 100 cc. are required to decolorise 10 cc. copper test, it implies that 0·5 gram of the sugar tested contains 0·05 gram of glucose, or that there is 10 per cent. of glucose in the sugar.

A doubt sometimes arises, when the sugar solution is not quite colourless, as to the exact point at which the blue colour vanishes and all the copper is thrown down. In such a case the red deposit is allowed to settle, and a few drops of the clear supernatant liquor are removed by a small pipette to a test tube, or a little may be filtered into the latter. The liquor is then made slightly acid with acetic acid, and a little solution of ferrocyanide of potassium is added, when a brown coloration, or precipitate, of ferrocyanide of copper will be produced if any copper is still present. In working with the copper test, when the copper has been completely thrown down, a slight addition of sugar solution will, on boiling, change the colour of the liquid to yellowish brown, owing to the action of the soda in the Fehling's test upon the glucose present in the raw sugar.

Beet sugars contain little, if any, glucose, and in testing them it is therefore expedient to operate upon a large quantity, say 20 or 25 grams in 100 cc., and to use only 2 or 3 cc. of the copper test. Some improved methods of determining small quantities of glucose in beet sugar will be described further on.

Determination of Glucose and Invert Sugar by the Gravimetric Method.—In working by this method it is usual to take about 25 cc. of Fehling's copper test in a 5 or 6 oz. beaker, dilute it with 50 cc. of boiling water which has been previously boiled for some time. The beaker should be heated by being placed in a vessel containing boiling water, and after a few minutes a known weight or measure of the solution to be tested (previously clarified and neutralised if requisite) is added, and the water in the outer vessel is boiled for about a quarter of an hour. The Fehling test should be in excess, which is indicated by the blue colour of the liquid, and if such is not the case more Fehling's test may be added to restore the blue colour; it is, however, preferable to make a fresh determination, using a smaller quantity of the solution to be tested. The precipitate is allowed to subside, the clear liquid is decanted through a filter, on which the precipitate is afterwards washed with well-boiled boiling water. It is then dried and strongly ignited in an open porcelain crucible for a few minutes, when the red precipitate of suboxide of copper first obtained is converted into black protoxide. To make sure that this conversion is complete, it is advisable to allow the crucible to cool and then to add a few drops of nitric acid, dry, and again ignite, finally weighing as soon as the crucible is cold. The weight of the protoxide of copper thus found, when multiplied by the factor 0·4535, gives the weight of glucose in the amount of sugar solution used.

Determination of Ash.—From 2 to 5 grams of sugar are weighed in a platinum dish, sufficient sulphuric acid is then added to thoroughly moisten the sugar, the mixture being meanwhile stirred with a platinum wire. When there is much moisture in the sugar, the action of the sulphuric acid is very energetic; dry sugar, on the other hand, should be slightly wetted before adding the acid, or should be heated for a few moments with the latter, so as to start the action. The mixture swells up very much, becoming carbonised, and giving off considerable amounts of steam and sulphurous acid. When all action has ceased, the dish should be heated over the flame of a Bunsen burner, or to low redness in a muffle. When there are no more black particles left, that is when the carbon has been entirely consumed, the dish is re-weighed, and its increase of weight gives the amount of sulphatic ash in the quantity of sugar taken.

By this mode of procedure, any carbonic acid, &c., which would have been present in the ash had no sulphuric acid been used, is expelled, and the bases are converted into sulphates, the ash being thereby rendered heavier, as the combining weight of sulphuric acid is greater than that of carbonic acid. To allow for this, it is customary to deduct one-tenth of its weight from the sulphatic ash, and the remainder is assumed to represent the ash contained in the weight of sugar taken for analysis.

Determination of Soluble Ash.—Should any insoluble matters, such as sand and clay, be present in the raw sugar the soluble ash must be ascertained, since it alone serves to hinder the crystallisation of the sugar. For this purpose, a solution of the raw sugar is made containing 10 grams in

100 cc., and this is passed through a dry filter, the first portion being returned to the filter. When a sufficient amount of clear liquor has passed through, 20 cc., equal to 2 grams of the raw sugar, are measured out with a pipette, and transferred to a platinum dish, in which it is evaporated to a pasty condition. It is then allowed to cool, and stirred up after moistening with sulphuric acid, and when the action is over it is incinerated until all the carbonaceous matter has been got rid of, and lastly weighed; one-tenth being deducted as before.

Determination of Insoluble Ash.—The insoluble ash may be obtained by deducting the soluble from the total ash. A more accurate mode, however, is to take 2 to 10 grams of the raw sugar in a beaker, and dissolve the sugar with hot water, allowing it to pass through a filter to which all the insoluble matter is transferred. The contents of the filter are then washed till the sugar is removed, and the filter is then dried, and incinerated in a platinum dish, the increase of weight giving the insoluble ash in the quantity of raw sugar taken.

Determination of Moisture.—Five grams are weighed out in a porcelain dish, and are then heated to 212° F. (100° C.), or a little higher temperature, till the weight is constant.

In operating with low sugars, or with molasses, a crust often forms on heating, and prevents the water from passing off. In such cases, a quantity of finely divided dry sand, several times the weight of the sugar, is placed in a porcelain dish, together with a small glass or platinum stirrer. The total weight of the dish, sand and stirrer is then taken, and 2 to 5 grams of the raw sugar or molasses are added thereto and well incorporated by stirring. The whole is then heated to 220° F., the contents being stirred from time to time. The escape of moisture may also be greatly facilitated by adding a little alcohol to the mixture of sand and sugar, stirring and then heating very gently at first, and afterwards when the alcohol has gone off more strongly, say to 220° F. This process may be advantageously repeated once or twice.

Statement of Results.—The results are usually stated under the following heads:—sugar, glucose, ash, moisture and undetermined organic matters, &c., the last item being made up by difference. Thus a sample of cane jagghery gave, on analysis, the subjoined results.

Sugar	79·00
Glucose	6·22
Soluble ash	3·11
Insoluble ash	0·69
Moisture	6·24
Undetermined organic matters	4·74
	100·00
Rendement, or net sugar	57·23

In order to calculate the rendement, or nett sugar, which should be obtained from a given sample of sugar or molasses, it is usual to assume that 1 part of glucose prevents 1 part of sugar from crystallising, and 1 part of soluble ash prevents 5 parts of sugar from crystallising. In accordance with this view, it is therefore only necessary to take the percentage of sugar and to deduct from it the amount of glucose and 5 times that of the soluble ash.

Determination of the Alkalinity of the Ash.—It is sometimes necessary to determine the amount of the carbonates of potash and soda present in the ash, and this may be readily done, without taking the trouble to make a complete analysis, in the following manner. The sugar is heated in a platinum dish without the addition of sulphuric acid, and calcined to a fairly grey ash. The residue is then boiled in water, and the whole is thrown on a filter, and washed two or three times. To the filtrate a few drops of carbonate of ammonia are added, and it is then evaporated to dryness in a platinum basin, and ignited at a low red heat. The contents of the basin are then washed into a flask, and after adding a little litmus, titrated with normal acid, and the results calculated out as carbonate of potash.

Special Processes.—Having dealt with the ordinary and recognised modes of sugar analysis, reference will now be made to certain methods which are used as subsidiary processes in some cases in commercial work, and in other cases only for the purpose of special tests in refineries or sugar factories.

Payen's Process.—The alcohol process which is often called Payen's process, consists in washing the sample on a filter with alcohol of 88 per cent. strength, which has already been saturated with cane sugar and slightly acidified with acetic acid. The washing alcohol, being already saturated with pure sugar, cannot dissolve any more of that substance; but it is capable of dissolving uncrystallisable sugar, and the salts occurring as impurities, while the acid which is present is sufficient in quantity to dissolve almost, if not quite, all the soluble matters which are insoluble in alcohol, and to decompose the sucrates. The test is carried out as follows. Three solutions are prepared, viz. (1) a mixture of absolute alcohol and ether, (2) 88 per cent. alcohol, to which has been added 50 cc. of acetic acid per litre, and which has been saturated with pure sugar (loaf sugar answers perfectly well), (3) 95 per cent. alcohol, also saturated in the same way with sugar. The sample to be tested is weighed and transferred to a small tube, similar to a chloride of calcium tube, but preferably longer. Solution No. 1 is then passed on to the sugar in quantity about equal to the bulk of the sugar itself, so as not only to remove the water, but to precipitate any cane sugar which may be in combination, or in solution in the water. If the raw sugar is too moist, it is desirable to dry it previously, so that it does not contain more than 4 to 5 per cent of moisture. The tube should be provided with a stopcock at the bottom, and the solvents should be allowed to remain in contact with the sugar for a sufficient time.

After 10 to 15 minutes, the liquid may be run off by opening the stopcock, and solution No. 2 added. The sample acted upon in this way will be practically freed from water, and the diluted acetic acid solution will dissolve out any lime-salts which may be present, and so free the sugar from mineral impurities naturally existing in it. This solution is withdrawn in the same way as No. 1, and solution No. 3

is then poured on, a second or third portion of this solution being used if necessary, until it ceases to take up anything more, and the sugar under treatment has become as white as possible. After this, it is necessary to draw air through the tube containing the sugar, in order to remove the alcohol, and the residue of the sample is emptied from the tube into a tared capsule, dried and weighed, or, if preferred, the crystals of sugar thus obtained may be dissolved in water made up to a definite volume, and polarised. This process appears a complicated one, and it is no doubt difficult of execution by those who are unused to it; but the opinion of some who have employed it is, that the residue thus obtained does really represent very closely the amount of crystallisable sugar which can be obtained by ordinary refining processes. The differences which occur in the execution of the analysis are mainly those due to alteration of temperature and possible changes in the strength of the solutions of sugar employed in washing. A rapid fall in temperature in the laboratory during the process of washing will render the results incorrect, owing to the deposition of sugar on the surface of the crystals of the sample treated.

Fermentation Process.—It is possible to determine the proportion of sugar in a given solution, by fermenting it in contact with yeast and noting the amount of one or both of the following products, viz.: (1) the alcohol produced, and (2) the carbonic acid given off. The mode of carrying out these operations will now be described.

(1) Cane sugar when fermented yields about 51 per cent. of alcohol. The solution of sugar should contain from 12 to 16 per cent. of sugar, and it is best to use not less than from 50 to 100 cc. This is placed in an apparatus similar to that used in analysing carbonates, and to it a small proportion of pressed fresh yeast (4 to 5 per cent.) is added, the contents of the flask being kept at a temperature of 22° to 25° C. (71·5° to 77° F.) until the fermentation has ceased, which will be in 3 to 4 days. The solution is then distilled to one-third

or so; the distillate is weighed and its density ascertained, and from this the amount of alcohol can be found by reference to a table. To get the corresponding amount of sugar, multiply the percentage of alcohol by 2·02 for glucose, or by 1·96 for cane sugar.

(2) The sugar solution is fermented in a similar way, the evolved carbonic acid passing through a tube containing calcium chloride so as to absorb any moisture. The process is continued as long as any gas is given off, and then a current of air previously dried and freed from carbonic acid is drawn through the apparatus. The difference between the weight of the apparatus before and after the fermentation gives the amount of carbonic acid evolved, and to convert this into glucose it is only necessary to multiply by 2·0454, and the result so obtained, when multiplied by 0·95, gives the corresponding weight of cane sugar.

The results obtained by the fermentation process are not always accurate, because secondary fermentation may take place attended with the formation of various bodies.

Determination of the Total Sugar by Fehling's Method.—Crystallisable sugar in dilute solution when heated with an acid is rapidly changed into invert sugar which is capable of reducing the copper test. The solution of sugar employed for this purpose must be highly dilute, containing only ½ or at the most 1 per cent. of sugar. Before making up to bulk add 1 or 2 cc. of hydrochloric acid, and heat to 212° F. for a quarter of an hour. Allow to cool; neutralise the acid by the addition of a solution of soda; make up to 100 cc. with water and well mix. Then proceed exactly as in the determination of glucose, and from the number of cc.'s required to precipitate 10 cc. of the copper test, the amount of sugar can be easily calculated. As 95 parts of crystallisable sugar yield on inversion 100 parts of invert sugar, 5 per cent. must be deducted from the result to obtain the correct percentage of the former. If a sample of sugar be tested with Fehling's test before and after inversion, the first result gives the glucose or invert sugar actually contained in it, and the second result includes the first plus the invert sugar produced by the process. Thus, by way of example, if the two results come out 5 per cent. before inversion and 86 after, it is necessary to deduct from the 86 the 5 per cent. of glucose normally present in the sample and then to deduct 5 per cent., or one-twentieth part, from the remaining 81, leaving 76·95, which is the percentage of crystallisable sugar.

Determination of Glucose in Beet Sugars.—When beet sugars contain glucose, its amount is usually so small that there is some difficulty in accurately determining it by the ordinary process, involving as it does, in such cases, the use of a very strong solution of the sugar, e. g. 25 grams in 100 cc., and a very small quantity of copper test, sometimes only 1 cc.

Several processes have been devised to overcome the difficulty, and the two best of these are those of J. W. Biggart and T. L. Patterson. The first-named chemist makes use of a standard solution of invert sugar of such strength that 1 cc. of it corresponds to ·001 gram of uncrystallisable sugar, or 25 cc. of it to 5 cc. of the copper test. To carry out this process, introduce 15 grams of the sugar to be examined into a 100 cc. flask with a small quantity of water; add 25 cc. of the standard invert sugar, and after dissolving the sugar make up to 100 cc. Well mix the solution, and having poured it into a burette, test its strength by using 5 cc. of copper test, and carry out the rest of the process just as in the ordinary mode of determining glucose. If the beet sugar tested contains no glucose, it will take 100 cc. of the solution to decolorise 5 cc. copper test, but, if glucose be present, a smaller number of cc. will suffice. From the number thus found the percentage of glucose in the beet sugar can be readily calculated.

Patterson's Process.—This process is one of backward titration, in which a measured volume of the copper test is boiled with a weighed quantity of the sugar under examination, and the unreduced oxide of copper determined by means of a standard solution of invert sugar (containing ·002 gram of invert sugar per cc.), the amount of which requisite to reduce 10 cc. of copper test is carefully determined. In carrying out this process, 10 grams of the beet sugar to be examined are placed in a 250-cc. flask; 40 cc. of water are added, and the sugar dissolved by a gentle heat; 10 cc. of the copper test are next added, and the contents of the flask boiled, when the uncrystallisable sugar or glucose present will reduce a portion of the oxide of copper. What remains is completely reduced by running into the flask from a burette a standard solution of invert sugar. It is evident that if the sugar under examination contained any glucose, a smaller number of cc. of standard invert sugar solution will be needed in this titration than was required in titrating the copper test when no sugar was added. It is then only necessary to deduct the former number from the latter to get the number of cc. of standard invert sugar solution, which contains the same amount of invert sugar as 10 grams of the sample. This difference × ·002 × 10, or × ·02, gives the percentage of glucose in the sugar taken. For example, 26 cc. of the standard invert sugar solution were required to reduce 10 cc. of copper test, but after the addition of 10 grams of a sample of beetroot sugar, only 21 cc. were needed to attain the same result. Therefore 26 − 21 = 5 cc. of invert sugar solution, and 5 × ·02 = ·10 per cent. of glucose in the sample. For a full account of the two processes just described see the 'Sugar Cane' for March, 1885.

Inversion. Clerget's Method.—It sometimes happens that samples of sugar and saccharine matter contain other substances which have an optical rotary effect in the polariscope, and in such cases it is necessary to employ the process of inversion. Solutions of cane sugar left in contact with air, especially when dilute, undergo inversion, and in presence of acids this process proceeds with much greater rapidity. In the latter case the rate of inversion is principally dependent upon the strength of the sugar solution, the amount and also the kind of acid used, the temperature to which the mixture is heated, and the time during which heat is applied.

For analytical purposes a solution of sugar is inverted in the following way:—A dry flask is taken with two marks on its neck, the lower one indicating 50 cc. and the upper one 55 cc. A portion of the sugar solution, which has already been prepared for the direct reading in the polariscope, is poured into the flask up to the 50 cc. mark. Enough strong hydrochloric acid is then added to reach the second mark at 55 cc. The flask is next heated in a sand or water bath until a thermometer placed in it marks a temperature of 68° C. (154° F.), and the liquid is then allowed to cool. If not quite clear, the liquid should be filtered, and it is then poured into a polariscope tube 220 mm. long, having a vertical side tube, through the top of which a thermometer is introduced in order that the exact temperature of the liquid may be carefully observed at the moment when the degree of strength is read off on the scale.

By turning the milled head or handle of the polariscope, the two semi-discs are brought to precisely the same tint, and the figure on the scale is then read off.

Two distinct readings are thus given by the polariscope, the first being obtained with the ordinary decolorised sugar solution, and the second with the same solution after the sugar in it has been completely inverted by warming with hydrochloric acid. It will be remembered that in carrying out the inversion process the volume of sugar solution is increased by one-tenth owing to the acid added, and to compensate for this partial dilution, the liquid, after inversion, is placed in a tube one-tenth longer than that ordinarily used, or 220 instead of 200 mm. in length. If the readings before and after inversion are both either to the right or left of the polariscope scale, the smaller is deducted from the greater to give the number of degrees or angle of rotation. If, however, after inversion, the right-handed rotation is changed to left, so that the two readings are right and left of zero, their sum is taken, and the percentage of cane sugar originally present is found by reference to Clerget's table.

CLERGET'S TABLES FOR THE ANALYSES OF SACCHARINE SUBSTANCES.

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.).																										Per cent. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B.
																											gram.
1·4	1·4	1·4	1·4	1·4	1·4	1·4	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1	1·64
2·8	2·8	2·8	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2	3·29
4·2	4·1	4·1	4·1	4 1	4·1	4·1	4·1	4·0	4·0	4·0	4·0	4·0	4·0	4·0	3·9	3·9	3·9	3·9	3·9	3·9	3·8	3·8	3·8	3·8	3·8	3	4·94
5·6	5·5	5·5	5·5	5·5	5·5	5·4	5·4	5·4	5·4	5·4	5·3	5·3	5·3	5·3	5·3	5·2	5·2	5·2	5·2	5·2	5·1	5·1	5·1	5·1	5·1	4	6·58
6·9	6·9	6·9	6·9	6·8	6·8	6·8	6·8	6·7	6·7	6·7	6·7	6·6	6·6	6·6	6·6	6·5	6·5	6·5	6·5	6·4	6·4	6·4	6·4	6·3	6·3	5	8·23
8·3	8·3	8·3	8·2	8·2	8·2	8·2	8·1	8·1	8·1	8·0	8·0	8·0	7·9	7·9	7·9	7·9	7·8	7·8	7·8	7·7	7·7	7·7	7·7	7·6	7·6	6	9·88
9·7	9·7	9·7	9·6	9·6	9·5	9·5	9·5	9·4	9·4	9·4	9·3	9 3	9·3	9·2	9·2	9·2	9·1	9.1	9·1	9·0	9·0	9·0	8·9	8·9	8·8	7	11·52
11·1	11·1	11·0	11·0	11·0	10·9	10·9	10·8	10·8	10·8	10·7	10·7	10·6	10·6	10·6	10·5	10·5	10·4	10·4	10·4	10·3	10·3	10·3	10·2	10·2	10·1	8	13·17
12·5	12·5	12·4	12·4	12·3	12·3	12·2	12·2	12·1	12·1	12·1	12·0	12·0	11·9	11·9	11·8	11·8	11·7	11·7	11·6	11·6	11·6	11·5	11·5	11·4	11·4	9	14·82
13·9	13·8	13·8	13·7	13·7	13·6	13·6	13·5	13·5	13·4	13·4	13·3	13·3	13·2	13·2	13·1	13·1	13·0	13·0	12·9	12·9	12·8	12·8	12·7	12·7	12·6	10	16·47
15·3	15·2	15·2	15·1	15·1	15·0	15·0	14·9	14·8	14·8	14·7	14·7	14·6	14·6	14·5	14·5	14·4	14·3	14·3	14·2	14·2	14·1	14·1	14·0	14·0	13·9	11	18·11
16·7	16 6	16·6	16·5	16·4	16·4	16·3	16·3	16·2	16·1	16·1	16·0	16·0	15·9	15·8	15·8	15·7	15·7	15·6	15·5	15·5	15·4	15·4	15·3	15·2	15·2	12	19·76
18·1	18·0	17·9	17·9	17·8	17·7	17·7	17·6	17·5	17·5	17·4	17·3	17·3	17·2	17·2	17·1	17·0	17·0	16·9	16·8	16·8	16·7	16·6	16·6	16·5	16·4	13	21·41
19·5	19·4	19·3	19·2	19·2	19·1	19·0	19·0	18·9	18·8	18·8	18·7	18·6	18·5	18·5	18·4	18·3	18·3	18·2	18·1	18·1	18·0	17·9	17·8	17·8	17·7	14	23·05
20·8	20·8	20·7	20·6	20·5	20·5	20·4	20·3	20·2	20·2	20·1	20·0	19·9	19·9	19·8	19·7	19·6	19·6	19·5	19·4	19·3	19·3	19·2	19·1	19·0	19·0	15	24·70
22·2	22·2	22·1	22·0	21·9	21·8	21·8	21·7	21·6	21·5	21·4	21·4	21·3	21·2	21·1	21·0	21·0	20·9	20·8	20·7	20 6	20·6	20·5	20·4	20·3	20·2	16	26·35
23·6	23·5	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	22·7	22·6	22·5	22·4	22·3	22·3	22·2	22·1	22·0	21·9	21·8	21·7	21·7	21·6	21·5	17	28·00
25·0	24·9	24·8	24·7	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	23·9	23·8	23·8	23·7	23·6	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	18	29·64
26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·5	25·4	25·3	25·2	25·1	25·0	24·9	24·8	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	19	31·29
27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26 9	26·8	26·7	26·6	26·5	26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·4	25·3	20	32·94
29·2	29·1	29·0	28·9	28·8	28·7	28·6	28·4	28·3	28·2	28·1	28·0	27·9	27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26·9	26·8	26·7	26·6	21	34·58
30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·6	29·5	29·4	29·3	29·1	29·0	28·9	28·8	28·7	28·6	28·5	28·4	28·3	28·2	28·0	27·9	27·8	22	36·23
32·0	31·8	31·7	31·6	31·5	31·4	31·3	31·2	31·0	30·9	30·8	30·7	30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·5	29·5	29·3	29·2	29·1	23	37·88
33·4	33·2	33·1	33·0	32·9	32·8	32·6	32·5	32·4	32·3	32·2	32·0	31·9	31·8	31·7	31·6	31·4	31·3	31·2	31·1	30·9	30·8	30·7	30·6	30·5	30·4	24	39·53
34·7	34·6	34·5	34·4	34·2	34·1	34·0	33·9	33·7	33·6	33·5	33·4	33·2	33·1	33·0	32·9	32·7	32·6	32·5	32·4	32·2	32·1	32·0	31·9	31·7	31·6	25	41·17
36·1	36·0	35·9	35·7	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·2	34·1	33·9	33·8	33·7	33·5	33·4	33·3	33·1	33·0	32·9	26	42·82
37·5	37·4	37·3	37·1	37·0	36·8	36·7	36·6	36·4	36·3	36·2	36·1	35·9	35·8	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·1	27	44·47
38·9	38·8	38·6	38·5	38·4	38·2	38·1	37·9	37·8	37·7	37·5	37·4	37·2	37·1	37·0	36·8	36·7	36·5	36·4	36·3	36·1	36·0	35·8	35·7	35·6	35·4	28	46·11
40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·9	38·7	38·6	38·4	38·3	38·1	38·0	37·8	37·7	37·5	37·4	37·3	37·1	37·0	36·8	36·7	29	47·76
41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·5	40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·8	38·7	38·5	38·4	38·2	38·1	37·9	30	49·41
43·1	42·9	42·8	42·6	42·5	42·3	42·2	42·0	41·8	41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·4	40·3	40·1	39·9	39·8	39·7	39·5	39·4	39·2	31	51·06
44·5	44·3	44·2	44·0	43·8	43·7	43·5	43·4	43·2	43·0	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·8	41·6	41·4	41·3	41·1	41·0	40·8	40·6	40·5	32	52·70
45·9	45·7	45·5	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·6	43·4	43·2	43·1	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·7	33	54·35

CLERGET'S TABLES FOR THE ANALYSES OF SACCHARINE SUBSTANCES—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.).

10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	Per cent. sought. By wt. A.	By vol. B.
																											gram.
47·3	47·1	46·9	46·7	46·6	46·4	46·2	46·1	45·9	45·7	45·6	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·5	43·3	43·2	43·0	34	56·00
48·6	48·5	48·3	48·1	47·9	47·8	47·6	47·4	47·2	47·1	46·9	46·7	46·5	46·4	46·2	46·0	45·8	45·7	45·5	45·3	45·1	45·0	44·8	44·6	44·4	44·3	35	57·64
50·0	49·9	49·7	49·5	49·3	49·1	49·0	48·8	48·6	48·4	48·2	48·1	47·9	47·7	47·5	47·3	47·2	47·0	46·8	46·6	46·4	46·3	46·1	45·9	45·7	45·5	36	59·29
51·4	51·2	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·8	49·6	49·4	49·2	49·0	48·8	48·6	48·5	48·3	48·1	47·9	47·7	47·5	47·4	47·2	47·0	46·8	37	60·94
52·8	52·6	52·4	52·2	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·2	50·0	49·8	49·6	49·4	49·2	49·0	48·8	48·7	48·4	48·3	48·1	38	62·58
54·2	54·0	53·8	53·6	51·4	53·2	53·0	52·8	52·6	52·4	52·3	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·7	49·5	49·3	39	64·23
55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·6	53·4	53·2	53·0	52·8	52·6	52·4	52·2	52·0	51·8	51·6	51·4	51·2	51·0	50·8	50·6	40	65·88
57·0	56·8	56·6	56·4	56·2	56·0	55·8	55·5	55·3	55·1	54·9	54·7	54·5	54·3	54·1	53·9	53·7	53·5	53·3	53·1	52·9	52·7	52·5	52·3	52·1	51·9	41	67·53
58·4	58·2	58·0	57·5	57·5	57·3	57·1	56·9	56·7	56·5	56·3	56·1	55·9	55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·5	53·3	53·1	42	99·17
59·8	59·5	59·3	59·1	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	55·5	55·2	55·0	54·8	54·6	54·4	43	70·82
61·2	60·9	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	59·0	58·7	58·5	58·3	58·1	57·9	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	44	72·47
62·5	62·3	62·1	61·9	61·6	61·4	61·2	61·0	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·1	56·9	45	74·11
63·9	63·7	63·5	63·2	63·0	62·8	62·6	62·3	62·1	61·9	61·6	61·4	61·2	60·9	60·7	60·5	60·3	60·0	59·8	59·6	59·3	59·1	58·9	58·6	58·4	58·2	46	75·76
65·3	65·1	64·9	64·6	64·4	64·1	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·3	62·0	61·8	61·6	61·3	61·1	60·9	60·6	60·4	60·2	59·9	59·7	59·4	47	77·41
66·7	66·5	66·2	66·0	65·8	65·5	65·3	65·0	64·8	64·6	64·3	64·1	63·8	63·6	63·4	63·1	62·9	62·6	62·4	62·2	61·9	61·7	61·4	61·2	61·0	60·7	48	79·06
68·1	67·9	67·6	67·4	67·1	66·9	66·6	66·4	66·1	65·9	65·7	65·4	65·2	64·9	64·7	64·4	64·2	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·2	62·0	49	80·70
69·5	69·2	69·0	68·7	68·5	68·2	68·0	67·7	67·5	67·2	67·0	66·7	66·5	66·2	66·0	65·7	65·5	65·2	65·0	64·7	64·5	64·2	64·0	63·7	63·5	63·2	50	82·35
70·9	70·6	70·4	70·1	69·9	69·6	69·4	69·1	68·8	68·6	68·3	68·1	67·8	67·6	67·3	67·1	66·8	66·5	66·3	66·0	65·8	65·5	65·3	65·0	64·8	64·5	51	84·00
72·3	72·0	71·8	71·5	71·2	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·9	67·6	67·3	67·1	66·8	66·6	66·3	66·0	65·8	52	85·64
73·7	73·4	73·1	72·9	72·6	72·3	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	70·0	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·8	67·6	67·3	67·0	53	87·29
75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·2	72·9	72·6	72·4	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·1	68·8	68·6	68·3	54	88·94
76·4	76·2	75·9	75·6	75·3	75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·1	72·9	72·6	72·3	72·0	71·8	71·5	71·2	70·9	70·7	70·4	70·1	69·8	69·6	55	90·59
77·8	77·6	77·3	77·0	76·7	76·3	76·2	75·9	75·6	75·3	75·0	74·8	74·5	74·2	73·9	73·6	73·4	73·1	72·8	72·5	72·2	72·0	71·7	71·4	71·1	70·8	56	92·23
79·2	79·0	78·7	78·4	78·1	77·8	77·5	77·2	76·9	76·7	76·4	76·1	75·8	75·5	75·2	74·9	74·7	74·4	74·1	73·8	73·5	73·2	73·0	72·7	72·4	72·1	57	93·88
80·6	80·3	80·0	79·7	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·6	76·3	76·0	75·7	75·4	75·1	74·8	74·5	74·2	73·9	73·7	73·4	58	95·53
82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·1	78·8	78·5	78·2	77·9	77·6	77·3	77·0	76·6	76·4	76·1	75·8	75·5	75·2	74·9	74·6	59	97·17
83·4	83·1	82·8	82·5	82·2	81·9	81·6	81·3	81·0	80·7	80·4	80·1	79·8	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·5	76·2	75·9	60	98·82
84·8	84·5	84·2	83·9	83·6	83·3	83·0	82·6	82·3	82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·0	78·7	78·4	78·1	77·8	77·5	77·2	61	100·47
86·2	85·9	85·6	85·2	84·9	84·6	84·3	84·0	83·7	83·4	83·1	82·8	82·5	82·1	81·8	81·5	81·2	80·9	80·6	80·3	80·0	79·7	79·4	79·0	78·7	78·4	62	102·12
87·6	87·2	86·9	86·5	86·3	86·0	85·7	85·4	85·0	84·7	84·4	84·1	83·8	83·5	83·2	82·8	82·5	82·2	81·9	81·6	81·3	80·9	80·6	80·3	80·0	79·7	63	103·76
89·0	88·6	88·3	88·0	87·7	87·4	87·0	86·7	86·4	86·1	85·8	85·4	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·6	82·2	81·9	81·6	81·3	81·0	64	105·41
90·3	90·0	89·7	89·4	89·0	88·7	88·4	88·1	87·7	87·4	87·1	86·8	86·4	86·1	85·8	85·5	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·5	82·2	65	107·06
91·7	91·4	91·1	90·7	90·4	90·1	89·8	89·4	89·1	88·8	88·4	88·1	87·8	87·7	87·1	86·8	86·5	86·1	85·8	85·5	85·1	84·8	84·5	84·1	83·8	83·5	66	108·70

CLERGET'S TABLES FOR THE ANALYSES OF SACCHARINE SUBSTANCES—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.).																										Per cent. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B.
																											gram.
93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·8	90·4	90·1	89·8	89·4	89.1	88·8	88·4	88·1	87·8	87·4	87·1	86·8	86·4	86 1	85·8	85·4	85·1	84·8	67	110·35
94·5	94·2	93·8	93·5	93·2	92·8	92·5	92·1	91·8	91·5	91·1	90·8	90·4	90·1	89·8	89·4	89·1	88·7	88·4	88·1	87·7	87·4	87·0	86.7	86·4	86·0	68	112·00
95·9	95·6	95·2	94·9	94·5	94·1	93·8	93 5	93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·7	90·4	90·0	89·7	89·3	89·0	88·7	88·3	88·0	87.6	87·3	69	113·64
97·3	96·9	96·6	96·2	95·9	95·5	95·2	94·8	94·5	94·1	93·8	93·4	93·1	92·7	92·4	92·0	91·7	91·3	91·0	90·6	90·3	89·9	89·6	89 2	88·9	88·5	70	115·29
98·7	98·3	98·0	97·6	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·8	94·4	94·1	93·7	93·4	93·0	92·6	92·3	91·9	91·6	91·2	90·9	90·5	90·2	89·8	71	116·94
100·1	99·7	99·4	99·0	98·6	98·3	97·9	97·9	97·2	96·8	96·5	96·1	95·8	95·4	95·0	94·7	94·3	94·0	93·6	93·2	92·9	92·5	92·2	91·8	91·4	91·1	72	118·59
101·5	101·1	100·7	100·4	100·0	99·6	99·3	98·9	98·5	98·2	97·8	97·4	97·1	96·7	96·4	96·0	95·6	95·3	94·9	94·5	94·2	93·8	93·4	93·1	92·7	92·3	73	120·23
102·9	102·5	102·1	101·7	101·4	101·0	100·6	100·3	99·9	99·5	99·2	98·8	98·4	98·0	97 7	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·7	94·3	94·0	93·6	74	121·88
104·2	103·9	103·5	103·1	102·7	102·4	102·0	101·6	101·2	100·9	100·5	100·1	99·7	99·4	99·0	98·6	98·2	97·9	97·5	97·1	96·7	96·4	96·0	95·6	95·2	94·9	75	123·53
105·6	105·3	104·9	104·5	104·1	103·7	103·4	103·0	102·6	102·2	101·8	101·5	101·1	100·7	100·3	99·9	99·6	99·2	98·8	98·4	98·0	97·7	97·3	96·9	96·5	96·1	76	125·17
107·0	106·6	106·3	105·9	105·5	105·1	104·7	104·3	103·9	103·6	103·2	102·8	102·4	102 0	101·6	101·2	100·9	100·5	100·1	99·7	99·3	98·9	98·6	98·2	97·8	97·4	77	126·82
108·4	108·0	107·6	107·2	106·9	106·5	106·1	105·7	105·3	104·9	104·5	104·1	103·7	103·3	103·0	102·6	102·2	101·8	101·4	101·0	100·7	100·2	99·8	99·4	99·1	98·7	78	128·47
109·8	109·4	109·0	108·6	108·2	107.8	107·4	107·0	106·6	106·2	105·9	105·5	105·1	104·7	104·3	103·9	103·5	103·1	102·7	102·3	101·9	101·5	101·1	100·7	100·3	99·9	79	130·12
111·2	110·8	110·4	110·0	109·6	109·2	108·8	108·4	108·0	107·6	107·2	106·8	106·4	106·0	105·6	105·2	104·8	104·4	104·0	103·6	103·2	102·8	102·4	102·0	101·6	101·2	80	131·76
112·6	112·2	111 8	111·4	111·0	110·6	110·2	109·7	109·3	108·9	108·5	108·1	107·7	107·3	106·9	106·5	106·1	105·7	105·3	104·9	104·6	104·1	103·7	103·2	102·9	102·5	81	133·41
114·0	113·6	113·2	112·7	112·3	111 9	111·5	111·1	110·7	110·3	109·9	109·5	109·1	108·6	108·2	107·8	107·4	107·0	106·6	106·2	105 9	105·4	105·0	104 5	104·1	103·7	82	135·06
115·4	114·9	114·5	114 1	113·7	113·1	112·9	112·5	112·0	111·6	111·2	110·8	110·4	110·0	109·6	109·1	108·9	108·3	107·9	107·5	107·2	106·6	106·2	105·8	105·4	105·0	83	136·70
116·8	116·3	115·9	115·5	115·1	114·7	114·2	113·8	113·4	113·0	112·6	112·1	111·7	111·3	110·9	110·5	110·0	109·6	109·2	108·8	108·5	107·9	107·5	107·1	106·6	106·3	84	138·35
118·1	117·7	117·3	116·9	116·4	116·0	115·6	115·2	114·7	114·3	113·9	113·5	113·0	112·6	112·2	111·8	111·3	110·9	110·5	110·1	109·7	109·2	108·8	108·4	107·9	107·5	85	140·00
119·5	119·1	118·7	118·2	117·8	117·4	117·0	116·5	116·1	115·7	115·2	114·8	114·4	113·9	113·5	113·1	112·7	112·2	111·8	111·4	111·0	110·5	110·1	109·6	109·2	108·8	86	141·65
120·9	120·5	120·1	119 6	119·2	118·7	118·3	117·9	117·4	117·0	116·6	116·1	115·7	115·3	114·8	114·4	114·0	113·5	113·1	112·7	112·3	111·8	111·4	110·9	110·5	110·0	87	143·29
122·3	121·9	121·4	121·0	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·2	115.7	115·3	114·8	114·4	114·0	113·6	113·1	112·6	112·2	111·8	111·3	88	144·94
123·7	123·2	122·8	122·4	121·9	121·5	120·9	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·1	115·7	115·2	114·9	114·4	113·9	113·5	113·0	112·6	89	146·59
125·1	124·6	124·2	123·7	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·8	118·3	117·6	117·4	117·0	116·5	116·2	115·6	115·2	114·7	114·3	113·9	90	148·23
126·5	126·0	125·6	125·1	124·7	124·2	123·8	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·7	118·3	117·8	117·5	116·9	116·5	116·0	115·6	115·1	91	149·86
127·9	127·4	127·0	126·5	126·0	125·6	125·1	124·7	124·2	123·7	123·3	122·8	122·4	121·9	121·4	121·0	120·3	120·1	119·6	119·1	118·8	118·2	117·8	117·3	116·8	116·4	92	151·53
129·3	128·8	128·3	127·9	127·4	126·9	126·5	126 0	125·5	125·1	124·6	124·1	123·7	123·2	122·8	122·3	121·8	121·4	120·9	120·4	120·1	119·5	119·0	118·6	118·1	117·6	93	153·18
130·7	130·2	129·7	129·2	128·8	128·3	127·8	127·4	126·9	126·4	126·0	125·5	125·9	124·5	124·1	123·6	123·1	122·7	122·2	121·7	121·4	120·8	120·3	119·8	119·4	118·9	94	154·82
132·0	131·6	131·1	130·6	130·1	129·7	129·2	128·7	128·2	127·8	127·3	126 8	126·3	125·9	125·4	124·9	124·4	124·0	123·5	123·0	122·6	122·1	121·6	121·1	120·6	120·2	95	156·47
133·4	133·0	132·5	132·0	131·5	131·0	130·6	130·1	129·6	129·1	128·6	128·2	127·7	127·2	126·7	126·2	125·8	125·3	124·8	124·3	123·9	123·4	122·9	122·4	121·9	121·4	96	158·12
134·8	134·3	133·9	133·4	132·9	132·4	131·9	131·4	130·9	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·1	126·6	126·1	125·6	125·2	124·6	124·2	123·7	123·6	122·7	97	159·76
136 2	135·7	135·2	134·7	134·3	133·8	133·3	132·8	132·3	131·8	131·3	130·8	130·3	129·8	129·4	128·9	128·4	127·9	127·4	126·9	126·5	125·9	125·4	124·9	124·5	124·0	98	161·41
137·6	137·1	136·6	136·1	135·6	135·1	134·6	134·1	133·6	133·1	132·7	132·2	131·3	131·2	130·7	130·2	129·7	129·2	128·7	128·2	127·8	127·2	126·7	126·2	125·7	125·2	99	163 06
139·0	138·5	138·0	137·5	137·0	136·5	136·0	135·5	135·0	134·5	134·0	133·5	133·0	132·5	132·0	131·5	131·0	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·0	126·5	100	164·71

To illustrate the use of this table by an example, let us suppose that the original sugar solution gave a polarisation of 75, and that after inversion it gave a reading of minus 21 at 12° C. The sum of 75 and 21 is 96, and on looking vertically down the table under the temperature 12° for the number which most nearly approaches 96, the figure found is 96·6, in a horizontal line with which, and in the last vertical column but one, marked A, will be seen the number 70, indicating that the raw sugar submitted to examination contained 70 per cent. of actual crystallisable sugar. On the same horizontal line, and in the last vertical column, marked B, will be seen the figure 115·29, indicating that a litre of the sugar solution operated upon contains 115·29 grams of pure sugar.

Mode of calculation without the use of the table.—It was found by Clerget that the normal solution used for the Soleil-Duboscq polariscope, containing 16·35 grams of sugar in 100 cc., and which read 100° in the polariscope, gave, after inversion, a reading of 44° to the left at 0° C., showing a difference in rotation of 144 produced by the inversion. The degree given in the polariscope after inversion varies to a considerable extent with the temperature—in fact, the deviation decreases by very nearly half a degree of the Soleil-Duboscq scale for each rise of 1° C. From the preceding data the following formula is deduced:—

$$144 - \tfrac{1}{2}T : 100 :: s : R$$
$$288 - T : 200 :: s : R,$$

whence

$$R = \frac{200\,s}{288 - T}.$$

In this formula s signifies the sum or difference of the readings in the polariscope before and after inversion (the sum being taken when the readings are in opposite directions, and the difference when in the same direction); T the temperature of the inverted solution when in the polariscope; and R the percentage of sugar sought.

Cane and Beet Juices.—In the ordinary average work of the factory, the percentage of sugar present in the juice being treated is determined mainly by means of the saccharometer, according to the following tables :—

TABLE SHOWING THE RELATION OF PERCENTAGES, SPECIFIC GRAVITIES, AND DEGREES BAUMÉ IN CANE-SUGAR SOLUTIONS.

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
0·0	1·0000	0·0	4·2	1·0165	2·3	8·4	1·0335	4·7	12·6	1·0510	7·0
·1	1·0003	0·06	·3	1·0169	2·4	·5	1·0339	4·7	·7	1·0514	7·05
·2	1·0007	0·11	·4	1·0173	2·4	·6	1·0343	4·8	·8	1·0519	7·1
·3	1·0011	0·17	·5	1·0177	2·5	·7	1·0347	4·8	·9	1·0523	7·2
·4	1·0015	0·22	·6	1·0181	2·6	·8	1·0351	4·9	13·0	1·0527	7 2
·5	1·0019	0·28	·7	1·0185	2·6	·9	1·0355	4·9	·1	1·0531	7·3
·6	1·0023	0·33	·8	1·0189	2·7	9·0	1·0359	5·0	·2	1·0536	7·3
·7	1·0027	0·39	·9	1·0193	2·7	·1	1·0364	5·05	·3	1·0540	7·4
·8	1·0031	0·44	5·0	1·0197	2.8	·2	1·0368	5·1	·4	1·0544	7·4
·9	1·0034	0·5	·1	1·0201	2·8	·3	1·0372	5·2	·5	1·0548	7·5
1·0	1·0038	0·55	·2	1·0205	2·9	·4	1·0376	5·2	·6	1·0553	7·5
·1	1·0042	0·6	·3	1·0209	2·9	·5	1·0380	5·3	·7	1·0557	7·6
·2	1·0046	0·7	·4	1·0213	3·0	·6	1·0384	5·3	·8	1·0561	7·65
·3	1·0050	0·7	·5	1·0217	3·0	·7	1·0388	5·4	·9	1·0566	7·7
·4	1·0054	0·8	·6	1·0221	3·1	·8	1·0393	5·4	14·0	1·0570	7·8
·5	1·0058	0·8	·7	1·0225	3·2	·9	1·0397	5·5	·1	1·0574	7·8
·6	1·0062	0·9	·8	1·0229	3·2	10·0	1·0401	5·55	·2	1·0578	7·9
·7	1·0066	0·9	·9	1·0233	3·3	·1	1·0405	5·6	·3	1·0583	7·9
·8	1·0070	1·0	6·0	1·0237	3·3	·2	1·0409	5·7	·4	1·0587	8·0
·9	1·0074	1·05	·1	1·0241	3·4	·3	1·0413	5·7	·5	1·0591	8·0
2·0	1·0077	1·1	·2	1·0245	3·4	·4	1·0418	5·8	·6	1·0596	8·1
·1	1·0081	1·2	·3	1·0249	3·5	·5	1·0422	5·8	·7	1·0600	8·15
·2	1·0085	1·2	·4	1·0253	3·6	·6	1·0426	5·9	·8	1·0604	8·2
·3	1·0089	1·3	·5	1·0257	3·6	·7	1·0430	5·9	·9	1·0609	8·3
·4	1·0093	1·3	·6	1·0261	3·7	·8	1·0434	6·0	15·0	1·0613	8·3
·5	1·0097	1·4	·7	1·0265	3·7	·9	1·0439	6·05	·1	1·0617	8·4
·6	1·0101	1·4	·8	1·0269	3·8	11·0	1·0443	6·1	·2	1·0621	8·4
·7	1·0105	1·5	·9	1·0273	3·8	·1	1·0447	6·2	·3	1·0626	8·5
·8	1·0109	1·55	7·0	1·0277	3·9	·2	1·0451	6·2	·4	1·0630	8·5
·9	1·0113	1·6	·1	1·0281	3·9	·3	1·0455	6·3	·5	1·0634	8·6
3·0	1·0117	1·7	·2	1·0286	4·0	·4	1·0459	6·3	·6	1·0639	8·65
·1	1·0121	1·7	·3	1·0290	4·1	·5	1·0464	6·4	·7	1·0643	8·7
·2	1·0125	1·8	·4	1·0294	4·1	·6	1·0468	6·4	·8	1·0647	8·8
·3	1·0129	1·8	·5	1·0298	4·2	·7	1·0472	6·5	·9	1·0652	8·8
·4	1·0133	1·9	·6	1·0302	4·2	·8	1·0476	6·55	16·0	1·0656	8·9
·5	1·0137	1·9	·7	1·0306	4·3	·9	1·0481	6·6	·1	1·0660	8·9
·6	1·0141	2·0	·8	1·0310	4·3	12·0	1·0485	6·7	·2	1·0665	9·0
·7	1·0145	2·0	·9	1·0314	4·4	·1	1·0489	6·7	·3	1·0669	9·0
·8	1·0149	2·1	8·0	1·0318	4·4	·2	1·0493	6·8	·4	1·0674	9·1
·9	1·0153	2·2	·1	1·0322	4·5	·3	1·0497	6·8	·5	1·0678	9·1
4·0	1·0157	2·2	·2	1·0327	4·55	·4	1·0502	6·9	·6	1·0682	9·2
·1	1·0161	2·3	·3	1·0331	4·6	·5	1·0506	6·9	·7	1·0687	9·25

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
16·8	1·0691	9·3	21·8	1·0914	12·05	26·8	1·1144	14·8	31·8	1·1383	17·5
·9	1·0695	9·4	·9	1·0918	12·1	·9	1·1149	14·8	·9	1·1388	17·55
17·0	1·0700	9·4	22·0	1·0923	12·2	27·0	1·1154	14·9	32·0	1·1393	17·6
·1	1·0704	9·5	·1	1·0927	12·2	·1	1·1158	14·9	·1	1·1398	17·7
·2	1·0709	9·5	·2	1·0932	12·3	·2	1·1163	15·0	·2	1·1403	17·7
·3	1·0713	9·6	·3	1·0936	12·3	·3	1·1168	15·1	·3	1·1408	17·8
·4	1·0717	9·6	·4	1·0941	12·4	·4	1·1172	15·1	·4	1·1412	17·8
·5	1·0722	9·7	·5	1·0945	12·4	·5	1·1177	15·2	·5	1·1417	17·9
·6	1·0726	9·75	·6	1·0950	12·5	·6	1·1182	15·2	·6	1·1422	17·9
·7	1·0730	9·8	·7	1·0954	12·55	·7	1·1187	15·3	·7	1·1427	18·0
·8	1·0735	9·9	·8	1·0959	12·6	·8	1·1191	15·3	·8	1·1432	18·0
·9	1·0739	9·9	·9	1·0964	12·7	·9	1·1196	15·4	·9	1·1437	18·1
18·0	1·0744	10·0	23·0	1·0968	12·7	28·0	1·1201	15·4	33·0	1·1442	18·15
·1	1·0748	10·0	·1	1·0973	12·8	·1	1·1206	15·5	·1	1·1447	18·2
·2	1·0753	10·1	·2	1·0977	12·8	·2	1·1210	15·55	·2	1·1452	18·25
·3	1·0757	10·1	·3	1·0982	12·9	·3	1·1215	15·6	·3	1·1457	18·3
·4	1·0761	10·2	·4	1·0986	12·9	·4	1·1220	15·7	·4	1·1462	18·4
·5	1·0766	10·2	·5	1·0991	13·0	·5	1·1225	15·7	·5	1·1466	18·4
·6	1·0770	10·3	·6	1·0996	13·0	·6	1·1229	15·8	·6	1·1471	18·5
·7	1·0775	10·35	·7	1·1000	13·1	·7	1·1234	15·8	·7	1·1476	18·5
·8	1·0779	10·4	·8	1·1005	13·15	·8	1·1239	15·9	·8	1·1481	18·6
·9	1·0783	10·5	·9	1·1009	13·2	·9	1·1244	15·9	·9	1·1486	18·6
19·0	1·0788	10·5	24·0	1·1014	13·3	29·0	1·1248	16·0	34·0	1·1491	18·7
·1	1·0792	10·6	·1	1·1019	13·3	·1	1·1253	16·0	·1	1·1496	18·7
·2	1·0797	10·6	·2	1·1023	13·4	·2	1·1258	16·1	·2	1·1501	18·8
·3	1·0801	10·7	·3	1·1028	13·4	·3	1·1263	16·1	·3	1·1506	18·85
·4	1·0806	10·7	·4	1·1032	13·5	·4	1·1267	16·2	·4	1·1511	18·9
·5	1·0810	10·8	·5	1·1037	13·5	·5	1·1272	16·25	·5	1·1516	18·95
·6	1·0815	10·85	·6	1·1042	13·6	·6	1·1277	16·3	·6	1·1521	19·0
·7	1·0819	10·9	·7	1·1046	13·6	·7	1·1282	16·4	·7	1·1526	19 1
·8	1·0824	11·0	·8	1·1051	13·7	·8	1·1287	16·4	·8	1·1531	19·1
·9	1·0828	11·0	·9	1·1056	13·7	·9	1·1291	16·5	·9	1·1536	19·2
20·0	1·0832	11·1	25·0	1·1060	13·75	30·0	1·1296	16·5	35·0	1·1541	19·2
·1	1·0837	11·1	·1	1·1065	13·8	·1	1·1301	16·6	·1	1·1540	19·3
·2	1·0841	11·2	·2	1·1070	13·9	·2	1·1306	16·6	·2	1·1551	19·3
·3	1·0846	11·2	·3	1·1074	14·0	·3	1·1311	16·7	·3	1·1556	19·4
·4	1·0850	11·3	·4	1·1079	14·0	·4	1·1315	16·7	·4	1·1561	19·4
·5	1·0855	11·3	·5	1 1083	14·1	·5	1·1320	16 8	·5	1·1566	19·5
·6	1·0859	11·4	·6	1·1088	14·1	·6	1·1325	16·85	·6	1·1571	19·55
·7	1·0864	11·45	·7	1·1093	14·2	·7	1·1330	16·9	·7	1·1576	19·6
·8	1·0868	11·5	·8	1·1097	14·2	·8	1·1335	17·0	·8	1·1581	19·65
·9	1·0873	11·6	·9	1·1102	14·3	·9	1·1340	17·0	·9	1·1586	19·7
21·0	1·0877	11·6	26·0	1·1107	14·35	31·0	1·1344	17·1	36·0	1·1591	19·8
·1	1·0882	11·7	·1	1·1111	14·4	·1	1·1349	17·1	·1	1·1596	19·8
·2	1·0886	11·7	·2	1·1116	14·5	·2	1·1354	17·2	·2	1·1601	19·9
·3	1·0891	11·8	·3	1·1121	14·5	·3	1·1359	17·2	·3	1·1606	19·9
·4	1·0895	11·8	·4	1 1125	14·6	·4	1·1364	17·3	·4	1·1611	20·0
·5	1·0900	11·9	·5	1·1130	14·6	·5	1·1369	17·3	·5	1·1616	20·0
·6	1·0904	11·95	·6	1·1135	14·7	·6	1·1374	17·4	·6	1·1621	20·1
·7	1·0909	12·0	·7	1·1140	14·7	·7	1·1378	17·4	·7	1·1626	20·1

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
36·8	1·1631	20·2	41·8	1·1887	22·9	46·8	1·2153	25·5	51·8	1·2427	28·1
·9	1·1636	20·2	·9	1·1892	22·9	·9	1·2158	25·6	·9	1·2433	28·2
37·0	1·1641	20·3	42·0	1·1898	23·0	47·0	1·2163	25·6	52·0	1·2439	28·2
·1	1·1646	20·35	·1	1·1903	23·0	·1	1·2169	25·7	·1	1·2444	28·3
·2	1·1651	20·4	·2	1·1908	23·1	·2	1·2174	25·7	·2	1·2450	28·3
·3	1·1656	20·5	·3	1·1913	23·1	·3	1·2180	25·8	·3	1·2455	28·4
·4	1·1661	20·5	·4	1·1919	23·2	·4	1·2185	25·8	·4	1·2461	28·4
5	1·1666	20·6	·5	1·1924	23·2	·5	1·2191	25·9	·5	1·2467	28·5
·6	1·1671	20·6	·6	1·1929	23·3	·6	1·2196	25·9	·6	1·2472	28·5
·7	1·1676	20·7	·7	1·1934	23·3	·7	1·2201	26·0	·7	1·2478	28·6
·8	1·1681	20·7	·8	1·1940	23·4	·8	1·2207	26·0	·8	1·2483	28·65
·9	1·1686	20·8	·9	1·1945	23·45	·9	1·2212	26·1	·9	1·2489	28·7
38·0	1·1692	20·8	43·0	1·1950	23·5	48·0	1·2218	26·1	53·0	1·2495	28·75
·1	1·1697	20·9	·1	1·1955	23·55	·1	1·2223	26·2	·1	1·2500	28·8
·2	1·1702	20·9	·2	1·1961	23·6	·2	1·2229	26·2	·2	1·2506	28·85
·3	1·1707	21·0	·3	1·1966	23·7	·3	1·2234	26·3	·3	1·2512	28·9
·4	1·1712	21·05	·4	1·1971	23·7	·4	1·2240	26·35	·4	1·2517	28·9
·5	1·1717	21·1	·5	1·1976	23·8	·5	1·2245	26·4	·5	1·2523	29·0
·6	1·1722	21·15	·6	1·1982	23·8	·6	1·2250	26·45	·6	1·2529	29·1
·7	1·1727	21·2	·7	1·1987	23·9	·7	1·2256	26·5	·7	1·2534	29·1
·8	1·1732	21·3	·8	1·1992	23·9	·8	1·2261	26·6	·8	1·2540	29·2
·9	1·1737	21·3	·9	1·1998	24·0	·9	1·2267	26·6	·9	1·2546	29·2
39·0	1·1743	21·4	44·0	1·2003	24·0	49·0	1·2272	26·7	54·0	1·2551	29·3
·1	1·1748	21·4	·1	1·2008	24·1	·1	1·2278	26·7	·1	1·2557	29 3
·2	1·1753	21·5	·2	1·2013	24·1	·2	1·2283	26·8	·2	1·2563	29·4
·3	1·1758	21·5	·3	1·2019	24·2	·3	1·2289	26·8	·3	1·2568	29·4
·4	1·1763	21·6	·4	1·2024	24·2	·4	1·2294	26·9	·4	1·2574	29·5
·5	1·1768	21·6	·5	1·2029	24·3	·5	1·2300	26·9	·5	1·2580	29·5
·6	1·1773	21·7	·6	1·2035	24·35	·6	1·2305	27·0	·6	1·2585	29·6
·7	1·1778	21·7	·7	1·2040	24·4	·7	1·2311	27·0	·7	1·2591	29·6
·8	1·1784	21·8	·8	1·2045	24·45	·8	1·2316	27·1	·8	1·2597	29·7
·9	1·1789	21·85	·9	1·2051	24·5	·9	1·2322	27·1	·9	1·2602	29·7
40·0	1·1794	21·9	45·0	1·2056	24·6	50·0	1·2327	27·2	55·0	1·2608	29·8
·1	1·1799	22·0	·1	1·2061	24·6	·1	1·2333	27·2	·1	1·2614	29·8
·2	1·1804	22·0	·2	1·2067	24·7	·2	1·2338	27·3	·2	1·2620	29·9
·3	1·1809	22·1	·3	1·2072	24·7	·3	1·2344	27·3	·3	1·2625	29·9
·4	1·1815	22·1	·4	1·2077	24·8	·4	1·2349	27·4	·4	1·2631	30·0
·5	1·1820	22·2	·5	1·2083	24·8	·5	1·2355	27·45	·5	1·2637	30·05
·6	1·1825	22·2	·6	1·2088	24·9	·6	1·2361	27·5	·6	1·2642	30·1
·7	1·1830	22·3	·7	1·2093	24·9	·7	1·2366	27·55	·7	1·2648	30·15
·8	1·1835	22·3	·8	1·2099	25·0	·8	1·2372	27·6	·8	1·1654	30·2
·9	1·1840	22·4	·9	1·2104	25·0	·9	1·2377	27·7	·9	1·2660	30·25
41·0	1·1746	22·4	46·0	1·2110	25·1	51·0	1·2383	27·7	56·0	1·2665	30·3
·1	1·1851	22·5	·1	1·2115	25·1	·1	1·2388	27·8	·1	1·2671	30·4
·2	1·1856	22·5	·2	1·2120	25·2	·2	1·2394	27·8	·2	1·2677	30·4
·3	1·1861	22·6	·3	1·2126	25·2	·3	1·2399	27·9	·3	1·2683	30·5
·4	1·1866	22·65	·4	1·2131	25·3	·4	1·2405	27·9	·4	1·2688	30·5
·5	1·1872	22·7	·5	1·2136	25·35	·5	1·2411	28·0	·5	1·2694	30·6
·6	1·1877	22·75	·6	1·2142	25·4	·6	1·2416	28·0	·6	1·2700	30·6
·7	1·1882	22·8	·7	1·2147	25·45	·7	1·2422	28·1	·7	1·2706	30·7

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
56·8	1·2712	30·7	61·8	1·3005	33·3	66·8	1·3309	35·8	71·8	1·3623	38·2
·9	1·2717	30·8	·9	1·3011	33·3	·9	1·3315	35·8	·9	1·3629	38·3
57·0	1·2723	30·8	62·0	1·3017	33·4	67·0	1·3322	35·9	72·0	1·3635	38·3
·1	1·2729	30·9	·1	1·3023	33·4	·1	1·3327	35·9	·1	1·3642	38·4
·2	1·2735	30·9	·2	1·3029	33·5	·2	1·3334	36·0	·2	1·3648	38·4
·3	1·2740	31·0	·3	1·3035	33·5	·3	1·3340	36·0	·3	1·3655	38·5
·4	1·2746	31·0	·4	1·2041	33·6	·4	1·3346	36·1	·4	1·3661	38·5
·5	1·2752	31·1	·5	1·3047	33·6	·5	1·3352	36·1	·5	1·3667	38·6
·6	1·2758	31·1	·6	1·3053	33·7	·6	1·3359	36·2	·6	1·3674	38·6
·7	1·2764	31·2	·7	1·3059	33·7	·7	1·3365	36·2	·7	1·3680	38·7
·8	1·2769	31·2	·8	1·3065	33·8	·8	1·3371	36·3	·8	1·3687	38·7
·9	1·2775	31·3	·9	1·3071	33·8	·9	1·3377	36·3	·9	1·3693	38·8
58·0	1·2781	31·3	63·0	1·3077	33·9	68·0	1·3384	36·4	73·0	1·3699	38·8
·1	1·2787	31·4	·1	1·3083	33·9	·1	1·3390	36·4	·1	1·3705	38·9
·2	1·2793	31·4	·2	1·3085	34·0	·2	1·3396	36·5	·2	1·3712	38·9
·3	1·2799	31·5	·3	1·3095	34·0	·3	1·3402	36·5	·3	1·3719	39·0
·4	1·2804	31·5	·4	1·3101	34·1	·4	1·3408	36·6	·4	1·3725	39·0
·5	1·2810	31·6	·5	1·3107	34·1	·5	1·3415	36·6	·5	1·3732	39·1
·6	1·2816	31·6	·6	1·3113	34·2	·6	1·3421	36·7	·6	1·3738	39·1
·7	1·2822	31·7	·7	1·3119	34·2	·7	1·3427	36·7	·7	1·3745	39·2
·8	1·2828	31·7	·8	1·3126	34·3	·8	1·3433	36·8	·8	1·3751	39·2
·9	1·2834	31·8	·9	1·3132	34·3	·9	1·3440	36·8	·9	1·3757	39·3
59·0	1·2840	31·85	64·0	1·3138	34·4	69·0	1·3446	36·9	74·0	1·3764	39·3
·1	1·2845	31·9	·1	1·3144	34·4	·1	1·3452	36·9	·1	1·3770	39·4
·2	1·2851	31·95	·2	1·3150	34·5	·2	1·3458	37·0	·2	1·3777	39·4
·3	1·2857	32·0	·3	1·3156	34·5	·3	1·3465	37·0	·3	1·3783	39·5
·4	1·2863	32·05	·4	1·3162	34·6	·4	1·3471	37·1	·4	1·3790	39·5
·5	1·2869	32·1	·5	1·3168	34·6	·5	1·3477	37·1	·5	1·3796	39·6
·6	1·2875	32·15	·6	1·3174	34·7	·6	1·3484	37·2	·6	1·3803	39·6
·7	1·2881	32·2	·7	1·3180	34·7	·7	1·3490	37·2	·7	1·3809	39·7
·8	1·2887	32·3	·8	1·3186	34·8	·8	1·3496	37·3	·8	1·3816	39·7
·9	1·2893	32·3	·9	1·3192	34·8	·9	1·3502	37·3	·9	1·3822	39·8
60·0	1·2898	32·4	65·0	1·3198	34·9	70·0	1·3509	37·4	75·0	1·3828	39·8
·1	1·2904	32·4	·1	1·3205	34·95	·1	1·3515	37·4	·1	1·3835	39·9
·2	1·2910	32·5	·2	1·3211	35·0	·2	1·3521	37·5	·2	1·3842	39·9
·3	1·2916	32·5	·3	1·3217	35·05	·3	1·3528	37·5	·3	1 3848	40·0
·4	1·2922	32·6	·4	1·3223	35·1	·4	1·3534	37·6	·4	1·3855	40·0
·5	1·2928	32·6	·5	1·3229	35·15	·5	1·3540	37·6	·5	1·3861	40·1
·6	1·2934	32·7	·6	1·3235	35·2	·6	1·3546	37·7	·6	1·3868	40·1
·7	1·2940	32·7	·7	1·3241	35·25	·7	1·3553	37·7	·7	1·3874	40·2
·8	1·2946	32·8	·8	1·3247	35·3	·8	1·3559	37·8	·8	1·3880	40·2
·9	1·2952	32·8	·9	1·3253	35·35	·9	1·3565	37·8	·9	1·3887	40·3
61·0	1·2958	32·9	66·0	1·3260	35·4	71·0	1·3572	37·9	76·0	1·3894	40·3
·1	1·2964	32·9	·1	1·3266	35·4	·1	1·3578	37·9	·1	1·3900	40·4
·2	1·2970	33·0	·2	1·3272	35·5	·2	1·3585	38·0	·2	1·3907	40·4
·3	1·2975	33·0	·3	1·3278	35·5	·3	1·3591	38·0	·3	1·3913	40·5
·4	1·2981	33·1	·4	1·3285	35·6	·4	1·3597	38·1	·4	1·3920	40·5
·5	1·2987	33·1	·5	1·3291	35·6	·5	1·3604	38·1	·5	1·3926	40·6
·6	1·2993	33·2	·6	1·3297	35·7	·6	1·3610	38·2	·6	1·3933	40·6
·7	1·2999	33·2	·7	1·3303	35·7	·7	1·3616	38·2	·7	1·3940	40·7

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree B·umé.	Per cent. of Sugar.	Specific Gravity.	Degree Beumé.	Per cent. of Sugar.	Specific Gravity.	Degrees Baumé.
76·8	1·3946	40·7	79·2	1·4105	41·9	81·5	1·4259	43·0	83 8	1·4416	44·1
·9	1·3953	40·8	·3	1·4112	41·9	·6	1·4266	43·0	·9	1·4423	44·1
77·0	1·3959	40·8	·4	1·4119	42·0	·7	1·4273	43·1	84·0	1·4430	44·2
·1	1·3966	40·8	·5	1·4125	42·0	·8	1·4280	43 1	·1	1·4437	44 2
·2	1·3972	40·9	·6	1·4132	42·1	·9	1·4287	43·2	·2	1·4443	44·3
·3	1·3979	41·0	·7	1·4138	42·1	82·0	1·4293	43·2	·3	1·4450	44·3
·4	1·3986	41·0	·8	1·4145	42·2	·1	1·4300	43·3	·4	1·4457	44·3
·5	1·3992	41·0	·9	1·4152	42·2	·2	1·4307	43·3	·5	1·4464	44·4
·6	1·3999	41·1	80·0	1·4158	42·2	·3	1·4314	43·4	·6	1·4471	44·4
·7	1·4005	41·1	·1	1·4165	42·3	·4	1·4320	43·4	·7	1·4478	44·5
·8	1·4012	41·2	·2	1·4172	42·3	·5	1·4327	43·5	·8	1·4485	44·5
·9	1·4019	41·2	·3	1·4179	42·4	·6	1·4334	43·5	·9	1·4492	44·6
78·0	1·4025	41·3	·4	1·4185	42·4	·7	1·4341	43·5	85·0	1·4498	44·6
·1	1·4032	41·3	·5	1·4192	42·5	·8	1·4348	43·6	·1	1·4505	44·7
·2	1·4039	41·4	·6	1·4199	42·5	·9	1·4354	43·6	·2	1·4512	44·7
·3	1·4045	41·4	·7	1·4205	42·6	83·0	1·4361	43·7	·3	1·4519	44·8
·4	1·4052	41·5	·8	1·4212	42·6	·1	1·4368	43·7	·4	1·4526	44·8
·5	1·4058	41·5	·9	1·4219	52·7	·2	1·4375	43·8	·5	1·4533	44·9
·6	1·4065	41·6	81·0	1·4226	42·7	·3	1·4382	43·8	·6	1·4540	44·9
·7	1·4072	41·6	·1	1·4232	42·8	·4	1·4388	43·9	·7	1·4547	45·0
·8	1 4078	41·7	·2	1·4239	42·8	·5	1·4395	43·9	·8	1·4554	45·0
·9	1·4085	41·7	·3	1·4246	42·9	·6	1·4402	44·0	·9	1·4561	45·1
79·0	1·4092	41·8	·4	1·4253	42·9	·7	1·4409	44·0	86·0	1·4568	45·1
·1	1·4098	41·8									

The preceding table gives the proportions of sugar present in the juice as indicated by the specific gravity or the degrees B. of the solution. The B. degrees are more frequently used in sugar-factories than the actual specific gravity, and this table gives the data for the comparison between the two. In either case, the specific gravity or B. may be determined by the specific-gravity bottle or the hydrometer spindle; and if the usual precautions are taken, the results are directly comparable. The use of the specific-gravity bottle is of course the more correct method of the two.

Determination of Sugar in Beetroot.—The roots are cleaned from any adhering earthy matter; the green portion at the top being carefully trimmed off. If an average result is desired, it is best to cut the roots in half from top to bottom, and then to similarly divide one of the halves, so as to get a quarter of each root. These are reduced to pulp by a rasp, and a portion of the well-mixed pulp is then folded in a cloth and pressed in a tincture press, the resulting juice being taken for analysis. 52·096 grams of the juice are weighed and transferred to a 100 cc. flask, a solution of basic acetate of lead being added in quantity sufficient to precipitate the colouring matters and various other impurities. The bulk is then made up to the 100 cc. mark on the neck of the flask and the whole well mixed. The contents of the flask are then filtered, the clear liquor introduced into the 200 mm. tube of the polariscope, and the figure read off. The result must be halved, since twice the normal weight was taken, and it then indicates the percentage of sugar in the juice. By deducting one-twentieth from this (since the roots are considered to contain 5 per cent. of insoluble dry matter) the percentage of sugar in the roots is obtained.

Another method of determining the sugar in beetroot is to take a known weight, say 200 grams, of the well mixed pulp, to fold this in a cloth and press it in a tincture press. The nearly exhausted pulp is next mixed with a little water and again pressed, these operations being repeated twice or thrice. To the mixture of juice and washings sufficient water is added to make up to 400 grams, or double the weight of the pulp taken. The percentage of sugar in this dilute juice is determined in the same way as in the ordinary juice, and the reading in the polariscope gives, without further calculation, the percentage in the pulp or roots, the doubling of weight of the latter being compensated by double the normal weight having been taken for analysis.

Sugar-cane Analysis.—A correct estimation of the amount of sugar obtainable from sugar-canes is more difficult than in the case of beetroots; the best plan to be pursued is as follows:—Obtain a true sample of the canes of about 4 to 6 lb. in weight, drawn in such a way as to obtain a fair proportion of the joints in the canes, so as to faithfully represent the entire canes. Slice the pieces longitudinally with a sharp knife, making at least 3 or 4 cuts, so as to divide them into slips not more than $\frac{1}{8}$ to $\frac{3}{8}$ inch in thickness. Pass these slips between the rollers of a hand-roller press provided with a tray underneath and a spout to carry away the liquid which is pressed out. After passing the slips through twice, increasing the pressure on the second occasion, dip them into hot water for a few seconds, so as to moisten them, and pass again through the press 2 or 3 times, still increasing the pressure each time. When this has been done, the liquid pressed out is in a state fit for analysis, and this may be carried through at once on the liquid, calculations being made on the original material, i. e. the sugar-cane put in the press.

Determination of Sugar. Optical Methods. Polarised Light.—The following account of the nature of polarised light and of the polariscope, is taken, by special permission, from the admirably clear and highly interesting paper on the 'Polariscope and its Applications,' by J. Heron, recently read before the Society of Chemical Industry.

If we examine an ordinary ray of light, emitted from any source whatever, we shall find that it exhibits the self-same properties on all sides—it is capable of being reflected or refracted in any position whatever; but if we subject this ray to certain conditions, we shall then find that it is possible to restrict its vibrations to some one particular direction, and such a ray is said to be polarised.

Light may be polarised in either of the following ways:—

1. By reflection from the surface of transparent media.
2. By ordinary refraction.
3. By double refraction.

It is with the last of these methods that we have most particularly to deal.

It is well known that certain crystals have the property, when a ray of light passes through them, of splitting up that ray into two others of equal intensity. Such a phenomenon is known as double refraction, and such crystals are said to be double refracting. In every such crystal there is at least one direction in which no such splitting up of the ray takes place, and this direction is called the optic axis of the crystal. Iceland spar exhibits this phenomenon in a notable manner. In a crystal of Iceland spar the line joining the points where the three obtuse angles meet is the principal or optic axis, and any ray of light transmitted through the crystal in a direction parallel to this axis is not divided. If, however, the crystal be tilted out of this position, the emergent ray is found to be separated into two. The angular divergence of the two rays depends upon the angle through which the crystal has been turned; when this angle amounts to a right angle the separation is at its greatest; and if the crystal be still further turned, the two rays begin to come together again, until, when it has turned through another right angle, they coincide. On examination by a method which we shall refer to presently, it will be found that both of these rays are completely polarised, the plane of polarisation of one being parallel to the principal section of the crystal, that is to say, to a plane passing through the optic axis and the direction in which the ray traverses the crystal, the other in a plane at right angles to that section. The first of these rays follows the ordinary law of refraction, and is called the ordinary ray; but the other ray, which is polarised at right angles to the principal section, follows different laws of refraction, and is termed the extraordinary ray. For polariscopic purposes it is best to give exit to only one of these polarised rays, that, namely, which is parallel with the incident ray, and to throw the other completely out of the field of view. This can be done in various ways, but best by means of what is known as a Nicol's prism. For this purpose a rhombohedron of Iceland spar, double its natural length, Fig. 212, of which *a, b, c, d,* Fig. 213, represents a section, is taken, and the terminal faces *a b* and *c d,* which naturally make an angle of 71° with the sides *a d* and *b c,* as at *a c*, are cut obliquely, so as to give the new faces an inclination of 68° to these edges. The whole block is then divided into two by a cut in the direction *d b*, and at right angles to

FIG. 212.

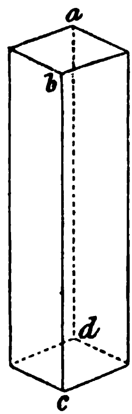
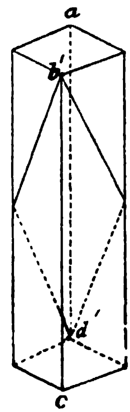


FIG. 213.



Iceland Spar.

the new face *a b'*. The faces of this cut are then carefully polished and cemented together again in their original position with Canada balsam. Such an arrangement is called a Nicol's prism, as shown in Fig. 214.

If now a ray of light, *l m*, parallel to the edges of the longer side, fall on the face *a b'*, it is split up into two rays, both of which are polarised, but at right angles to each other. The less refracted or extraordinary ray *m p q* traverses the film of balsam at *p*, and emerges in the direction *q s* parallel to *l m*. The more refracted or ordinary ray, *m o*, meets the balsam at *o*, which, from its being a medium of so much feebler refractive power, causes *total reflection* of the ray in the direction *o r*, whereby it becomes absorbed by the case of the prism. The other ray emerges in the direction of the incident one, but possesses only half its luminous power.

The plane of polarisation of this ray (or the plane in which it vibrates) is at right angles to the principal section, and therefore passes through the longer diagonals of the end faces of the prism.

In order to study the behaviour of a polarised ray we have to make use of a second Nicol's prism so placed that its

FIG. 214.

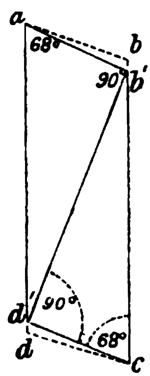
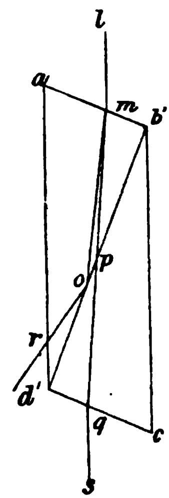


FIG. 215.



Nicol's Prism.

principal axis is in a line with that of the first. Two such prisms, when thus used together, are respectively called the polariser and the analyser.

In Figs. 216 and 217 such a combination is shown. In the first case both prisms are arranged so that the plane of polarisation *a' a' n* of the analyser A is parallel with the plane of polarisation *a a m* of the polariser P, and also the principal section *b b m* and *b' b' n* of the two prisms are brought into the same direction. The ray *m* which enters P as ordinary light and emerges polarised at *n* is not decomposed on passing through A, it is merely refracted in the direction of an extraordinary ray *m p q*, Fig. 215, and emerges so at the opposite end of the analyser.

The same happens if the latter be turned through an angle of 180°, so as to bring the planes again parallel. If, now, the analyser be turned round so that its plane of polarisation, instead of being parallel, is at right angles to that of the polariser, as is seen in Fig. 217, then the ray, after passing

FIG. 216.

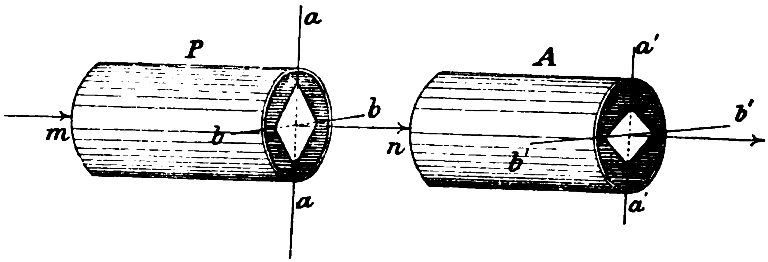
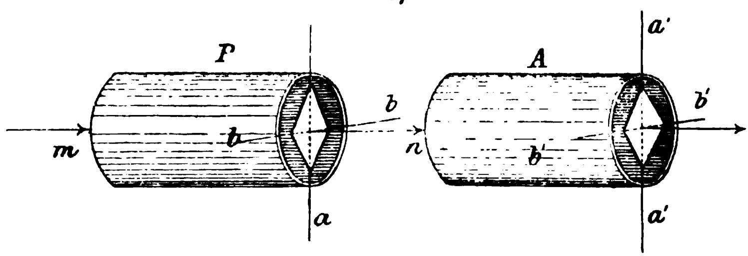


FIG. 217.



Polariser and Analyser.

through P, when it enters A, will take the direction of the ordinary ray, as represented by *m o r*, Fig. 215, and is eliminated by the film of balsam. No light leaves the analyser, and hence the field of vision appears dark. The same thing happens at a distance of 180°. At all intermediate positions between these two, that is when the two Nicol's are neither parallel nor at right angles to each other, polarised light, as it enters the analyser, is separated into an ordinary and an extraordinary ray, varying in intensity with the angle at which the planes of polarisation of the two prisms are inclined to each other, and we get the field of vision more or less illuminated.

These phenomena will be more fully understood if we throw upon a screen, by means of a polarising apparatus, a beam of monochromatic light, such as is furnished by placing a bead of common salt in the flame of a Bunsen burner. Now, suppose that the two Nicol's are crossed as before, so that no light is transmitted by the analyser. If, then, a plate of quartz be interposed, a red light makes its appearance on the screen ; and to render the field again dark, it is necessary to turn the analyser through a certain angle either to the right or to the left. Hence it follows that the ray which has traversed the quartz must have had its plane of vibration deflected through an angle equal to that through which the analyser has been turned. The angle through which the analyser has to be turned to bring a recurrence of darkness in the field of vision, and which can be read off on the graduated rim of the disc, is called the angle of rotation, and is the measure of the deflection experienced by the plane of polarisation.

Precisely similar effects are produced with yellow, green, violet, or any other kind of homogeneous light, but the angle of rotation varies according to the nature of the ray, being least for red and greatest for violet light, as shown in the following table :—

ROTATION PRODUCED BY QUARTZ PLATES FOR DIFFERENT RAYS.

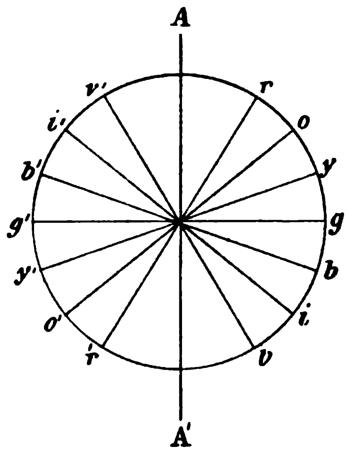
	Plate, 1 mm.	Plate, 3·75 mm.
Medium red	15°	56·4°
,, orange	19°	71·2°
,, yellow	24°	90·0°
,, green	27°	101·2°
,, blue	32°	120·0°
,, indigo	38°	142·5°
,, violet	44°	165·0°

Some crystals of quartz rotate the plane of polarisation to the right, others to the left: the former are called right-handed quartz, the latter left-handed. But in whatever direction the rotation takes place, a plate of quartz of given thickness always produces the same amount of angular deviation for a ray of given refrangibility, and for plates of different thicknesses the deviation for any particular ray increases in direct proportion to the thickness.

This rotation of the plane of vibration or of polarisation is called circular polarisation, and substances which exhibit this power are said to be circular polarising or optically active, and are also distinguished as right rotating or left rotating, whilst those substances which have not this power are said to be inactive. Thus, for instance, if instead of the quartz plate we interpose a tube filled with a solution of cane sugar, it will be found that the ray of light is rotated to the right, whilst the same ray is rotated to the left by a solution of invert sugar. Now, if instead of causing a beam of monochromatic light to pass, we employ white light, as from an ordinary Argand lamp, a system of coloured rings will be observed—red, yellow, green, blue, &c., according to the thickness of the plate. On turning the analyser on its axis the colours in the centre go through the regular prismatic series from red to violet, or the contrary, according to the direction of rotation, but no alteration of colour is produced by rotating the plate of quartz while the analyser remains stationary.

Now let us see how this can be explained. Suppose a beam of white light, polarised by a Nicol's prism, whose principal section is parallel to A A′, Fig. 218, to pass through a plate of right-handed quartz 3·75 mm. thick, the vibrations of the several coloured rays composing the beam of polarised light are all at first parallel to A A′, but by passing through the quartz their planes of vibration are deflected through the several angles given in the above table, the red ray then vibrating in the line $r\,r'$, the yellow in $y\,y'$. Now let the ray be viewed through another Nicol's prism placed with its principal section also parallel to A A′; then on resolving each of these vibrations into two others, one parallel and the other perpendicular to A A′, it will be seen that the red and violet rays will be transmitted with but slightly diminished intensity, the orange and blue with less, the yellow still less, and the green not at all. The result will therefore be a purple tint. Now

FIG. 218.



Nicol's Prism.

let the eye-piece be turned from left to right as the principal section passes successively over the lines *r r′*, *o o′*, &c., the red, orange, yellow, &c., will in succession be more fully transmitted than the other rays, so that a series of tints will be produced, agreeing nearly with colours of the spectrum, and following in the same order from red through yellow to violet. If the analyser be turned the contrary way the order of the tints will be reversed. If the quartz were left-handed the phenomena would be precisely similar, excepting that the colours would change from red through yellow to violet when the analyser was turned from right to left.

The tint produced with a quartz plate 3·75 mm. thick when the principal sections of the polariser and analyser are parallel to one another deserves particular notice. As already observed, it is a purple, and moreover it changes very quickly to red or to violet when the analyser is turned one way or the other, the change of colour thus produced being, in fact, very much more rapid and decided than in any other part of the circuit: this particular tint is accordingly distinguished by the term "transition tint." And in measuring the rotation produced by various substances this is often taken as the standard instead of the darkened disc used with monochromatic light. It is therefore evident that the rotative power of substances can be measured in two ways, either by means of monochromatic light, taking as our zero a field of either maximum or minimum illumination, or by means of ordinary light with aid of quartz plate interposed, using the transition tint for zero.

Instruments of various forms have been devised for observing and measuring this rotative power, and have hence been termed Polariscopes or Polarimeters.

The simplest of all forms of polariscope consists of two Nicol's prisms, enclosed in brass tubes and fixed one at each end of a metallic bar, along which they may be made to slide to and fro. The polariser is contained in a brass tube, and is made to turn on its axis if required, being fixed in any desired position by means of a small screw. The tube containing the analyser is also capable of rotating on its axis, and has an arm attached to it, as well as a pointer, which measures off the amount of rotation upon a fixed graduated circle of brass. The graduation of this circle is in degrees and tenths, from 0° to 360°. The observation tube, which may be made of brass or of stout glass, with brass fittings, is designed to hold the saccharine solution under examination, and is closed at each end by a screw cap having a small circular hole in its centre. Glass discs are placed between the caps and the ground ends of the tube, and washers of cork or india-rubber between the glass plates and caps, so that when the tube is filled with liquid and the whole screwed up, a tight-fitting joint is made at each end. In using an instrument of this kind it will be found best to employ a monochromatic yellow light, such as that furnished by a sodium flame ; but this form of instrument is now comparatively little used, if at all, being replaced by much more accurate forms of polarising apparatus.

HALF-SHADE INSTRUMENTS.

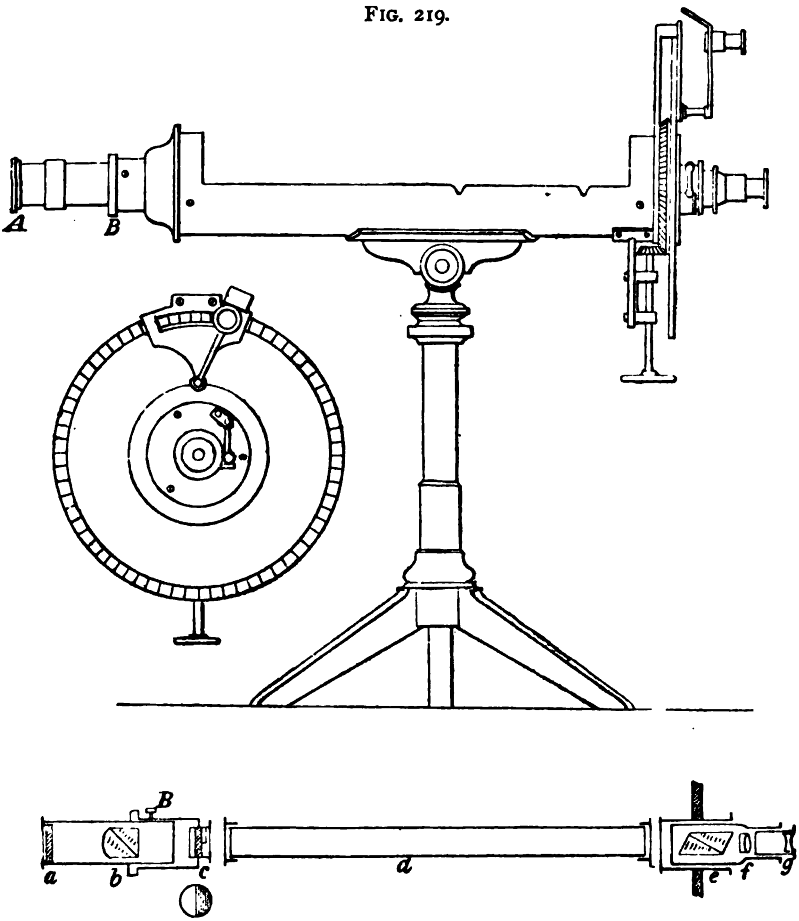
The distinguishing characteristic of this class of polarimeters is that, for a certain position of the optical parts, the field of vision appears divided into halves, the one being very bright and the other very dark, whilst, for another position, the whole field exhibits a uniform greyish shadow, without any trace of vertical line. Monochromatic sodium light is used with such instruments.

The earliest instrument of this kind was constructed by Jellett in 1860. Other forms have been devised by Cornu and Duboscq, but the one in most general use is that of Laurent.

Fig. 219 shows the principle of construction of this instrument. *a* is a plate of bichromate of potassium, or a glass cell filled with a concentrated solution of the same, and which serves to cut off any green, blue, or violet rays, thus rendering the light more fully monochromatic. *b*, the polariser, is a calc spar prism ; the face of the prism towards *a* is ground convex, so that light may emerge approximately parallel. These two parts are placed in the movable brass tube *a b*, which may be kept in any desired position by means of the screw-stop B. *c* is a circular diaphragm covered by a plate of glass, to which is cemented a thin plate of quartz, cut parallel to its axis, in such a manner that only one-half of the circular aperture is covered by it. *d* is the solution tube, *e* the analysing Nicol, and *f* and *g* the lenses of a small telescope.

The theory of this polarimeter is as follows:—If the plane of polarisation of the transmitted ray of light is parallel to the axis of the quartz plate, that is, lies in the direction A B, Fig. 220, the two halves of the field of vision will then appear equally dark or equally bright in every position of the analyser. But if the *polariser* be inclined to A B at an angle *a*, the plane of polarisation of the rays passing through the quartz plate will undergo deviation through an angle *a'* in the opposite

FIG. 219.



Laurent's Polariscope.

direction. Therefore, when, in the uncovered half, the plane of polarisation has the direction A C, in the covered half it will have the direction A C'. If now we turn the *analyser* until its ***principal section is perpendicular to that of the polariser,*** there will be ***a total extinction of the light to the right,*** but only partial to the left (Fig. 221). On the contrary, if the principal section of the ***analyser is perpendicular to that which corresponds***

FIG. 220.

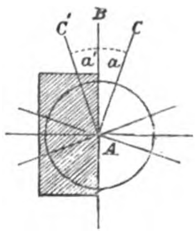


FIG. 221.

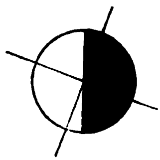


FIG. 222.

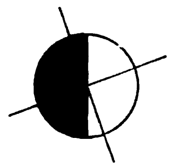
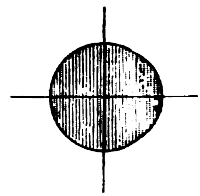


FIG. 223.



Laurent's Polariscope.

to the quartz plate, then there will be ***total extinction to the left*** and partial to the right (Fig. 222). If, finally, the principal section of the analyser is intermediate in position, that is neither perpendicular to the axis of the crystal or parallel to it, there will be partial extinction both to the right and left, and of equal intensity, so that the two halves of the luminous disc constituting the field of the instrument will appear uniformly in shadow (Fig. 223), but a very slight movement of the analyser one way or the other will at once destroy this uniformity. The same phenomena are apparent when the analyser has moved through 180°.

TRANSITION TINT INSTRUMENTS.

The transition tint instruments are specially constructed for determining the percentages of sugar in solutions of known density.

The earliest form of these instruments is known as the Soleil Saccharimeter; this has been much improved by Duboscq, and in its present form is called the Soleil-Duboscq Saccharimeter.

The optical principles of the transition tint instruments are based upon the following facts :—

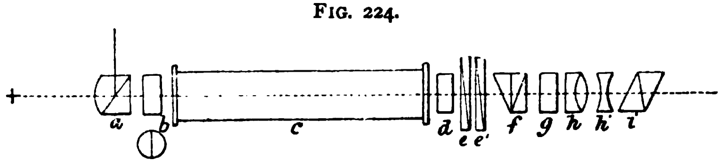
1. That when a polarised ray is transmitted through several media possessing rotatory power in different directions, their separate activities may become partially or wholly neutralised according to the lengths of the media.

2. That the rotatory dispersion of cane sugar is the same as that of quartz.

This latter fact is generally taken for granted by the Continental chemists, but English observers find that there is a slight difference between the dispersion of quartz and that of cane sugar, and quite sufficient to make an appreciable difference in the results of analysis.

In Fig. 224 is shown the apparatus :—*a* is the polariser, consisting of a calc spar prism; *b* is a plate of quartz called the plate of double rotation or bi-quartz, and is composed of

FIG. 224.



Soleil-Duboscq Saccharimeter.

two halves of equal thickness cut perpendicularly to the axis of crystallisation, and joined together so that the line of junction is vertical. These half discs have different rotations, the one being left-handed and the other right-handed. *c* is the solution tube; *d* is a quartz plate either right- or left-handed, and of a certain thickness; *e e'* are two wedge-shaped quartz plates, both having the same kind of rotation, but different to that of *d*. These plates are each fixed in a brass frame, and by means of a rack and pinion, are made to slide over one another, so that their combined thickness may be made either equal to, greater, or less than that of *d*. The distance moved to effect any particular adjustment is shown by a graduated scale attached to the brass frame. *f* is the analyser, which may consist of an achromatised calc spar prism; its principal section must be arranged parallel to that of the polariser *a*, when the thickness of the bi-quartz *b* is 3·75 millimetres, and perpendicular thereto when the thickness is 7·5 millimetres.

Soleil introduced an extra Nicol prism, shown at *i*, and a plate of quartz, *g*, ground perpendicular to the axis, fixed in a movable case, and which may be turned at will through an angle of 180°. This arrangement is called the regulator, and is used for the purpose of counteracting, to a certain extent, the influence of the coloration in the liquids subjected to examination, and to restore the sensitive tint, which would otherwise be destroyed when using such coloured liquids. *h h'* is a small Galilean telescope.

In order to understand the action of the several parts, let us first consider that light is passing through the polariser and analyser only. These are arranged with their principal sections parallel so that the field is at its maximum of illumination. Now let the active bi-quartz *b* be interposed between *a* and *f*; the white light coming from *a* will be rotated and decomposed into its component coloured rays. Of these emergent rays those whose plane of polarisation is at right angles to that of the analyser will not be transmitted, and should these be the yellow rays, the remainder will in transmission combine to a pale lilac tint, which, with the slightest alteration of the plane of polarisation, passes into pure red or pure blue. This intermediate colour is the transition tint.

If now we put the combination *d e e'*, known as the rotation compensator, in its place, the quartz wedges *e e'* being so adjusted that their combined thickness is exactly equal to that of the plate *d*, as the rotatory powers of *d* and *e e'* act in exactly opposite directions they neutralise each other and the sensitive tint still prevails. This position of the wedges corresponds with the zero point of the scale. If now a tube containing a solution, say, of cane sugar, be interposed, the uniformity of colour between the two half discs is immediately destroyed, appearing differently coloured, green and blue predominating in one, red and orange in the other; by sliding the quartz wedges so as to produce rotation opposite to that of the solution, a position may be found where the action of the latter is neutralised, and this will be indicated when the halves of the field of vision again exhibit uniformly the sensitive tint.

This action of the compensator shows not only whether the solution of the substance examined is right or left rotating, but also the degree as measured by the thickness of quartz necessary to neutralise the deviation of the body examined. The latter is measured by means of a graduated scale fixed to one of the slides, while upon the other is a mark serving as an indicator.

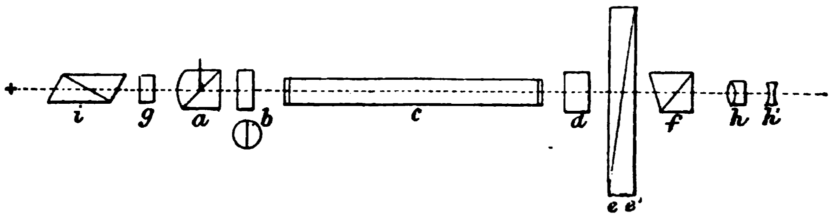
The Soleil-Ventzke-Scheibler saccharimeter, in the principles of its construction, is identically the same as the Soleil-Duboscq, but the mechanical parts have been greatly improved and the optical arrangement slightly altered.

These alterations were made in Germany by Ventzke, who introduced a different scale, the mechanical improvements being made by Scheibler. The various parts as shown in section, Fig. 225, are lettered respectively the same as the Soleil-Duboscq, so that the description there given will apply equally to the Ventzke.

For further particulars on the subject the reader is referred to Mr. J. Heron's paper, 'Journ. Soc. Chem. Indus.,' April 30 1888.

In addition to the polariscopes above described, attention must be called to a half-shadow instrument constructed by Schmidt and Haensch of Berlin, whose English agent is W. Halse, of 16, Mark Lane, London. This polariscope is similar in many respects to the Soleil-Ventzke-Scheibler, but differs from it mainly by the introduction of a shadow Nicol prism of peculiar construction. It is worked with ordinary white light, and thus does away with the trouble of the sodium

FIG. 225.



Soleil-Ventzke-Scheibler Saccharimeter.

flame, and it is capable of being employed with solutions of a somewhat dark colour. It is quite as delicate as any other form of polariscope, and can be successfully used by persons who, owing to colour-blindness, are incapable of making correct observations in the transition-tint instruments.

Specific Rotatory Power.—The peculiar tint called the "transition" tint (*teint de passage*) is produced when a ray of light is caused to pass through a quartz plate 3·75 mm. thick. The tint is perhaps best described as rose-purple of a somewhat delicate character, but it is easily altered by the slightest movement in the position of the analyser. To most persons who are not colour-blind this is a most delicate colour for detecting changes in the shades of tint produced by polarisation.

The mode in which the specific rotatory power of liquids is measured is somewhat peculiar. It follows from what has been said that the rotation is directly proportionate to the length of the column of liquid through which the ray passes, and is also proportional, sometimes directly and sometimes indirectly, to the quantity of active substance dissolved in the liquid. If e be the amount of substance dissolved in a unit of weight of the solution, l the length of the liquid column, and a the observed angle of rotation for any particular column, at the transition tint, the angle of rotation for the unit of length will be $\frac{a}{el}$; but as the solution of the optically active body is often attended with alteration of volume, it is desirable, in order to obtain an expression independent of such irregularities, to refer the observed angle of deviation to a hypothetical unit of density—that is, to divide the quantity $\frac{a}{el}$ by the density g of the solution. The expression $[a]j = \frac{a}{elg}$ is called the specific rotatory power, and represents the angle of deviation which the pure substance in a column of the unit of length and density 1 would impart to the ray corresponding to the transition tint. For instance, a solution containing 0·155 grm. of cane sugar to 1 grm. of liquid has a sp. gr. of 1·06, and deflects the polarised ray for the transition tint 24° in a tube 20 mm. long. The specific rotatory power is therefore

$$[a]j = \frac{24}{\cdot 155 \times 20 \times 1\cdot 06} = 7\cdot 30^\circ.$$

[a] is the expression for the specific rotatory power in general; a letter affixed shows the particular ray of the spectrum at which the deviation was observed, thus [a] D and [a] j are the expressions for the line D of the spectrum, and for the mean yellow ray or transition tint respectively. The minus sign is prefixed to the degree when the substance rotates to the left.

The following table, compiled by J. Heron, gives the specific rotatory powers of the principal carbohydrates, according to the latest researches :—

SPECIFIC ROTATORY POWERS OF CARBOHYDRATES.

	{α} D.	{α} j.	Readings for 1 Gram per 100 cc. in 200 mm. Tube.		
			Ray D Laurent.	Transition Tint.	
				Soleil-Ventzke-Scheibler.	Soleil-Duboscq.
Dextrin ..	+195·0	+216·0	+3·900	+11·25	+18·00
Maltose ..	+135·4	+150·0	+2·708	+ 7·81	+12·50
Cane sugar ..	+ 66·5	+ 73·8	+1·330	+ 3·84	+ 6·15
Dextrose ..	+ 52·88	+ 58·6	+1·057	+ 2·96	+ 4·88
*Levulose ..	− 95·65	−105·98	−1·913	− 5·52	− 8.83
Invert sugar ..	− 21·30	− 23·6	−0·426	− 1·23	− 1 96

* Very recently Herzfeld and Winter (Ann. des Chemic **244**, pp. 274–295) find the value of {α} D for pure crystallised levulose (C = 20) at 20° C. to be − 71·4, but this number requires further confirmation.

The subjoined statement shows the equivalence in degrees of different polariscopes :—

			Grm. Sugar in 100 cc.
1°	Scale of Mitscherlich	=	·750
1°	,, Soleil-Duboscq	=	·1619
1°	,, Ventzke-Soleil	=	·26048
1°	,, Wild (sugar scale)	=	·1000
1°	,, Shadow sacchar. (of Laurent and Duboscq)	=	·1619

1° Mitscherlich	=	4·635° Soleil-Duboscq.
1° ,,	=	2·879° Soleil-Ventzke.
1° Soleil-Duboscq	=	·215° Mitscherlich.
1° ,, ,,	=	·620° Ventzke-Soleil.
1° ,, ,,	=	1·619° Wild.
1° ,, Ventzke	=	·346° Mitscherlich.
1° ,, ,,	=	1·608° Soleil-Duboscq.
1° ,, ,,	=	2·648° Wild.
1° Wild (sugar scale)	=	·618° Soleil-Duboscq.
1° ,, ,,	=	·384° Soleil-Ventzke.
1° ,, ,,	=	·133° Mitscherlich.

Equivalence in circular degrees :—

Wild (sugar scale)	1° =	·1328 circ. degree	D.
Soleil-Duboscq	*j* 1° =	·2167 ,, ,,	D.
,, ,,	*j* 1° =	·2450 ,, ,,	*j*.
Soleil-Ventzke	*j* 1° =	·3455 ,, ,,	D.
,, ,,	*j* 1° =	·3906 ,, ,,	*j*.

Instruments reading angular degrees, such as Wild's, Laurent's, and Duboscq's *saccharimètre à pénombre* may be made to give the concentration—i. e. the number of grm. of sugar in 100 cc. of solution—by the following formula :—

$$C = \frac{100\,a}{k\,[a]\,D},$$

in which a is the observed angle of rotation, k the length of the observation-tube in decimetres, and $[a]$ D the specific rotatory power of cane sugar for monochromatic light, which, for most purposes, may be placed at 66·4°. When the sp. gr. of the solution operated upon is known, the percentage by weight can be calculated by dividing the value of C obtained as above by the density.

Analysis of Commercial Glucose or Starch Sugar.—The production of this sugar has already been described (see pp. 551–96). It occurs either as a solid mass, as a granular powder, or as a syrup. As in the case of cane sugar, the full and complete analysis is attended with considerable difficulty, and it is therefore customary to return only 4 or 5 leading figures, which in most cases are sufficient for commercial purposes. The different processes will first be dealt with separately, and then the way in which they are carried out, and the mode in which the results are returned.

The specific gravity of dextrose solution differs somewhat from that of cane sugar containing the same amount of solid matter; Pohl gives the following table :—

Per cent. Sugar.	Density of Solution.		Difference in Density.
	Cane Sugar.	Grape Sugar.	
2	1·0080	1·0072	− 8
5	1·0201	1·0200	− 1
7	1·0281	1·0275	− 6
10	1·0405	1·0406	+ 1
12	1·0487	1·0480	− 7
15	1·0616	1·0616	0
17	1·0704	1·0693	− 11
20	1·0838	1·0831	− 7
22	1·0929	1·0909	− 20
25	1·1068	1·1021	− 47

Determination of Dextrose by means of Fermentation.— A standard solution of the sample to be examined is made, and the percentage of dry matter estimated. A weighed quantity of yeast is then added to the solution, and it is submitted to fermentation; after the alcohol and carbonic acid formed have been expelled, the percentage of dry matter is again determined by the difference in weight of the entire apparatus before and after fermentation. The difference between the amounts of dry matter before and after the fermentation shows the amount of sugars in the fermentable form. The process incurs a certain loss, which may and frequently does amount to 5 per cent. of the total fermentable sugars present; because part of these in the course of the vinous fermentation are converted into glycerine, succinic acid, and other bodies, which are fixed at the temperature of boiling water, and consequently remain with the residue.

For instance, 100 grm. of glucose or starch-sugar, after dissolving in water, and making up to 1 litre, would have a sp. gr. of about 1·030, and this corresponds to a percentage of the dried substance of 7·463; but as the substance has been weighed instead of being measured in cc. the true percentage as contained in the solution will be 76·87 per cent. dry substance, and 23·13 per cent. water; ½ litre of the solution thus made is taken, and a sufficient quantity of fresh yeast which is active and in good condition, is added; the whole is then placed in a fermenting apparatus, so that the carbonic acid can escape after drying. After weighing the whole apparatus, it is placed on one side at a proper temperature for about 3 days, weighing at intervals in order to ascertain when the action is complete. The liquid in the flask to which the yeast has been added is then measured, and boiled in order to drive off any residual alcohol, and, after cooling, is made up to its original volume, and returned to the flask. The amount of fermentable sugars is ascertained by the difference between the weight of the entire apparatus before and after fermentation. Thus if 500 cc. contained originally dry substance equal to 76·87 per cent. of total matter, and the liquid after fermentation contains the equivalent of only 20·67 of unfermentable matters, the residue of fermentable sugars will be 56·20; adding to this 5 per cent. on the quantity found, say 2·04 per cent., gives 58·24 per cent. as the total amount of fermentable sugars probably present.

The main difficulty in this process is the time which it takes, and the fact that from possible non-activity of the yeast it is essential to make 2 analyses of each sample with yeast obtained from different sources.

The proportions of maltose, dextrine, and glucose in brewing sugars prepared from starch may be determined by the optical method in conjunction with Fehling's test. It is necessary first to determine the specific rotatory power of the sample, which is done by dissolving a known weight of the substance in water, and making up to a certain volume; the solid matter is determined from the sp. gr. of the solution, by dividing by 3·85. This figure is constant, and allows an increase of 3·86 in density for each 1 grm. of sugar or other carbohydrate in 100 cc. of the liquid. The following example is given by A. H. Allen:—

(*a*) On ignition the sample left 0·63 per cent. of ash.

(*b*) The sp. gr. of a solution of 20 grm. of the sample diluted to 100 cc. was 1063·32 at 15½° C. (60° F.). This figure divided by 3·85 gives:—

Total solids	82·23 per cent.
Less ash	0·63 ,, ,,
Carbohydrates	81·60 ,, ,,

(*c*) By Fehling's test the sample was found to have a reducing power equivalent to 72·6 per cent. of glucose. The reducing power of maltose may be taken as $\frac{62}{100}$ that of glucose.

(*d*) A solution of 20 grm. per 100 cc. observed in a

2-decim. tube caused an angular rotation of + 23·7° for the sodium line D. Hence the value of [a] D for the sample was + 59·25°, thus—

$$[a]D = \frac{23 \cdot 7}{2 \times \frac{20}{100}} = 59 \cdot 25.$$

The values of [a] D for dextrose, maltose, and dextrine are respectively + 52°, + 139°, and + 193°, ignoring fractional parts of a degree.

Let [a] D be the apparent specific rotatory power, K the cupric oxide reducing power of the sample, and g, m, and d the respective amounts of glucose, maltose, and dextrine contained in 1 grm. of the sample. Then from the above data the following equations result:—

1. $g + m + d = \cdot 816.$
2. $g + \cdot 62\, m = K = \cdot 726.$
3. $52 g + 139 m + 193 d = [a]_D = 59 \cdot 25.$

From these

$$g = \cdot 726 - \cdot 62\, m.$$
$$d + g = \cdot 816 - m.$$
$$d + \cdot 726 - \cdot 62\, m = \cdot 816 - m.$$
$$\text{and } d = \cdot 09 - \cdot 38\, m.$$

Substituting the above values for g and d in equation 3 we get

$$52\,(\cdot 726 - \cdot 62\, m) + 139\, m + 193\,(\cdot 09 - 38\, m) = 59 \cdot 25.$$

Simplifying this,

$$37 \cdot 752 - 32 \cdot 24\, m + 139\, m + 17 \cdot 37 - 73 \cdot 34\, m = 59 \cdot 25.$$

Simplifying again, and transposing, we get

$$33 \cdot 42\, m = 4 \cdot 128,$$

whence

$$m = \cdot 1235.$$

The value of m being found, those of g and d are easily derived from equations 1 and 2. Thus :—

$$g = \cdot 726 - \cdot 62\ (\cdot 1235) = \cdot 726 - \cdot 07657 = \cdot 64943.$$
$$d = \cdot 816 - m - g = \cdot 816 - \cdot 1235 - \cdot 6494 = \cdot 0431.$$

As these values represent the respective weights of glucose, maltose, and dextrine in 1 grm. of the sample, the percentages will be 64·94, 12·35, and 4·31, together making up to 81·60 per cent.

Determination of Sugar by Fehling's solution.—This process alone is incorrect as applied to brewing sugars, because maltose, which is almost invariably present, acts upon Fehling's solution in a different proportion to that in which dextrose acts; thus, 10 cc. Fehling's solution = ·0500 grm. dextrose, 10 cc. Fehling's solution = ·0807 grm. maltose. This test, therefore, is only of relative value.

Rumpf and Heinzerling state that solutions of (1) caustic soda and sulphate of copper at the boiling-point do not act on dextrine entirely free from sugar, which corrects Gerhardt's observation, who asserted that dextrine caused a reduction; (2) solutions of alkaline tartrates and Fehling's solution each act upon dextrine, making the results of the dextrose estimation too high in direct proportion to the length of time the heating is continued. When the reduction is quickly effected, and the heating is continued only a few minutes, they have found that the error in the estimation of dextrose in the presence of dextrine in starch sugars is too small to sensibly affect the results.

Anthon's method depends on the fact that the impurities present in commercial starch sugar have a greater density than the sugar. The process is somewhat empirical, but is said to give fairly accurate results. A saturated solution of starch sugar is made by dissolving an excess of sugar in a finely divided state in water. The sp. gr. of the clear solution thus produced is ascertained, and from this the percentage of impurity is calculated according to the following table :—

Density of Sat. Solution.	Per ct. of Impurities.	Density of Sat. Solution.	Per ct. of Impurities.	Density of Sat. Solution.	Per ct. of Impurities.
1·2060	0	1·2350	15	1·2587	30
1·2082	1	1·2368	16	1·2603	31
1·2104	2	1·2386	17	1·2618	32
1·2125	3	1·2404	18	1·2633	33
1·2147	4	1·2422	19	1·2649	34
1·2169	5	1·2440	20	1·2665	35
1·2189	6	1·2456	21	1·2680	36
1·2208	7	1·2473	22	1·2695	37
1·2228	8	1·2489	23	1·2710	38
1·2247	9	1·2506	24	1·2725	39
1·2267	10	1·2522	25	1·2740	40
1·2284	11	1·2535	26	1·2755	41
1·2300	12	1·2548	27	1·2770	42
1·2317	13	1·2561	28	1·2785	43
1·2333	14	1·2574	29		

Water.—This is determined by drying the sample after mixing it with dry and well-washed sand, as described under the analysis of sugars (see p. 691). When solid samples of glucose have to be examined for moisture, the solid matter is first melted in a weighed dish in the water-bath at a gentle heat, and a weighed quantity of sand is stirred in.

Admixture of Starch Sugar with Refined Sugars.—It is stated that refined sugars are sometimes adulterated with starch sugar, and the following methods have been suggested for the detection of the adulteration. It does not appear that the admixture has ever been common in this country, but in America it is said to be of frequent occurrence; and it is quite possible that it may prove profitable, because not only is the price of glucose sometimes lower than that of refined sugar, but it is somewhat similar in colour.

If the suspected sugar is mixed with water and absolute alcohol, or with alcohol of 95 per cent., and the sugar is washed with it on the filter, there will in most cases be a white coagulum of dextrine left behind, which is recognised by its appearance. If cane sugar has been adulterated with starch sugar, the sample on solution in water generally leaves some particles of glucose, which do not dissolve easily or readily. They are mostly white in colour, and if they are sufficient in quantity, it will be found that, on dissolving them in a larger quantity of water, and submitting them to the polariscopic test, the reading is markedly different to that of cane sugar, and not only so, but it gradually diminishes for some hours after the solution has been made. As the rotatory power of starch sugar widely differs from that of cane sugar, samples which are adulterated with any notable proportion of starch sugar will give a reading differing from that which is due to the cane sugar present.

Casamajor has recommended the use of methylic alcohol of 50 per cent. strength, saturated with starch sugar, as a solution for the purpose of detecting the admixture of starch sugar with cane sugar. The mode of applying this test is to wash the suspected sugar with the saturated solution of starch sugar in methylic alcohol, which readily dissolves the cane sugar and other impurities, leaving the starch sugar insoluble; this method, though of value as a qualitative test, cannot be recommended for quantitative work.

Chandler and Rickett's method is probably the best which has yet been proposed for the detection of starch sugar in cane sugar, but it is not readily applicable, and is attended with some degree of difficulty in execution. It depends upon the fact that the rotation of a solution of levulose varies with the temperature, while the rotation of dextrose is constant for all temperatures. As invert sugar consists of a mixture of dextrose and levulose in equal proportions, it follows that there is a certain temperature at which invert sugar has no effect upon the polariscope. If, therefore, a sample of commercial sugar, whether raw or refined, is inverted and heated to a certain definite temperature, viz. 87·2° C. (189° F.), the rotation of the levulose is neutralised by the dextrose, and the sample does not produce any rotation. Hence if the tube containing the solution of the sample is placed between the polariser and the analyser, and surrounded by a jacket or water-bath in such a way that its temperature can be kept at 87·2° C. (189° F.), the rotatory effect due to the cane sugar is eliminated, and the rotation which is found by the optical examination is due entirely to glucose or intermediate products present. It is obvious that this method requires a special apparatus, inasmuch as the water-bath must be kept uniformly at a fixed temperature; but it is a decided advantage in detecting the presence of the adulterant if its quantity is at all notable, though it is not of use for detecting the character of that adulterant without the use of additional processes.

Milk-sugar Analysis.—To determine the amount of milk-sugar present in milk, it is necessary first to remove the fat and caseine: the former obscures the liquid to such an extent that it is not possible to obtain accurate readings if the determination is made by the polariscope, nor accurate results if by means of Fehling's solution; and the caseine has a considerable left-hand rotation. Owing to the birotation which is exhibited by milk sugar, it is undesirable to employ the optical method if it can be avoided, and Fehling's process is the more reliable of the two.

The mode in which the estimation is carried out is similar to that used for glucose and invert sugar (see p. 687), except that the solutions have to be heated or boiled somewhat longer, as the action does not take place so rapidly, though the volumetric or gravimetric methods may be used.

It is preferable to employ a dilute solution of milk-sugar, say 0·1 per cent.; to a measured quantity while boiling is added excess of boiling Fehling's solution; the mixture is boiled for a few minutes, and the precipitate is allowed to settle, filtered, and treated as described under the "Determination of Glucose and Invert Sugar by the Gravimetric Method," p. 689.

The weight of protoxide of copper when multiplied by the factor ·6153 gives the weight of milk-sugar.

Composition of Commercial Sugars.—The following are analyses of characteristic raw and refined commercial sugars made in 1881, by Wigner and Harland, for the Food Collection at the Bethnal Green Museum :—

Raw Sugars.	No.	Crystallisable Sugar.	Uncrystallisable Sugar.	Ash.	Moisture.	Unknown Organic Matters.
Dominica	5930	88·30	3·36	1·22	4·95	2·17
Grenada	5931	87·00	3·61	·90	4·74	3·75
Guatemala	5932	82·40	5·48	·78	6·30	5·04
Havana	5933	91·90	2·98	·72	1·70	2·70
Jamaica	5936	90·40	3·47	·36	4·22	1·55
Porto Rico	5940	87·50	4·84	·81	4·25	2·60
St. Kitts	5941	88·70	4·88	1·02	2·79	3·21
St. Lucia	5942	84·20	5·38	1·32	2·39	6·71
St. Vincent	5943	92·50	3·61	·63	·81	2·45
Surinam	5947	86·80	4·31	2·28	5·27	1·34
Trinidad	5948	88·00	5·14	·96	4·23	1·67
Grainy Peruvian ..	5949	94·80	1·44	·60	1·02	2·14
Cheney	5951	87·40	3·18	1·33	2·74	5·35
China	5952	72·50	9·19	1·80	6·76	9·75
Benares	5957	94·50	2·6	1·50	·98	·39
E. I. Date	5960	86·00	2·19	2·88	6·04	2·89
White Java	5961	99·20	·20	·20	·40	trace
Unclayed Manilla ..	5962	82·00	6·79	2·00	5·97	3·24
Refined Sugars—						
Tate's crystals ..	5973	99·90	none	trace	trace	none
French pulverised	5983	99·70	trace	·10	·20	,,
Martineau	5984	99·70	,,	·10	·20	,,
Duncan's granulated	5985	99·80	,,	·10	·10	,,
Say's loaves	5987	99·80	,,	·10	·10	,,
Martineau's tablets	5988	99·80	none	·10	·10	,,
Boyd's titlers	5989	99·70	trace	·10	·20	,,
Beet-sugar loaf ..	6074	99·60	,,	·15	·25	,,
,, crystals	6076	99·90	none	trace	trace	,,

Analysis of Char.—The following is a brief account of one or more methods by which the principal ingredients in char may be determined.

Determination of Moisture.—5 grams are weighed into a tared porcelain dish and heated in an air bath to 250° F. for some hours until the weight directly after cooling remains constant between two successive weighings made at intervals of an hour or two. The loss of weight multiplied by twenty gives the percentage of moisture. Chemists are by no means agreed as to the temperature at which char ought to be dried; thus, Patterson recommends 212° F. and Wallace 350° F., while 250° F. is used by many. It is therefore absolutely necessary in stating the percentage of moisture to also give the temperature at which the result has been obtained.

Determination of Carbon.—5 grams are heated with a mixture of 25 cc. hydrochloric acid and 70 cc. water to gentle ebullition and kept so for 15 minutes, the whole is then transferred to a tared filter, and thoroughly washed with boiling water until the washings give no precipitate with nitrate of silver, and is then dried at 250° F., until the weight remains constant when taken at intervals of an hour or so. The tared filter used for this purpose must be previously dried at 250° F. and weighed in a stoppered glass tube till the weight is constant, and the filter with the carbon in it is also weighed in the same tube. The increase of weight gives the joint amount of carbon and silica, and by carefully incinerating the filter and its contents in a platinum dish and weighing the residue the weight of the silica is obtained, and this deducted from the total weight gives the carbon.

Determination of Lime.—One gram is dissolved in dilute hydrochloric acid, being heated with it for some minutes, and the insoluble siliceous matter is then separated by filtration and the filter is washed with hot water till the washings are free from chlorine. To the filtrate, dilute ammonia is now added drop by drop until a faint opalescence is produced, due to the precipitation of a trace of tribasic phosphate of lime. A few drops of a dilute solution of oxalic acid are next added until this trace of phosphate of lime has been converted into oxalate, which change is easily noticed by the precipitate becoming granular. A strong solution of oxalate of ammonia is now added in quantity sufficient to precipitate all the lime as oxalate. The liquid is heated to the boiling-point for a few minutes and the precipitate is thrown upon a filter (double

Swedish by preference), which is afterwards washed, dried, and incinerated in a platinum dish. The precipitate must then be well moistened with solution of carbonate of ammonia and gently heated over an Argand lamp to expel all ammonia salts. Then weigh and repeat the addition of carbonate of ammonia with subsequent heating until the weight of the precipitate, which now consists of carbonate of lime, remains stationary. 100 parts of carbonate of lime = 56 parts of lime.

Determination of Phosphoric Acid, P_2O_5.—To the filtrate from the precipitate of lime, as oxalate, just described, add a few grams of citric acid and stir till it has dissolved. Then add ammonia in slight excess, and afterwards ammoniacal solution of magnesia in moderate excess. Stir well, taking care not to scratch the sides of the beaker, which would cause the precipitate to adhere to it, and leave the whole to stand for 12 hours or so. Then filter, removing any adhering precipitate by means of a quill with a small piece of feather remaining on it. Wash with dilute ammonia till the washings, after a portion has been acidified with nitric acid, give no indication of chlorine when tested with nitrate of silver. The precipitate, when dry, should be detached as far as possible from the filter and carefully ignited in a platinum crucible, which is then allowed to cool, the filter being afterwards ignited and added to the contents of the crucible, and the whole well heated till the carbonaceous matter has been completely burned off.

The residue in the crucible consists of pyrophosphate of magnesia, of which 222 parts = 142 parts of phosphoric acid, or 310 parts of tribasic phosphate of lime.

Determination of Magnesia.—Take the filtrate from the carbon determination, representing 5 grams of char, separate the lime, and then add a few grams of citric acid and make the solution ammoniacal. Then add solution of phosphate of ammonia in excess and stir well and allow to stand for 12 hours, when the precipitate of phosphate of magnesia and ammonia will settle out. This precipitate must be treated as mentioned under phosphoric acid, and weighed as pyrophosphate of magnesia, of which 222 parts = 80 parts magnesia.

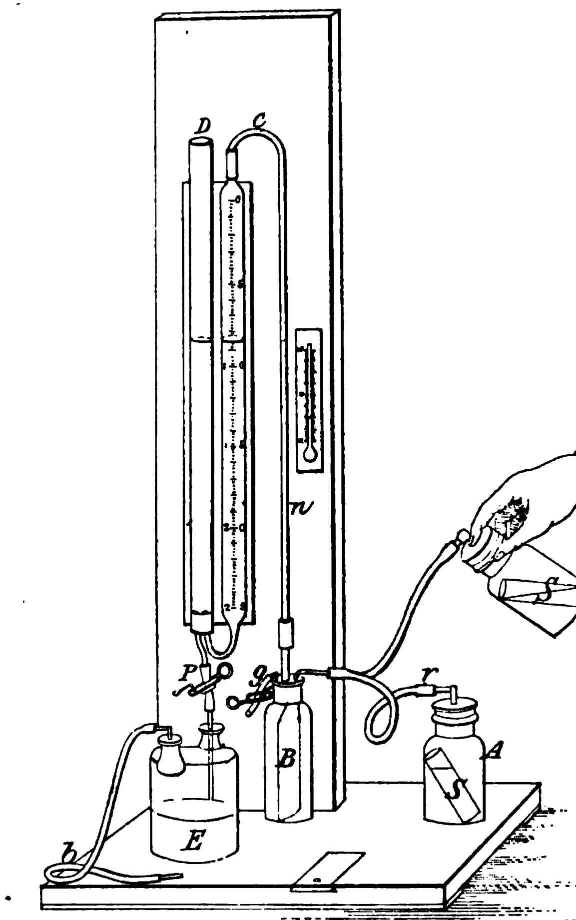
Determination of Peroxide of Iron and of Alumina.—To the dilute solution of 5 grams of char, from which the siliceous matter has been separated, add enough acetate of ammonia to precipitate all the peroxide of iron and the alumina as phosphate. Warm gently and allow to stand some time, then filter, wash, dry, incinerate, and weigh. The weight gives the peroxide of iron and the alumina as phosphates. The precipitate is next dissolved in warm dilute hydrochloric acid and the resulting solution is divided into two equal portions. In one half the phosphoric acid is determined in the manner already given, and in the other the amount of peroxide of iron is found by reduction with zinc and subsequent titration with a standard solution of permanganate of potash. The joint weights of phosphoric acid and peroxide of iron must be deducted from the total weight of the phosphate of peroxide of iron and alumina, and the remainder is alumina.

Determination of Organic Matter.—Incinerate 2 grams in a platinum dish until all the carbonaceous matter has been oxidised. Allow to cool, and moisten with carbonate of ammonia solution, and subsequently heat to drive off ammonia salts, allow to cool, and weigh. Repeat this last-named treatment until the weight is constant. From the loss of weight deduct the moisture and carbon as previously obtained, and the difference gives the organic matter. When new char has been incinerated the residual ash will be of a uniform white or cream colour, but the ash left by spent char is usually red, owing to the peroxide of iron present.

Determination of Carbonate of Lime.—This may be effected by the use of a carbonic acid apparatus, consisting of a small flask, provided with a tightly fitting cork, through which pass two glass tubes. The longer of these tubes extends from an inch above the upper surface of the cork to nearly the bottom of the flask, and its upper end is closed during the greater part of the process by a small cork stopper. The shorter tube has its lower extremity projecting only slightly below the cork, and its upper extremity is connected with a wide tube containing anhydrous chloride of calcium, terminating in a small orifice. The cork of the apparatus having been removed, 2 grm. of the char are introduced into the flask, and a little water is then added. A small tube three-fourths full of strong hydrochloric acid and attached to a fine thread is carefully lowered into the flask, taking care to keep it as vertical as possible. The cork of the apparatus is replaced, and the whole is weighed. The apparatus is then tilted so as to upset the hydrochloric acid in the tube, and this decomposes the carbonate of lime, the carbonic acid given off being deprived of any accompanying moisture by passing through the chloride of calcium. The apparatus should now be gently warmed to complete the action, and then allowed to cool, when the cork stopper is removed from the long tube and a current of dry air is drawn through the apparatus to remove any carbonic acid. The cork stopper is replaced, and the apparatus is reweighed, when the loss of weight gives the amount of carbonic acid produced from the 2 grams of char. This multiplied by 50 gives the percentage of carbonic acid, of which 44 parts are equal to 100 parts of carbonate of lime.

Determination of Carbonate of Lime by the use of Scheibler's Calcimeter.—This method is not very accurate, but the results are to be relied upon within 0·2 to 0·3 per cent., and therefore sufficiently near for ordinary work in refineries. The apparatus is shown in Fig. 226, and consists of the following parts. The evolution-bottle A, in which the sample of char is treated with hydrochloric acid, contains the glass tube S. The bottle is shown in two positions, one in the stand on the base-board, and the other when lifted in the hand during the process of analysis. The glass stopper of the flask A is perforated, and carries a tube to which is joined an indiarubber tube *r*, connecting the flask A with the bottle B. This bottle B has an indiarubber stopper with 3 holes, each

FIG. 226.



Scheibler's Calcimeter.

fitted with a tube; the tube joined to *r* passes a short distance inside the vessel B, and the end of it is fastened to a thin indiarubber bag or bladder, similar to those commonly used for making toy balls. Tube *g* has a piece of indiarubber tubing connected with it, which is closed by a pinchcock while the estimation is being made, and serves to bring the vessel B into communication with the air when necessary. The glass tube *n* connects the interior of the vessel B with the top of the graduated tube C, which is divided into 25 equal parts (about 4 cc. each), each division being subdivided into tenths; the lower part of this is in communication with the straight tube D, which is open at the upper end and closed at the lower end by an indiarubber cork pierced with two holes, through one of which is passed a pipe leading from the graduated tube C and through the other a tube leading to the two-necked Wolff-bottle E, the action between the two being regulated by the pinchcock P. E is a reservoir for water, and C D are filled from it by blowing through the flexible tube *b*, the pinchcock P preventing the reflux of the water. The whole apparatus excepting the bottles is fastened to an upright board, and the bottles are supported when necessary on a shelf attached to the board.

The test of a sample of char is carried out in the following way. By blowing through the flexible tube *b*, the liquid is forced into the tubes C and D until it reaches a little above the zero point in C, when it is allowed to fall by opening P until the level in C is at zero. The water must not be allowed to flow into B, as if this were done it would be necessary to take the apparatus to pieces to dry B. A sample of the char is reduced to powder, and the normal weight, viz. 1·702 grm., is placed in the flask A, which is carefully dried before use, and the small tube S is nearly filled with dilute hydrochloric acid of sp. gr. 1·120, and is cautiously placed in the flask, so that none of the acid shall be spilled. The stopper, which should be well greased, is now placed in A, and connection made with B by means of the tube *r*. If the levels of the liquids in D and C are unequal, the cock *g* must be opened for a few seconds to allow them to recover their

TABLE FOR CALCULATING THE PERCENTAGE OF CARBONATE OF LIME FROM THE VOLUME OF CARBONIC ACID: FOR USE WITH SCHEIBLER'S CALCIMETER.

Volume read.	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
1	·80	·80	·79	·79	·79	·78	·78	·77	·77	·77	·76	·76	·76	·75	·75	·74	·74	·73	·73
2	1·88	1·87	1·86	1·86	1·85	1·84	1·83	1·81	1·81	1·80	1·79	1·79	1·78	1·77	1·76	1·75	1·74	1·73	1·72
3	2·95	2·94	2·92	2·91	2·90	2·89	2·87	2·86	2·85	2·83	2·82	2·80	2·79	2·77	2·76	2·74	2·73	2·72	2·71
4	4·01	4·00	3·98	3·96	3·94	3·93	3·91	3·89	3·87	3·85	3·83	3·81	3·79	3·77	3·75	3·73	3·71	3·70	3·68
5	5·07	5·05	5·03	5·00	4·98	4·96	4·93	4·91	4·87	4·86	4·84	4·81	4·79	4·76	4·74	4·71	4·69	4·67	4·65
6	6·11	6·09	6·06	6·03	6·01	5·98	5·95	5·92	5·89	5·86	5·83	5·81	5·78	5·75	5·71	5·68	5·65	5·63	5·61
7	7·14	7·12	7·09	7·06	7·02	6·99	6·96	6·92	6·89	6·86	6·82	6·79	6·75	6·72	6·68	6·65	6·61	6·58	6·56
8	8·17	8·14	8·11	8·07	8·03	8·00	7·96	7·92	7·88	7·84	7·80	7·76	7·72	7·68	7·64	7·59	7·55	7·53	7·49
9	9·19	9·16	9·12	9·07	9·03	8·99	8·95	8·90	8·86	8·82	8·77	8·73	8·68	8·64	8·59	8·55	8·50	8·46	8·42
10	10·20	10·16	10·12	10·07	10·02	9·98	9·93	9·88	9·83	9·79	9·73	9·68	9·63	9·58	9·53	9·48	9·43	9·39	9·34
11	11·20	11·15	11·10	11·05	11·00	10·95	10·89	10·84	10·79	10·74	10·68	10·63	10·57	10·52	10·46	10·41	10·35	10·30	10·25
12	12·20	12·15	12·09	12·03	11·98	11·92	11·87	11·81	11·75	11·69	11·64	11·58	11·52	11·46	11·40	11·33	11·27	11·22	11·16
13	13·20	13·14	13·08	13·02	12·96	12·90	12·84	12·78	12·72	12·65	12·59	12·53	12·46	12·40	12·33	12·26	12·20	12·14	12·07
14	14·20	14·14	14·07	14·01	13·94	13·88	13·81	13·75	13·68	13·61	13·54	13·48	13·41	13·34	13·26	13·19	13·12	13·05	12·99
15	15·20	15·13	15·06	14·99	14·92	14·85	14·78	14·71	14·64	14·57	14·50	14·42	14·35	14·27	14·20	14·12	14·04	13·97	13·90
16	16·20	16·13	16·05	15·98	15·91	15·83	15·76	15·68	15·61	15·53	15·45	15·37	15·29	15·21	15·13	15·05	14·97	14·89	14·81
17	17·20	17·12	17·04	16·97	16·89	16·81	16·73	16·66	16·59	16·49	16·41	16·32	16·24	16·15	16·07	15·98	15·89	15·81	15·72
18	18·20	18·12	18·03	17·95	17·87	17·79	17·70	17·62	17·53	17·45	17·36	17·27	17·18	17·09	17·00	16·91	16·82	16·73	16·63
19	19·20	19·11	19·03	18·94	18·85	18·76	18·67	18·59	18·50	18·40	18·31	18·22	18·13	18·03	17·94	17·84	17·74	17·64	17·55
20	20·20	20·11	20·02	19·93	19·83	19·74	19·65	19·55	19·46	19·36	19·27	19·17	19·07	18·97	18·87	18·77	18·66	18·56	18·46
21	21·20	21·10	21·01	20·91	20·81	20·72	20·62	20·52	20·42	20·32	20·22	20·12	20·01	19·91	19·80	19·70	19·59	19·48	19·37
22	22·20	22·10	22·00	21·90	21·80	21·70	21·59	21·49	21·39	21·28	21·17	21·07	20·96	20·85	20·74	20·63	20·51	20·40	20·28
23	23·20	23·09	22·99	22·88	22·78	22·67	22·56	22·46	22·35	22·24	22·13	22·02	21·90	21·79	21·67	21·55	21·43	21·32	21·20
24	24·20	24·09	23·98	23·87	23·76	23·65	23·54	23·43	23·31	23·20	23·08	22·97	22·85	22·73	22·61	22·48	22·36	22·23	22·11
25	25·20	25·08	24·97	24·86	24·74	24·63	24·51	24·39	24·28	24·16	24·04	23·91	23·79	23·67	23·54	23·41	23·28	23·15	23·02

normal level. The vessel A is now lifted from the shelf into the upper position shown, so that the acid may flow out of the tube and come into contact with the char; the flask being then gently shaken so as to cause the acid to mix thoroughly with the sample. The gas evolved escapes into the india-rubber bag contained in the flask B, which, expanding, forces air up the tube *n*, and depresses the column of water in the graduated tube C. The stopcock P is now cautiously opened, so as to let the water in the tube D flow out, keeping the level of the water in the two tubes as nearly as possible alike. When all the gas has been given off, and the level of the liquid in the tube C becomes stationary, the liquid in the two tubes is brought to the same level by opening the pinch-cock P, and the volume and temperature are read off. The table on p. 742 gives the percentage of carbonate of lime corresponding to each division as read off on this instrument when the normal weight has been used, with the proper corrections for temperature (in degrees C.).

Determination of Sulphuric Acid SO_3.—5 grams of char are dissolved in warm dilute hydrochloric acid, the solution is filtered, and the filter is washed. To the filtrate add excess of chloride of barium, warm the liquid, filter, wash, dry, incinerate, and weigh: 233 parts of the resulting sulphate of baryta = 80 parts of sulphuric acid, or 32 parts of sulphur.

Determination of Sulphides.—5 grams of char are heated with 14 cc. of a mixture of equal parts of hydrochloric and nitric acids, the latter acid serving to oxidise any sulphide into sulphate. Then proceed as in the previous determination. This result gives the sulphate of baryta equal to the total sulphur, and from this the sulphate of baryta equal to the sulphuric acid must be deducted, the difference being calculated into sulphur, or sulphide of calcium: 233 parts of sulphate of baryta = 72 sulphide of calcium.

Determination of Chlorine.—New char contains an appreciable amount of chlorine in the form of common salt (chloride of sodium), but in old char there is only a minute proportion left, the greater part having been removed by repeated washing. To determine the chlorine, take 10 grams of the char, add some hot water, stir well, and filter. Wash the residue on the filter till the washings no longer give any turbidity with nitrate of silver and a few drops of nitric acid. To the clear liquor, when cold, add a few drops of a solution of chromate of potash, then run in from a burette standard solution of nitrate of silver, with occasional stirring until a faint reddish tinge is produced. From the number of cc.'s of nitrate of silver taken, it is easy to calculate the percentage of chlorine: 35·5 parts of chlorine = 58·5 parts of chloride of sodium.

Detection of Fluorine.—There is a small amount of fluoride of calcium present in char, and it may be tested for as follows:—Incinerate 10 grams of char in a platinum dish until all the carbonaceous matter has been removed. When cold, thoroughly moisten the residue with strong sulphuric acid, and cover it with a glass plate which has been previously coated with a thin surface of wax on its under side, the wax, however, having been scraped off in a few places by a pen. The dish must now be heated gently, care being taken not to melt the wax, and after some time, on taking away the glass plate and removing the wax therefrom, it will be found to be permanently etched by the action of hydrofluoric acid upon the silica of the glass.

Determination of Nitrogen.—Two grams may be taken for this operation which is carried out by the usual combustion process with soda-lime in an iron tube, the ammonia given off being collected in 25 cc. of standard hydrochloric acid contained in a set of bulbs. After the combustion is over the acid is transferred to a beaker and a few drops of litmus added. Standard ammonia is then run in from a burette until the bright red tint of the solution just begins to turn blue. The number of cc. of ammonia used is then read off and deducted from that required to neutralise 25 cc. of the standard acid. The difference × the ammonia contained in each cc. × 50 = percentage of ammonia produced from the char. To turn this into nitrogen × 14 and ÷ the product by 17.

Determination of the number of cubic feet in a ton of char, or of the number of pounds to a cubic foot.—To ascertain this, take a cubic measure holding one-tenth of a cubic foot, and balance it when empty against a counterpoise. The measure is then filled with char (adding a slight excess and removing such excess by drawing a straight-edge across the top). The weight taken with avoirdupois weights × 10 gives the number of pounds in a cubic foot of char, and from this the number of cubic feet in a ton can be easily reckoned.

Apparent Specific Gravity of Char.—The method just described gives the number of pounds in a cubic foot of char, and if this be divided by the weight of a cubic foot of water, viz. 62·5 lb., the quotient gives the apparent specific gravity of the char.

Real Specific Gravity of Char.—This is obtained by placing 100 grams of the char in a counterpoised 200 cc. flask, adding water till it is well covered, boiling for some time to remove the air, then cooling, filling up to the mark, and weighing at 60 F. The amount of water displaced by the char is obtained by comparison with the actual contents of the flask (200 grams), and gives the real specific gravity of the char.

When char is repeatedly reburned it becomes less porous and shrinks in volume, so that a ton of char which, when new, measures 48 to 54 cubic feet, may be reduced to as low as 28 cubic feet after being many times reburned, or, in other words, its apparent density may be nearly doubled. Dr. Wallace has, however, shown that the real specific gravity varies but little, thus a new char occupying 50·6 cubic feet per ton, or having an apparent specific gravity of 0·71, had a real specific gravity of 2·822, whilst a moderately old sample, occupying 35 cubic feet per ton, or having an apparent specific gravity of 1·03, had a real specific gravity of 2·857, or only a trifle over that of the new. Another proof that char loses its porosity to a considerable extent by long continued use and reburning is afforded by the fact pointed out by Dr. Wallace, that dry new char will absorb from 80 to 100 per cent. of its weight of water, whereas old char will only retain from 30 to 45 per cent.

Mode of Dividing the Space occupied by Char into Interstices, Pores, and Solid Structure.—This process, which was formerly employed in the laboratory of Fryer, Benson, and Forster, of Manchester, is carried out in the following way. Reduce glass to a rough powder, and separate it by sifting in grists of known sizes. Put a given volume of glass of known grist into a counterpoised 100 cc. flask, add water to cover it, boil to expel any adhering air, cool, fill up to the mark with water, weigh, and note how much water has been required. Next, put the same volume of char of the same grist as the glass into a 100 cc. counterpoised flask, cover it with water, boil, cool, fill up to mark, and weigh, as before.

The difference gives the quantity of water which the pores of the char have absorbed. By noting the amount of water taken in by the standard glass sample, the volume of interstices is obtained. The space occupied by char of known grist can thus be divided into interstices, pores, and solid structure. So long as char is properly burned, the volume of pores is a good index of quality, and it keeps a regular relation to the specific gravity.

Determination of the Grist of Char.—For this purpose it is usual to employ a set of circular sieves having respectively 10, 20, 30, 40, and 50 holes to the linear inch. These are so constructed that the bottom of one fits into the top of the next, the 10-hole sieve being uppermost, and the 50-hole sieve fitting into a circular vessel, the bottom of which is closed so as to collect the dust, the whole set when in use being thus joined together. 1000 grams of the char are placed upon the uppermost sieve, and the whole set is shaken backwards and forwards for a few minutes. Each sieve is removed in turn and its contents weighed; whatever passes through the 50-hole sieve is found in the closed vessel and weighed as "dust."

Decolorising Power of Char.—This may be determined by placing a known weight of the char in a vertical glass tube, 2 inches in diameter and 2 feet 6 inches high, which is open at the top and closed at the bottom by means of a conical brass screw-cap with a tap and a small circular piece of wire gauze covered with felt, to retain the char in the tube. The tube is supported by a convenient stand, and a hot solution containing a known weight of the sugar to be tested is then run on to the char, the portion first passing through being returned to the tube. It is convenient to employ about 900 cc. of solution of sugar at 27° B. hot, and to try the experiment with 600 grams of char, the amount of colour left in the liquor being estimated in one of the numerous forms of colorimeters now employed. The relative decolorising power of a given char can thus be found by testing it against an equal weight of a standard sample of char treated in precisely the same manner with a known amount of sugar solution. The methods of testing char by estimating its power of absorbing sucrate of lime or caramel from a solution are not to be recommended, as the results do not agree with those obtained with sugar solution.

Duboscq's colorimeter, which is perhaps most generally used, consists of two glass cylinders side by side, one of which is destined to receive the solution to be examined, and the other the standard liquor. Two small tubes capable of being moved up and down through the corks which close the tops of the larger tubes are shut at the bottom by clear glass plates, and passed through the corks. Below the larger tubes is a mirror to reflect the light in a vertical direction through them, and above them are two double-reflecting prisms, which bring the images of the two smaller tubes side by side into the luminous field of a small Galilean telescope. In this instrument the samples are compared with a solution of the sugar of the same strength which has been merely filtered through paper. If the colour left in solution be too intense to allow of accurate reading, the liquor must be diluted with once or twice its own bulk of water, and then tested in the colorimeter, allowance being made for the dilution.

Lovibond's tintometer will be found to answer very well for determining the amount of colour left. Instead of using a tube for the char, flasks may be employed in which a known weight of char is heated with a given weight of sugar solution, for a specified time, and then the contents are filtered and the colour is determined in a colorimeter.

The mode of stating the results of the analysis of char will now be illustrated by a few examples.

ANALYSES OF NEW CHAR.

	Calculated on the dry.	
Carbon	10·18	9·60
Phosphates of lime and magnesia	80·60	81·93
Carbonate of lime	8·43	7·78
Sulphate of lime	0·20	0·23
Peroxide of iron	0·10	0·12
Siliceous matters	0·29	0·18
Common salt (chloride of sodium)	0·20	0·16
	100·00	100·00
Moisture originally present	4·50	3·72
Space occupied by a ton dry	50 cubic ft.	46 cubic ft.
Sizes :—		
Above 10 meshes to the linear inch	4	0
From 10 to 20 meshes to the linear inch	90	36
„ 20 to 30 „ „ „	2	29
„ 30 to 40 „ „ „	1	25
„ 40 to 50 „ „ „	2	8
Below 50, or dust	1	2
	100	100

The following detailed analyses give the composition of the working chars in a refinery, in which 3 qualities of char were kept separate, No. I. being the most recent and No. III. the oldest. Even the newest of these had been some time in use, as shown by the large amount of iron contained in it.

ANALYSES OF THE STOCK CHARS FROM A REFINERY.
Calculated on the dry at 250° F.

	I.	II.	III.
Carbon	10·25	10·48	10·19
Organic matter	1·36	1·31	1·08
Tribasic phosphate of lime	78·89	79·05	79·98
Carbonate of lime	2·57	2·07	1·72
Sulphate of lime	0·43	0·30	0·27
Sulphide of calcium	0·17	0·15	0·13
*Lime	3·76	3·51	3·48
Tribasic phosphate of magnesia	0·38	0·36	0·27
Peroxide of iron (ferric oxide)	0·69	0·94	0·99
Alumina	0·27	0·44	0·56
Sand	1·23	1·39	1·33
	100·00	100·00	100·CO
Moisture at 250° F.	0·84	0·80	0·88

* This lime does not exist in the free state, but is probably in combination with the Phosphoric Acid P_2O_5, forming a more basic combination than Tribasic Phosphate of Lime.

The carbon in char always contains a certain proportion of nitrogen, amounting sometimes to one-tenth of its weight; there is also a minute proportion of hydrogen present. The nitrogen becomes continually less and less whilst the char is being used for sugar refining.

Further particulars relating to char will be found in the Chapters on Sugar Refining and on Animal Charcoal.

CHAPTER XXIV.

RUM AND OTHER ALCOHOLS.

THE name "rum" is applied to a spirit obtained from the sugar cane in the manner to be described presently. It is a spirit of excellent quality and flavour, and is much valued when old. That which comes from the West Indian Islands, and particularly from Jamaica, is the best. Martinique and Guadeloupe furnish very good qualities. Considerable quantities of rum are also made in Brazil, and imported into Europe and North America.

Chemistry.—Pure spirit or alcohol is a liquid substance, composed of carbon, hydrogen, and oxygen, in the following proportions:—

C	52·17
H	13·04
O	34·79
	100·00

Vinous alcohol is the most important member of an important series of organic compounds, all of which resemble each other closely, and possess many analogous properties. They are now classed by the chemist under the generic title of "Alcohols." Vinous alcohol is the principle of all spirituous, fermented liquors. The intoxicating properties of these liquors, due to the presence of this principle, have been known since the earliest times; but it was not until about the beginning of the fourteenth century that the principle was isolated in a pure state.

Alcohol does not occur in nature; it is the product of the decomposition of sugar, or, more properly, of glucose, which under the influence of certain organic, nitrogenous substances, called ferments, is split up into alcohol and carbonic anhydride. The latter is evolved in the form of gas, alcohol remaining behind mixed with water, from which it is separated by distillation. The necessary purification is effected in a variety of ways.

Pure, absolute alcohol is a colourless, mobile, very volatile liquid, having a hot, burning taste, and a pungent and somewhat agreeable odour. It is very inflammable, burning in the air with a bluish-yellow flame, evolving much heat, leaving no residue, and forming vapours of carbonic anhydride and water. Its specific gravity at 0° C. (32° F.) is 0·8095, and at 15·5° C. (60° F.), 0·794; that of its vapour is 1·613. It boils at 78·4° C. (173° F.). The boiling-points of its aqueous mixtures are raised in proportion to the quantity of water present. Mixtures of alcohol and water when boiled give off at first a vapour rich in alcohol, and containing but little aqueous vapour; if the ebullition be continued, a point is ultimately reached when all the alcohol has been driven off and nothing but pure water remains. Thus, by repeated distillation, alcohol may be obtained from its mixture with water in an almost anhydrous state.

The following table by Otto gives the boiling-points of alcoholic liquids of different strengths, and the proportions of alcohol in the vapours given off:—

Proportion of Alcohol in the Boiling Liquid in 100 vols.	Temperature of the Boiling Liquid.	Proportion of Alcohol in the Condensed Vapour in 100 vols.	Proportion of Alcohol in the Boiling Liquid in 100 vols.	Temperature of the Boiling Liquid.	Proportion of Alcohol in the Condensed Vapour in 100 vols.
90	78·8	92	15	90·0	66
80	79·4	90·5	12	91·3	61
70	80·0	89	10	92·5	55
60	81·3	87	7	93·8	50
50	82·5	85	5	95·0	42
40	83·8	82	3	96·3	36
30	85·0	78	2	97·5	28
20	87·5	71	1	98·8	13
18	88·8	68	0	100·0	0

Absolute alcohol has a strong affinity for water. It absorbs moisture from the air rapidly, and thereby becomes gradually weaker; it should therefore be kept in tightly-stoppered bottles. When brought into contact with animal tissues, it deprives them of the water necessary for their constitution, and acts in this way as an energetic poison. Considerable heat is disengaged when alcohol and water are brought together; if, however, ice be substituted for water, heat is absorbed, owing to the immediate and rapid conversion of the ice into the liquid state. When 1 part of snow is mixed with 2 parts of alcohol, a temperature as low as − 21° C. (5° F.) is reached.

When alcohol and water are mixed together, the resulting liquid occupies, after agitation, a less volume than the sum of the two original liquids. This contraction is greatest when the mixture is made in the proportion of 52·3 volumes of alcohol and 47·7 volumes of water, the result being, instead of 100 volumes, 96·35. A careful examination of the liquid when it is being agitated reveals a vast number of minute air-bubbles, which are discharged from every point of the mixture. This is due to the fact that gases which are held in solution by the alcohol and water separately are less soluble when the two are brought together; and the contraction described above is the natural result of the disengagement of such dissolved gases. The following table represents the contraction undergone by different mixtures of absolute alcohol and water.

100 Volumes of Mixture at 15° C. (59° F.).					
Alcohol.	Contraction.	Alcohol.	Contraction.	Alcohol.	Contraction.
100	0·00	65	3·61	30	2·72
95	1·18	60	3·73	25	2·24
90	1·94	55	3·77	20	1·72
85	2·47	50	3·74	15	1·20
80	2·87	45	3·64	10	0·72
75	3·19	40	3·44	5	0·31
70	3·44	35	3·14		

Alcohol is termed "absolute" when it has been deprived of every trace of water, and when its composition is exactly expressed by its chemical formula. To obtain it in this state, it must be subjected to a series of delicate operations in the laboratory, which it would be impossible to perform on an industrial scale. In commerce, it is known only in a state of greater or less dilution.

Alcohol possesses the power of dissolving a large number of substances insoluble in water and acids, such as many inorganic salts, phosphorus, sulphur, iodine, resins, essential oils, fats, colouring matters, &c. It precipitates albumen, gelatine, starch, gum, and other substances from their solutions. These properties render it an invaluable agent in the hands of the chemist.

Alcohol is found in, and may be obtained from, all substances—vegetable or other—which contain sugar. As stated above, it does not exist in these in the natural state, but is the product of the decomposition by fermentation of the saccharine principle contained therein; this decomposition yields the spirit in a dilute state, but it is readily separated from the water with which it is mixed by processes of distillation, which will subsequently be described. The amount of alcohol which may be obtained from the different unfermented substances which yield it varies considerably, depending entirely upon the quantity of sugar which they contain.

The following are some of the most important sources of alcohol which have been employed in Europe:—Grapes, rice, beet-root, potatoes, carrots, turnips, molasses, and grain. On the Continent, many fruits are used for the production of alcohol besides the grape, such as apricots, cherries, peaches, currants, gooseberries, raspberries, strawberries, &c.; figs, too, are used extensively in the East. In America, nearly the whole of the spirit of commerce is obtained from potatoes, Indian corn, and other grains. In India, Japan, and China, rice and sorghum are the chief sources. Among a variety of other substances which have been and are still used for the production of alcohol in smaller quantities, are roots of many kinds, such as those of asphodel, madder, &c. Seeds and nuts have been made to yield it; and even woody fibre, old linen, cotton, and hemp have been successfully converted into cellulose, glucose, and thence into alcohol. It will thus be seen that the sources of this substance are practically innumerable; anything, in fact, which contains or can be converted into sugar is what is called "alcoholisable."

Alcohol has become a substance of such prime necessity, in the arts and manufactures, and, in one form or other, enters so largely into the composition of the common beverages consumed by all classes of people, that its manufacture must, of necessity, rank among the most important industries of this and other lands. The traffic in spirituous liquors in this country has during the last few years developed, and is still developing, rapidly; and with the demands of an increasing population it is reasonable to expect that a still further impetus will be given to the production.

FERMENTATION.—Fermentation is a spontaneous change undergone, under certain conditions, by any animal or vegetable substance under the influence of ferments, by which are produced other substances not originally found in it. There are several kinds of fermentation, the most important being that by which alcohol is formed from glucose, or alcoholic fermentation. If this process be not carefully conducted, other fermentations ensue, resulting in the formation of acetic, lactic, and butyric acids, and sometimes of saccharine and viscous matters, which are productive of much annoyance to the distiller. These may be called the accidents of fermentation, and must be very carefully guarded against.

Glucose is said, therefore, to be subject to four principal kinds of fermentation—alcoholic, acetous, lactic, and viscous. There are others of a less important nature to which glucose is liable, but only the above four will be examined here.

The real nature of the process of fermentation, though it has been made the subject of much investigation, is still shrouded in a good deal of obscurity. Many theories have been put forward to account for it, of which the most probable is that of Pasteur, who tells us that the action of ferments is due to the life and growth of the minute cells of which they are composed. To effect this development, the cells require mineral food; and if this be withheld, no fermentation can take place. Pasteur has shown this by placing a small quantity of brewer's yeast, the ferment commonly employed in industrial operations, in an absolutely pure solution of sugar. He observed no sign of fermentation until he had introduced a soluble phosphate and a salt of ammonia, salts which constitute the mineral components of the ferment. The presence of albuminoid matters appears also to be indispensable; but these are contained in the ferment itself, so that in case the liquor is not sufficiently provided with such matter, the ferment will, so to speak, nourish itself with its own substance, throwing off at the same time the useless particles that are not necessary for its own growth. The results of careful microscopical examinations of the minute cellules of which yeast is composed fully bear out Pasteur's view of the subject.

The different varieties of fermentation to which glucose is liable will here be treated of separately.

Alcoholic Fermentation.—Five agents, each acting in a different direction, are necessary to produce this; in the absence of any one of them, fermentation cannot proceed. They are (1) Sugar, (2) Water, (3) A ferment, (4) Heat, and (5) Air. The part played by each of these five indispensable agents will now be examined.

Sugar.—Sugar when dissolved and brought into contact with a ferment is decomposed, yielding alcohol and carbonic anhydride. Before fermentation, the sugar has to be converted into glucose, by combination with two equivalents of water. This hydration is very easily effected; simple heating of a saccharine solution is sometimes sufficient; the presence of ferments themselves produce it, and a thousand other causes will bring it about when water is present. It is this ready conversion of sugar into glucose that renders saccharine matters so useful in the production of alcohol. The best proportion of sugar in an unfermented liquor or "must" is about 12 per cent. More than this hinders the fermentation.

Water.—The proportion of water employed in dissolving the glucose exercises considerable influence upon the products of the fermentation, as well as upon the time occupied by the process. The operation may be hurried or kept back by adding or subtracting water; the latter is effected by evaporation. The relative amount of water present is ascertained by means of a saccharometer. The water employed should contain no organic matter, and only a small proportion of mineral salts; it should always be clear and bright.

The Ferment.—A ferment is a substance undergoing decomposition, the ultimate particles of which are in a state of continual motion. When brought into contact with sugar, this atomic motion is communicated to the atoms of carbon, hydrogen, and oxygen of which the sugar is made up, the carbon dividing itself between the hydrogen and oxygen in such a manner that in place of the sugar, two more stable compounds are formed, viz. carbonic anhydride and alcohol. The elements of the ferment take no part in the formation of these products, but only act as the stimulant which provokes the change without participating therein chemically.

As stated above, brewers' yeast is the ferment chiefly employed by distillers. It is a frothy substance formed during the fermentation of the worts of beer. It collects on the surface, and is skimmed off and rendered dry and solid by the action of a press. That obtained from a strong beer is much to be preferred, as it is more certain in its action and less liable to engender acetous fermentation. It is best when newly prepared: old yeast should never be used when fresh can be obtained.

The proportions of yeast and sugar for quick fermentation are 5 parts of sugar to 1 part of yeast, although the same quantity of yeast will ferment a much larger quantity of sugar. Any nitrogenous substance, such as albumen, fibrin, gluten, &c., possesses the power of converting sugar into alcohol, when in a state of incipient decomposition, though in a less degree than yeast.

When required for storing, the yeast is subjected to processes of washing and pressing, in order to get rid of the water and other impurities which it contains. It is pressed through linen, or through a hair sieve, and the filtered liquid is then allowed to stand until the yeast has settled to the bottom. The clear liquid is decanted off, and the yeast is washed several times with cold water, and well stirred up, until the wash water exhibits no acid reaction. It is finally mixed with 15·30 per cent. of starch, filled into bags, and pressed.

Heat.—Heat is as necessary to fermentation as water, and, like water, may be the cause of hastening or checking the process. The lowest temperature at which the action is sustained is about 15° C. (59° F.), and it becomes more energetic and perfect as the temperature is increased up to 28° or 30° C. (82° to 86° F.). A higher temperature than this should be avoided, as likely to excite acid fermentation. As a means of cooling the vat rapidly, in case of necessity, a coil of pipe in which cold water circulates is sometimes laid in the bottom of the vats. Since heat is retained longer in large masses than in small, and the heat generated by the rapidity of the chemical action is in proportion to the bulk of liquor, it follows that the temperature should be raised in inverse proportion to the bulk of the liquor undergoing fermentation.

Air.—Air, though indispensable at the beginning of the process, becomes useless, and indeed injurious, during its continuation. It is essentially the initial force, but when once the impulse has been given, it is no longer necessary. Therefore air should be excluded as carefully as possible, by keeping the vat covered and allowing no movement to displace the layer of carbonic anhydride, resting on the surface of the liquor, because contact with the air is certain to produce an acid fermentation in place of the alcoholic ; this is especially liable to occur towards the end of the operation.

The whole process of alcoholic fermentation may be briefly described as follows :—

The liquor in the vat having been heated to the right temperature, the ferment, previously mixed with a small quantity of the saccharine liquor and then left to stand until fermentation begins, is thrown in, and the whole is well stirred together. In about three hours' time, the commencement of the fermentation is announced by small bubbles of gas which appear on the surface of the vat, and collect round the edges. As these increase in number, the whole contents are gradually thrown into a state of motion, resembling violent ebullition, by the tumultuous disengagement of carbonic anhydride. The liquor rises in temperature and becomes covered with froth. At this point the vat must be covered tightly, the excess of gas finding an exit through holes in the lid ; care must now be taken to prevent the temperature from rising too high, and also to prevent the action from becoming too energetic, thereby causing the contents of the vat to overflow. In about 24 hours, the action begins to subside, and the temperature falls to that of the surrounding atmosphere. An hour or two later, the process is complete ; the bubbles disappear, and the liquor, which now possesses the characteristic odour and taste of alcohol, settles out perfectly clear. The whole operation, as here described, usually occupies about 48 hours, more or less. The duration of the process is influenced, of course, by many circumstances, chiefly by the bulk of the liquor, its richness in sugar, the quality of the ferment, and the temperature and general state of the atmosphere.

Acetous Fermentation.—This perplexing occurrence cannot be too carefully guarded against. It results, as mentioned above, when the fermenting liquor is exposed to the air. When this is the case, the liquor absorbs a portion of the oxygen, which unites with the alcohol, thus converting it into acetic acid as rapidly as it is formed. When acetous fermentation begins, the liquor becomes turbid, and a long stringy substance appears, which, after a time, settles down to the bottom of the vat. It is then found that all the alcohol has been decomposed, and that an equivalent quantity of acetic acid remains instead. Is has been discovered that the presence of a ferment and a temperature of 20° to 35° C. (68° to 95° F.) are indispensable to acetous fermentation, as well as contact with the atmosphere. Hence, in order to prevent its occurrence, it is necessary not only to exclude the air, but also to guard against too high a temperature and the use of too much ferment. The latter invariably tends to excite acetous fermentation. It should also be remarked that it is well to cleanse the vats and utensils carefully with lime water before using, in order to neutralise any acid which they may contain; for the least trace of acid in the vat has a tendency to accelerate the conversion of alcohol into vinegar. A variety of other circumstances are favourable to acetification, such as the use of a stagnant or impure water, and the foul odours which arise from the vats; stormy weather or thunder will also engender it.

Lactic Fermentation.—Under the influence of lactic fermentation, sugar and starch are converted into lactic acid. When it has once begun, it develops rapidly, and soon decomposes a large quantity of glucose; but as it can proceed only in a neutral liquor, the presence of the acid itself speedily checks its own formation. Then, however, another ferment is liable to act upon the lactic acid already formed, converting it into butyric acid, which is easily recognised by its odour of rank butter. Carbonic anhydride and hydrogen are evolved by this reaction. The latter gas acts powerfully upon glucose, converting it into a species of gum called mannite, so that lactic fermentation—in itself an intolerable nuisance—becomes the source of a new and equally objectionable waste of sugar. It can be avoided only by keeping the vats thoroughly clean; they should be washed with water acidulated with 5 per cent. of sulphuric acid. An altered ferment, or the use of too small a quantity, will tend to bring it about. The best preventives are thorough cleanliness, and the use of good fresh yeast in the correct proportion.

Viscous Fermentation.—This is usually the result of allowing the vats to stand too long before fermentation begins. It is characterised by the formation of viscous or mucilaginous matters, which render the liquor turbid, and by the evolution of carbonic anhydride and hydrogen gases, the latter acting as in the case of lactic fermentation, and converting the glucose into mannite. Viscous fermentation may generally be attributed to the too feeble action of the ferment. It occurs principally in the fermentation of white wines, beer, and beet-juice, or of other liquors containing much nitrogenous matter. It may be avoided by the same precautions as are indicated for the prevention of lactic fermentation.

Apparatus.—It remains now to describe briefly the vessels or vats employed in the process of fermentation. They are made of oak or pine, firmly bound together with iron bands, and they should be somewhat deeper than wide, and slightly conical, so as to present as small a surface as possible to the action of the air. Their dimensions vary, of course, with the nature and quantity of the liquor to be fermented. Circular vats are preferable to square ones, as being better adapted to retain the heat of their contents. The lid should close securely, and a portion of it should be made to open without uncovering the whole. For the purpose of heating or cooling the contents when necessary, it is of great advantage to have a copper coil at the bottom of the vat, connected with two pipes, one supplying steam and the other cold water. The diameter of the coil varies according to the size of the vat.

The room in which the vats are placed should be made as free from draughts as possible, by dispensing with superfluous doors and windows; it should not be too high, and should be enclosed by thick walls in order to keep in the heat. As uniformity of temperature is highly desirable, a thermometer should be kept in the room, and there should be stoves for supplying heat in case it be required. Every precaution must be taken to ensure the most absolute cleanliness; the floors should be swept or washed with water daily, and the vats, as pointed out above, must be cleaned out as soon as the contents are removed. For washing the vats, lime-water should be used when the fermentation has been too energetic, or has shown a tendency to become acid; water acidulated with sulphuric acid is used when the action has been feeble, and the fermented liquor contains a small quantity of undecomposed sugar. Care must be taken to get rid of carbonic anhydride formed during the operation. Buckets of lime-water are sometimes placed about the room for the purpose of absorbing this gas; but the best way of getting rid of it is to have a number of holes, 3 or 4 inches square, in the floor, through which the gas escapes by reason of its weight. The dangerous action of this gas, and its effects upon animal life when unmixed with air, are too well known to necessitate any further enforcement of these precautions.

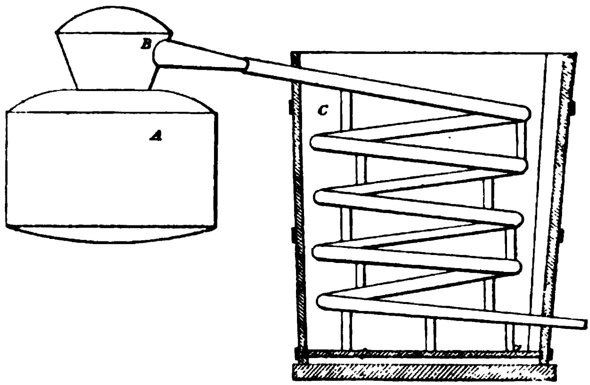
DISTILLATION.—The fermented liquors obtained in the manner described above, are composed essentially of volatile substances, such as water, alcohol, essential oils, and a little acetic acid, and of non-volatile substances, such as cellulose, dextrine, unaltered sugar and starch, mineral matters, lactic acid, &c.

The volatile constituents of the liquor possess widely different degrees of volatility; the alcohol has the lowest boiling-point, water the next, then acetic acid, and last the essential oils. It will thus be seen that the separation of the volatile and non-volatile constituents by evaporation and condensation of the vapours given off is very easily effected, and that also by the same process, which is termed "distillation," the volatile substances may be separated from one another. As the acetic acid and essential oils are present only in very small quantities, they will not require much consideration. The aim of the process is to separate as completely as possible the alcohol from the water which dilutes it. At p. 751 was given a table showing the amount of alcohol contained in the vapours given off from alcoholic liquids of different strengths, and also their boiling-points. A glance at this table will show to what an extent an alcoholic liquor may be strengthened by distillation, and how the quantity of spirit in the distillate increases in proportion as that contained in the original liquor diminishes. It will also be seen that successive distillations of spirituous liquors will ultimately yield a spirit of very high strength. As an example, suppose that a liquid containing 5 per cent. of alcohol is to be distilled. Its vapour condensed gives a distillate containing 45 per cent. of alcohol, which, if re-distilled, affords another containing 82 per cent. This, subjected again to distillation, yields alcohol of over 90 per cent. in strength. Thus three successive distillations have strengthened the liquor from 5 per cent. to 90 per cent. This, of course, is speaking theoretically; in practice, it is possible to obtain results so absolutely perfect, only by leaving behind a considerable quantity of spirit in the distilling apparatus after each distillation.

It will thus be clear that the richness in alcohol of the vapours given off from boiling alcoholic liquids is not a constant quantity, but that it necessarily diminishes as the ebullition is continued. For example, a liquor containing 7 per cent. of alcohol yields, on boiling, a vapour containing 50 per cent. (see table, p. 751). The first portion of the distillate will, therefore, be of this strength. But as the vapour is proportionately richer in alcohol, the boiling liquor must become gradually weaker, and, in consequence, must yield weaker vapours. Thus, when the proportion of alcohol in the boiling liquid has sunk to 5 per cent., the vapours condensed at that time will contain only 40 per cent.; at 2 per cent. of alcohol in the liquor, the vapours yield only 28 per cent.; and at 1 per cent., they will be found when condensed to contain only 13 per cent. From this it will be understood that if the distillation be stopped at any given point before the complete volatilisation of all the alcohol, the distillate obtained will be considerably stronger than if the process had been carried on to the end. Moreover, another advantage derived from checking the process before the end, and keeping the last portions of the distillate separate from the rest, besides that of obtaining a stronger spirit, is that a much purer one is produced. The volatile essential oils, mentioned above, are soluble only in strong alcohol, and insoluble in its aqueous solutions. They distil also at a much higher temperature than alcohol, and so are found only among the last products of the distillation, which result from raising the temperature of the boiling liquid. This system of checking the distillation and removing the products at different points is frequently employed in the practice of rectification.

The apparatus employed in the process of distillation is called a "still," and is of almost infinite variety. The very simplest form is shown in Fig. 227, and consists of two essential parts, the still or boiler A, which is made of tinned copper, and enters the furnace, and the cooler or warmer B, a pipe of block-tin or tinned copper, bent into a spiral and connected with the top of the still. The liquid is boiled in the still, and the vapours passing over are condensed in the pipe, which is placed in a tub or vessel C containing cold water. This apparatus is not much employed in distilling, as it is impossible to get sufficiently pure products from it on a commercial scale. In an arrangement of this kind, the vapours of alcohol and water are condensed together. But if, instead of filling the cooler with cold water, it be kept at a temperature of 80° C. (176° F.), the greater part of the water will

FIG. 227.

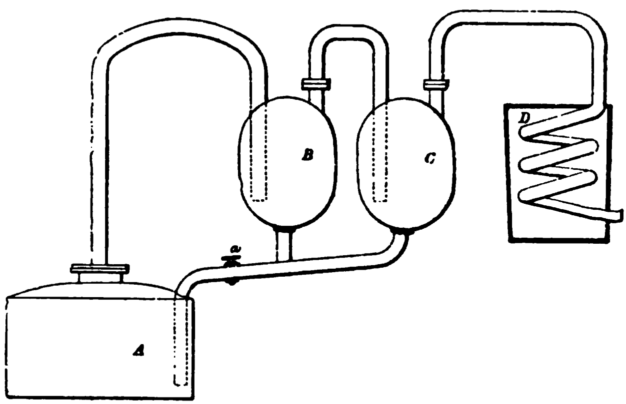


Simple Still.

be condensed; while the alcohol, boiling at 78° C. (172° F.), passes through the coil uncondensed. If, therefore, the water be condensed and collected separately in this manner, and the alcoholic vapours be conducted into another cooler, kept at a temperature below 78° C. (172° F.), the alcohol will be obtained in a much higher state of concentration than it would be by a process of simple distillation. Supposing, again, that vapours containing but a small quantity of alcohol are brought into contact with an alcoholic liquid of lower temperature than the vapours themselves, and in very small quantity, the vapour of water will be partly condensed, so that the remainder will be richer in alcohol than it was previously. But the water, in condensing, converts into vapour a portion of the spirit contained in the liquid interposed, so that the uncondensed vapours passing away are still further enriched by this means. Here, then, are the results obtained: the alcoholic vapours are strengthened, firstly, by the removal of a portion of the water wherewith they were mixed; and then by the admixture with them of the vaporised spirit placed in the condenser. By the employment of some such method as this, a very satisfactory yield of spirit may be obtained, both with regard to quality, as it is extremely concentrated, and to the cost of production, since the simple condensation of the water is made use of to convert the spirit into vapour without the necessity of having recourse to fuel. The construction of every variety of distilling apparatus now in use is based upon the above principles.

The first distilling apparatus for the production of strong alcohol on an industrial scale was invented by Edward Adam, in the year 1801. The arrangement is shown in Fig. 228 in

FIG. 228.



Adam's Still.

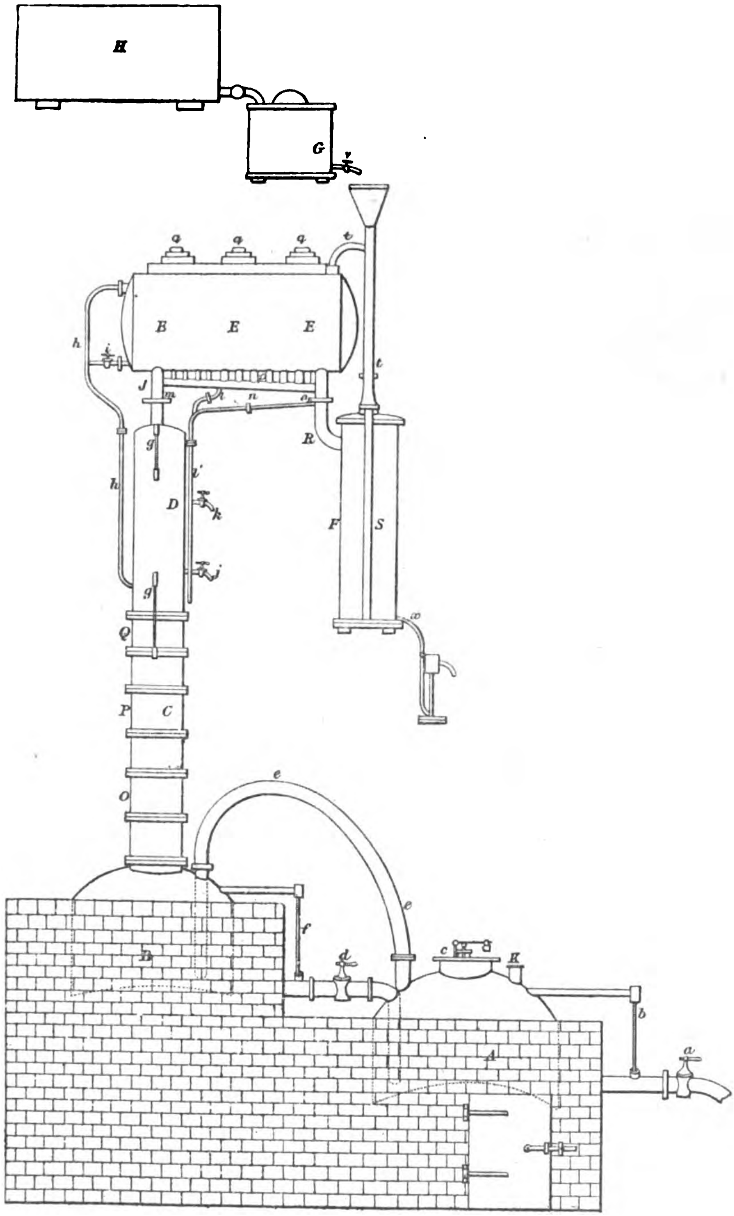
which A is a still to contain the liquor. The vapours are conducted by a tube into the egg-shaped vessel B, the tube reaching nearly to the bottom; they then pass out by another tube into a second egg C; then, in some cases, into a third, not shown in the figure, and finally into the worm D. The liquor condensed in the first egg is stronger than that in the still, while that found in the second and third is stronger than either. The spirit which is condensed at the bottom of the worm is of a very high degree of strength. At the bottom of each of the eggs is a tube connected with the still, by which the concentrated liquors can be run back into it. In the tube is a stop-cock *a*, by regulating which, enough liquor can be kept in the eggs to cover the lower ends of the entrance pipes; so that the alcoholic vapours are not only deprived of water by the cooling which they undergo in passing through the eggs, but are also mixed with fresh spirit obtained from the vaporisation of the liquid remaining in the bottom of the eggs, in the manner already described.

Adam's arrangement fulfilled, therefore, the two conditions necessary for the production of strong spirit inexpensively; but unfortunately it had also serious defects. The temperature of the egg could not be maintained at a constant standard, and the bubbling of the vapours through the liquor inside created too high a pressure. It was, however, a source of great profit to its inventor for a long period, although it gave rise to many imitations and improvements of greater or less merit. Among these are the stills of Solimani and Berard, which more nearly resemble those of the present day.

Utilising the experience which had been gained by Adam, Solimani, and Berard, and avoiding the defects which these stills presented, Cellier-Blumenthal devised an apparatus which has become the basis of all subsequent improvements; indeed, every successive invention has differed from this arrangement merely in detail, the general principles being in every case the same. The chief defect in the three stills above mentioned was that they were intermittent, while that of Cellier-Blumenthal is continuous; that is to say, the liquid for distillation is introduced at one end of the arrangement, and the alcoholic products are received continuously, and of a constant degree of concentration, at the other.

The saving of time and fuel resulting from the use of this still is enormous. In the case of the previous stills, the fuel consumed amounted to a weight nearly three times that of the

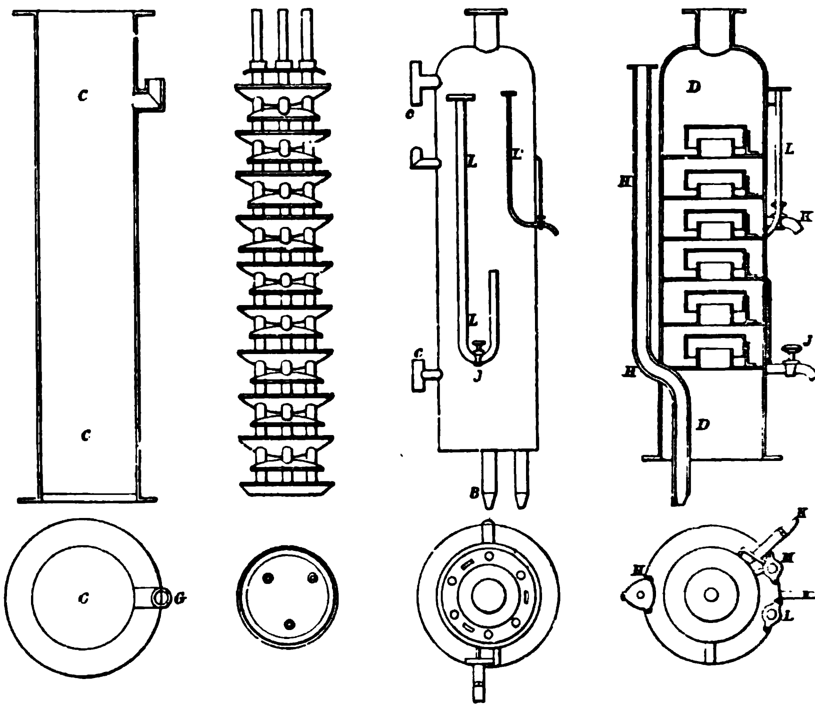
FIG. 229.



Cellier-Blumenthal Apparatus.

spirit yielded by it; whereas, the Cellier-Blumenthal apparatus reduces the amount to one-quarter of the weight of alcohol produced. Fig. 229 shows the whole arrangement, and Figs. 230–33 represent different parts of it in detail. In Fig. 229, A is a boiler, placed over a brick furnace; B is the still, placed beside it, on a slightly higher level, and heated by the

FIG. 230. FIG. 231. FIG. 232. FIG. 233.



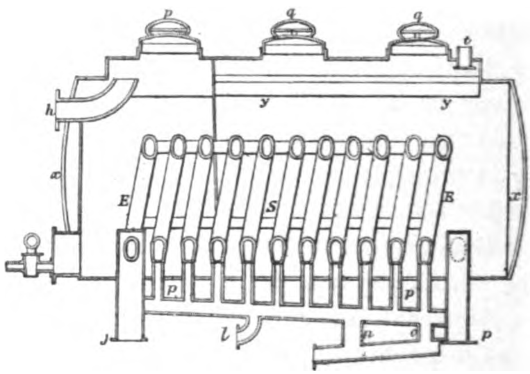
Cellier-Blumenthal Still, details.

furnace flue which passes underneath it. A pipe *e* conducts the steam from the boiler to the bottom of the still. By another pipe *d*, which is furnished with a stop-cock, and which reaches to the bottom of the still A, the alcoholic liquors in the still may be run from it into the boiler; by opening the valve K, the spent liquor may be run out at *a*. The glass tubes *b* and *f* show the height of liquid in the two vessels. The still is surmounted by a column C, shown in section in Fig. 230. This column contains the arrangement shown in Fig. 231, which consists of a series of spherical copper capsules, placed one above the other, and kept apart by three metallic rods passing through the series. These capsules are of different diameters; the larger ones, which are nearly the diameter of the column, are placed with the rounded side downwards, and are pierced with small holes; the smaller ones are turned bottom upwards. Into the top capsule is made to flow a stream of the liquid to be distilled, which, running through the small holes, falls upon the smaller capsule beneath, and from this upon the one next below, and so throughout the whole of the series, until it reaches the bottom and falls into the still. The vapours rise up into the column from the still and meet the stream of spirit, converting it partially into vapour, and pass out at the top, considerably enriched, into the column D, Fig. 229, which contains a system resembling in principle that of Adam; here the vapours are still further strengthened.

Fig. 232 is an exterior, and Fig. 233 a sectional view of this column, the "rectifying column," as it is called. It contains six vessels, placed one above the other in an inverted position. These are so disposed that the vapours traverse a thin layer of liquor in each. The condensed liquid flows back into the column C, and the uncondensed vapours pass into the next part of the apparatus.

Leaving this column, the vapours are conducted into a horizontal cylinder E containing a coil S, Fig. 234, which lies in a hot liquid. This liquid is the liquor which has to be distilled. Entering by the pipe *t*, Fig. 234, it is distributed over holes in the plate *y*, and, falling in drops into the cylinder, is heated by contact with the coil S. The cylinder is divided into two compartments by a diaphragm which is pierced with holes at its lower extremity; through these holes, the liquor flows into the second compartment, and passes out at the top, where it runs through the pipe *a*, into the top of the column C. The vapours are made to traverse the coil S, which is kept at an average temperature of 50° C. (122° F.) in the right-hand compartment, and somewhat higher in the other. They pass first through J into the hottest part of the coil, and there give up much of the water with which they are mixed; and the process of concentration continues as they pass through the coil. Each spiral is connected at the bottom with a vertical pipe, by which the condensed liquors are run off; these are conducted into the pipe P. Those liquors which are condensed in the hottest part of the coil, and are consequently the

FIG. 234.



Cellier-Blumenthal Still.

weakest, are led by the pipe L into the third vessel in the column D, Fig. 229, while the stronger portions pass through L into the fifth. The stop-cocks *a o* regulate the flow of liquid into these vessels, and consequently also the strength of the spirit obtained.

Lastly, as they leave the cylinder, the highly concentrated vapours are condensed in the vessel F, which contains another coil. This is kept cool by a stream of liquor flowing from the reservoir H into the smaller cistern G, from which a continuous and regular flow is kept up through the tap *o* into the funnel tube S, and thence into the condenser F; it ultimately flows into the cylinder E through the pipe *t*, there being no other outlet. The finished products run out by the pipe *x* into suitable receivers.

Special Processes relating to Rum.—Rum may be described as an alcohol obtained from molasses. Molasses is the uncrystallisable syrup which constitutes the residuum of the manufacture and refining of cane and beet sugar. It is a dense, viscous liquid, varying in colour from light yellow to almost black, according to the source from which it is obtained; it tests usually about 40° by Baumé's hydrometer. The molasses employed as a source of alcohol must be carefully chosen; the lightest in colour is the best, containing most uncrystallised sugar. The manufacture is extensively carried on in France, where the molasses from the beet sugar refineries is chiefly used on account of its low price, that obtained from the cane sugar factories being considerably dearer. The latter is, however, much to be preferred to the former variety, as it contains more sugar. Molasses from the beet sugar refineries yields a larger quantity and better quality of spirit than that which comes from the factories. Molasses contains about 50 per cent. of saccharine matter, 24 per cent. of organic matter, and about 10 per cent. of inorganic salts, chiefly of potash. It is thus a substance rich in matters favourable to fermentation. When the density of molasses has been lowered by dilution with water, fermentation sets in rapidly, more especially if it has been previously rendered acid. As, however molasses from beet generally exhibits an alkaline reaction, it is found necessary to acidify it after dilution; for this purpose, sulphuric acid is employed, in the proportion of about 4½ lb. of the concentrated acid to 22 gallons of molasses previously diluted with 8 or 10 volumes of water. Three processes are thus employed in obtaining alcohol from molasses: dilution, acidification, and fermentation. The latter is hastened by the addition of a natural ferment, such as brewers' yeast. It begins in about 8 or 10 hours, and lasts upwards of 60.

In Germany, where duty is imposed upon the distilleries according to the capacity of the fermenting vats, the molasses is not diluted to such an extent as in France, where the duty is upon the manufactured article. In the former case, the liquor, before fermentation, tests usually as high as 12° B., whereas in France it is diluted until it tests 6° or 8° B., a degree which is much more favourable to rapid and complete fermentation. In consequence of this difference in the concentration of the unfermented liquor, the degree of temperature at which the process is begun is higher in the case of the strong liquor than when it is more dilute. In Germany, the temperature at which fermentation begins is about 25° C. (77° F.), and this is raised during the operation to 30° C. (86° F.), whilst in France a much lower temperature suffices. Moreover, owing to the enormous size of the French vats, the temperature rises so quickly that it must be moderated by passing a current of cold water through a coil of pipe placed on the bottom of the vat. Two cwt. of molasses at 42° B. will furnish about 6 gallons of pure spirit. The spirit of molasses has neither the taste nor the odour of spirit from wine; it is sweeter, and when the distillation and rectification have been properly conducted, it may be considered as a type of alcohol in its purity, for it has neither taste nor any peculiar aroma. In this state it is called "fine spirits," and may be employed in the manufacture of liqueurs, for improving common brandies, and especially for refining the *trois-six* (rectified spirit) of Montpellier.

In those districts of France where the beet is largely cultivated for the manufacture of sugar, and the molasses is converted into alcohol, the waste liquor is made a source of no inconsiderable profit, by concentrating it and incinerating the residue, from which is obtained, for the use of the soap-boiler, a caustic potash of superior quality. In addition to the alcohol, good beet molasses will yield 10 or 12 per cent. of commercial, or from 7 to 8 per cent. of refined potash. In addition to this, a method has lately been proposed by Camille Vincent for collecting the ammonia-water, tar, and oils given off when this residue is calcined, and utilising them for the production of ammonia and chloride of methyl, which latter substance possesses considerable commercial value.

Besides the molasses of the French beet sugar refineries, large quantities result from the manufacture of cane sugar in Jamaica and the West Indies. This is entirely employed for the distillation of rum. As the pure spirit of Jamaica is never made from sugar, but always from molasses and skimmings, it is advisable to notice these two products, and together with them, the exhausted wash commonly called "dunder."

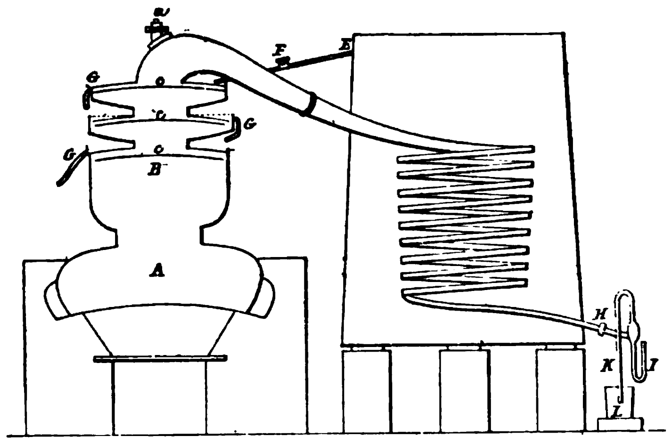
The molasses proceeding from the West Indian sugar cane contains crystallisable and uncrystallisable sugar, gluten, or albumen, and other organic matters which have escaped separation during the processes of defecation and evaporation, together with saline matters and water. It therefore contains in itself all the elements necessary for fermentation, i. e. sugar, water, and gluten, which last substance, acting the part of a ferment, speedily establishes the process under certain conditions. "Skimmings" comprise the matters separated from the cane juice during the processes of defecation and evaporation. The scum of the clarifiers, precipitators, and evaporators, and the precipitates in both clarifiers and precipitators, together with a proportion of cane sugar mixed with the various scums and precipitates, and the "sweet liquor' resulting from the washing of the boiling pans, &c., all become mixed together in the skimmings-receiver, and are fermented under the name of "skimmings." They also contain the elements necessary for fermentation, and accordingly they very rapidly pass into a state of fermentation when left to themselves; but in consequence of the glutinous matters being in excess of the sugar, this latter is speedily decomposed, and the second, or acetous fermentation commences very frequently before the first is far advanced. "Dunder" is the fermented wash after it has undergone distillation, by which it has been deprived of the alcohol it contained. To be good, it should be light, clear, and slightly bitter; it should be quite free from acidity, and is always best when fresh. As it is discharged from the still, it runs into receivers placed on a lower level, from which it is pumped up when cool into the upper receivers, where it clarifies, and is then drawn down into the fermenting cisterns as required. Well-clarified dunder will keep for six weeks without any injury. Good dunder may be considered to be the liquor, or "wash," as it is termed, deprived by distillation of its alcohol, and much concentrated by the boiling it has been subjected to; whereby the substances it contains, as gluten, gum, oils, &c., have become, from repeated boilings, so concentrated as to render the liquid mass a highly aromatic compound. In this state, it contains at least two of the elements necessary for fermentation, so that, on the addition of the third, viz. sugar, that process speedily commences.

The first operation is to clarify the mixture of molasses and skimmings previous to fermenting it. This is performed in a leaden receiver holding about 300 or 400 gallons. When the clarification is complete, the clear liquor is run into the fermenting vat, and there mixed with 100 or 200 gallons of water (hot, if possible), and well stirred. The mixture is then left to ferment. The great object that the distiller has in view in conducting the fermentation is to obtain the largest possible amount of spirit that the sugar employed will yield, and to take care that the loss by evaporation or acetification is reduced to a minimum. In order to ensure this, the following course should be adopted. The room in which the process is carried on must be kept as cool as it is possible in a tropical climate; say, 24° to 27° C. (75° to 80° F.).

Supposing that the fermenting vat has a capacity of 1000 gallons, the proportions of the different liquors run in would be 200 gallons of well-clarified skimmings, 50 gallons of molasses, and 100 gallons of clear dunder; they should be well mixed together. Fermentation speedily sets in, and 50 more gallons of molasses are then added, together with 200 gallons of water. When fermentation is thoroughly established, a further 400 gallons of dunder may be run in, and the whole well stirred up. Any scum thrown up during the process is immediately skimmed off. The temperature of the mass rises gradually until about 4° or 5° C. above that of the room itself. Should it rise too high, the next vat must be set up with more dunder and less water; if it keeps very low, and the action is sluggish, less must be used next time. No fermenting principle besides the gluten contained in the wash is required. The process usually occupies 8 or 10 days, but it may last much longer. Sugar planters are accustomed to expect 1 gallon of proof rum for every gallon of molasses employed. On the supposition that ordinary molasses contains 65 parts of sugar, 32 parts of water, and 3 parts of organic matter and salts, and that, by careful fermentation and distillation, 33 parts of absolute alcohol may be obtained, we may then reckon upon 33 lb. of spirit, or about 4 gallons, which is a yield of about 5⅜ gallons of rum, 30 per cent. over-proof, from 100 lb. of such molasses.

The operation of distilling is often carried on in the apparatus represented in Fig. 235. It was originally invented by Corty, but has since undergone much improvement. A is the body of the still, into which the wash is put; B the head of the still; *c*, three copper plates fitted upon the upper part of the three boxes; these are kept cool by a supply of water from the pipe E, which is distributed by means of the pipes G. The least pure portion of the ascending vapours is condensed as it reaches the lowest plate, and falls back, and the next portion as it reaches the second plate; while the purest and lightest vapours pass over the goose-neck, and are condensed in the worm. The temperature of the plates is regulated by altering the flow of water by means of the cock F. For the purpose of cleaning the apparatus, a jet of steam or water may

FIG. 235.



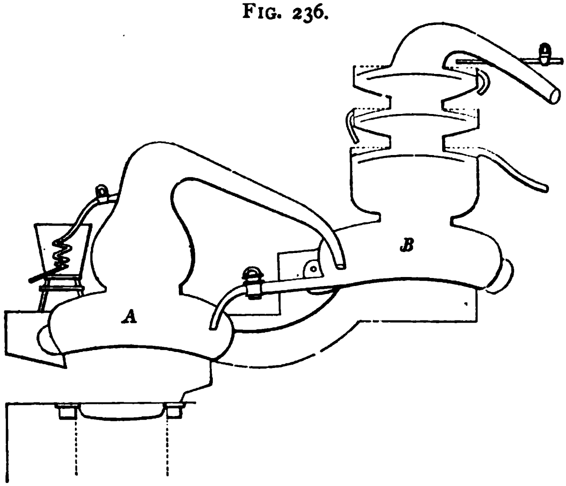
Corty's Rum Still.

be introduced at *a*. A gas apparatus is affixed at the screw-joint H, at the lower end of the worm, which addition is considered an important part of the improvement. The portion of the apparatus marked I becomes filled soon after the operation has commenced; the other end of the pipe K is immersed in water in the vessel L. The advantage claimed for this apparatus is that the condensation proceeds in a partial vacuum, and that there is therefore a great saving in fuel. One of these stills, having a capacity of 400 gallons, is said to work off four or five charges during a day of 12 hours, furnishing a spirit 35 per cent. over-proof.

Fig. 236 represents a double still which is largely employed in the colonies. It is simply an addition of the common still A to the patent still B. From time to time the contents of B are run off into A, those of A being drawn off as dunder, the spirit from A passing over into B. Both stills are heated by the same fire; and it is said that much fine spirit can be obtained by their use at the expense of a very inconsiderable amount of fuel.

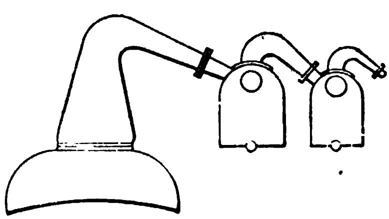
In Jamaica, however, nothing is likely to supersede the common still and double retorts, shown in Fig. 237. It is

FIG. 236.



Double Rum Still.

FIG. 237.

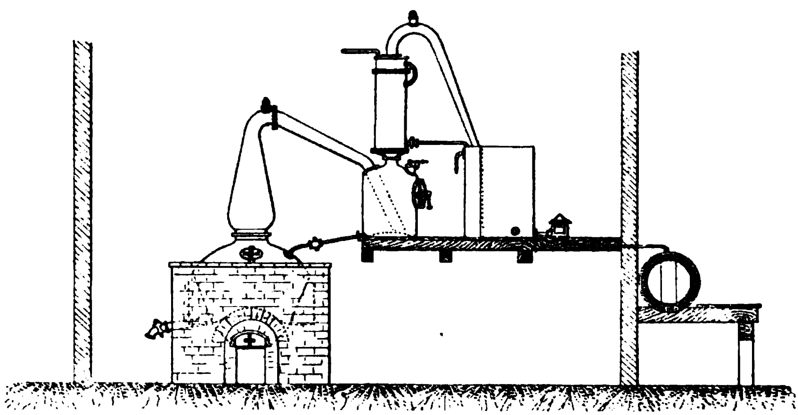


Jamaica Still.

usually the custom to pass the tube from the second retort through a charger containing wash, by which means the latter is heated previous to being introduced into the still; the tube then proceeds directly to the worm-tank. With an arrangement of this kind, a still holding 1000 gallons should produce 500 gallons of rum (30 to 40 per cent. over-proof), between the hours of five in the morning and eight in the evening. The first gallon of spirit obtained is termed "low wines," and is used for charging the retorts, each of which contains 15 to 20 gallons. After this, rum of 40 to 45 per cent. over-proof flows into clean cans or other vessels placed to receive it.

The fire-heated pot rum still in common use, as made by Manlove, Alliott, Fryer, & Co., is shown in Fig. 238. The

FIG. 238.

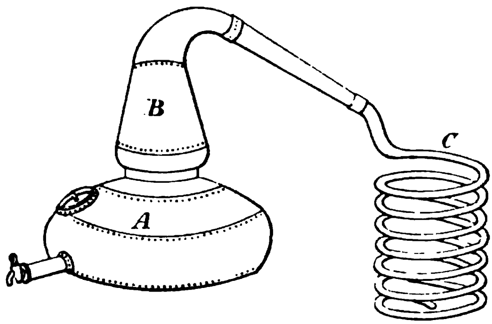


Manlove & Co.'s Fire-heated Rum Still.

copper still body, which is sometimes made as large as 12 feet in diameter, is set in brickwork over a furnace with a circular flue leading to a chimney. To the upper part of the still body a swan neck is connected, which again is connected with the upper part of the low wines receiver, a return cock and pipe being arranged for running low wines back to the still. A large outlet cock with copper connecting pipe leading outside the brickwork is provided for emptying the still body. Above the low wines receiver is fixed the rectifier—a cylindrical copper vessel filled with water, and containing a large number of small diameter tubes, upwards through which the alcoholic vapours are made to pass on their way to the worm. A continuous supply of cold water enters at the upper part of the rectifier casing, passes downwards through and around the tubes, and leaves by the lower part of the casing conveyed by a pipe to the worm tank. A taper copper pipe leads from the upper part of the rectifier downwards to a taper copper condensing worm, set in a large tank, through which a supply of cold water is continually passing. In this worm the final condensation of the alcoholic vapours takes place, and from the lower end of the worm the spirit is run off into a brass safe, with glass panels, brass cover and lock, and containing glass test vessels in which are floated areometers, thus enabling the attendant to divert the stream of spirit issuing from the safe by one or other of two separate copper pipes leading to the lock-up spirit room, so that spirit of varying densities may be run into separate collecting vessels without affording any ready means of access to the spirit in the still room. The usual fittings on the still body consist of manhole door, and cover of brass, air valve, wash-out cock, and supply cock. It is also frequently fitted with revolving brass stirrers and drag chains, worked by a vertical shaft passing upwards through a gland at the top of the swan neck, and worked by hand or steam-power gear outside. The stirrers are useful in preventing the adherence of any solid matter to the bottom of the still, and keeping up a constant admixture of the various contents. Automatic air valves are fixed on the highest part of the swan neck and pipe leading from the rectifier to the worm, so that all the air can be readily swept out of the still on commencing work, and thus prevent a vacuum forming in it, and any subsequent danger of its collapsing by external pressure.

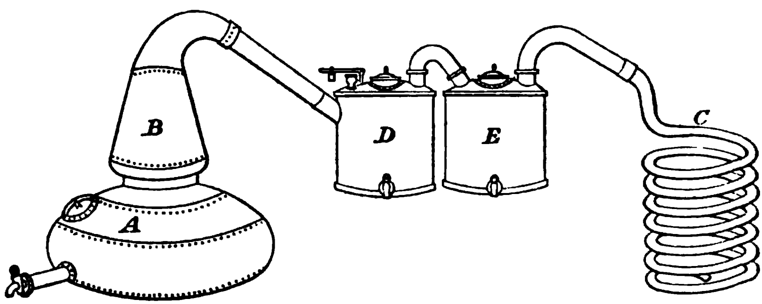
Pontifex and Wood, Limited, have supplied large numbers of the ordinary pot-fire stills to planters and distillers in Jamaica and the colonies; the most general form being similar to Fig. 239. A, is the still, B, the head, and C, the condensing worm. The retorts D and E (Fig. 240), having a limited rectifying effect, are sometimes inserted: we are informed that the manufacture of rum pays at the present time better than sending home the sugar, owing to the condition of that trade in England.

FIG. 239.



Copper Fire Still.

FIG. 240.

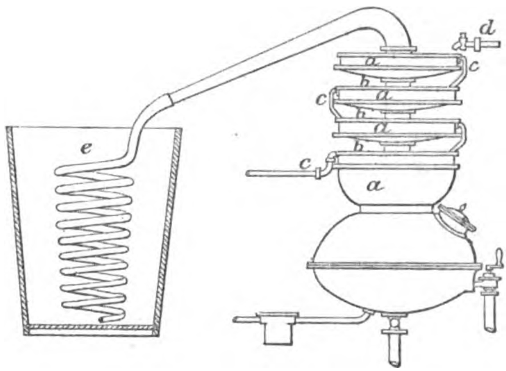


Copper Fire Still with 2 Retorts.

Fire stills are thought a great deal of by some distillers, as they state that the action of the fire imparts a flavour of its own to the spirit, but a copper steam still with head and worm is preferable, both for economy of fuel and cleanliness.

For obtaining a stronger spirit, and, at the same time, retaining the flavour, "Corty's" rectifying head is used, as in Fig. 241, in place of the ordinary head. Its action is as follows :—the vapour passes into the chambers *a* by means of pipes *b*, where it is made to go against the top of these chambers by means of baffle plates; the still is first charged with the wash, the steam then being turned on by means of the lower valve into the jacket. A small stream of cold

FIG. 241.

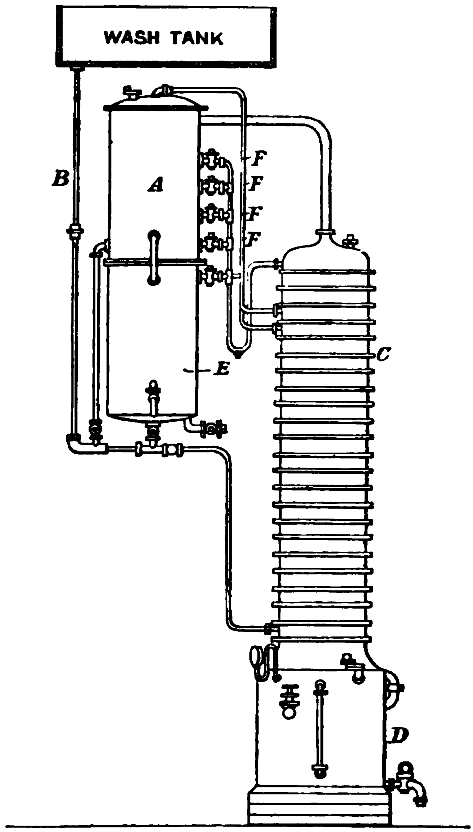


Steam Still with Corty's Head.

water is allowed to flow on the top chamber *a*, by the cock *d*, which overflows on the other chambers *a*, *a*, and *a*, by means of the overflow pipes *c*; the water gets gradually warmed, the cold water meeting the cooled or rectified vapour which passes into the condensing worm *e*, to be condensed.

The "Pontifex" Improved Steam Continuous-working Distilling Apparatus, Fig. 242, is the best for dealing with large quantities, say from six to 600 gallons of proof spirit per hour, from wash obtained from molasses. The advantages claimed are: great economy of fuel, time, labour, and that neutral spirit can be obtained 67 degrees over proof, of great purity, in one continuous and uninterrupted operation. Briefly, the method of working is as follows:—the wash is first elevated by means of a pump to the wash tank; thence it runs into the rectifier A by means of the pipe B; after rectifying, the vapour goes into the analysing column C, and flows down, by means of trapped drip-pipes, to the steam still D. The vapour generated by the steam in still D passes up the analysing column C, which is formed by a number of perforated plates or diaphragms and chambers with the above

FIG. 242.



Pontifex Continuous Still.

drip-pipes standing up so as to keep always a film of wash on the plates; the aqueous part of the vapour is then partially separated and condensed from the alcoholic vapour which ascends to the rectifying coil, with the improved pockets F for catching any water again condensed. The spirit then passes on to the condenser E, where it is condensed and cooled down to the ordinary temperature required, without the aid of any refrigerator, as is necessary with other stills of a similar class.

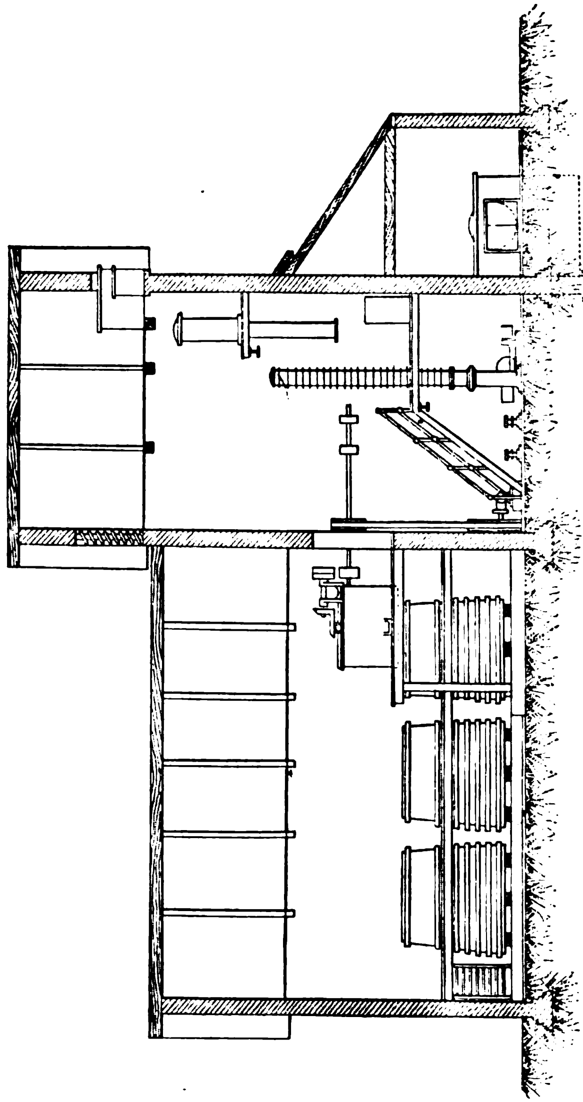
This class of continuous still gained the gold medal at the Cape Town Exhibition in 1877.

The alcohol made by these continuous stills is used for blending with various drinkable spirits, for methylating, and for being artificially flavoured and coloured, to make rum for the market.

Arrangement of Rum Distillery.—Figs. 243, 244, 245 show an arrangement designed by Manlove, Alliott, Fryer, & Co. Molasses, scum, sediment, and washings are mixed with "dunder" or spent wash in the mixing vat shown on the upper stage. After being thoroughly incorporated, the mixture is led down into the fermenting vats, where it is left until fermentation is completed. The fermented wash is then raised from the fermenting vats into a high-level wash-tank by means of a small steam pump. From the wash-tank the wash passes downwards through the refrigerator into the upper chamber of the continuous column of the still. This column consists of a number of duplicate chambers of brass or copper, each fitted with a horizontal diaphragm, with projecting nozzles so arranged that the wash in passing downwards through the system of boxes and flowing over the upper edges of the nozzles is met by an ascending current of vapour, which, being brought into intimate contact with the wash, is partially condensed, thus raising the temperature of the wash and permitting alcoholic vapours to become gradually purified on their passage upwards to the refrigerator.

Between the top of the column and the condenser a small save-all is provided to intercept any watery particles that may be carried over by the alcoholic vapours. In the refrigerator the wash on its way to the still column is heated by warm alcoholic vapours from the still column. These again are freed in the refrigerator from a further portion of watery vapour,

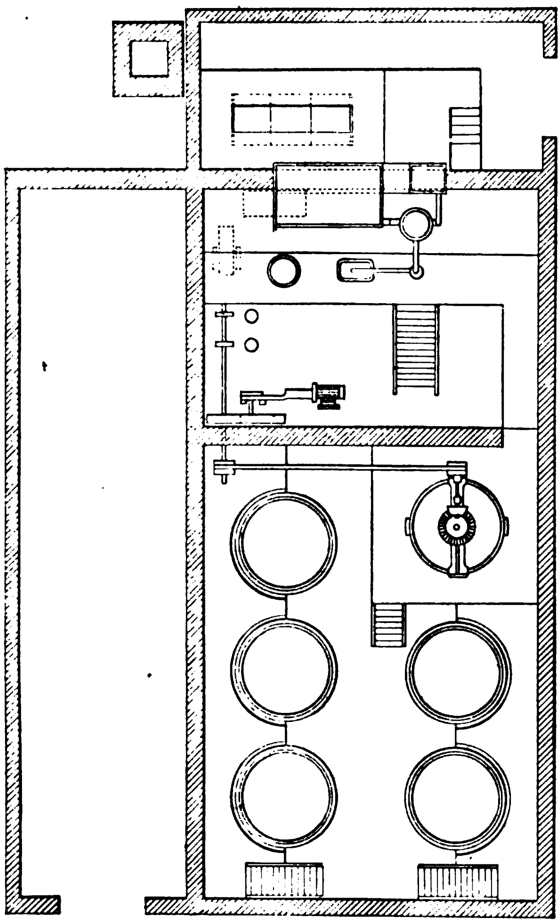
FIG. 243.



Manlove & Co.'s Rum Distillery.

and thence pass downwards into the condenser, where the final condensation of the alcoholic vapours takes place, and from the bottom of which the steam is drawn off to the spirit room. At the point where the spirit leaves the condenser a small closed glass vessel is provided with the necessary testing apparatus to ascertain the strength of the spirit. The

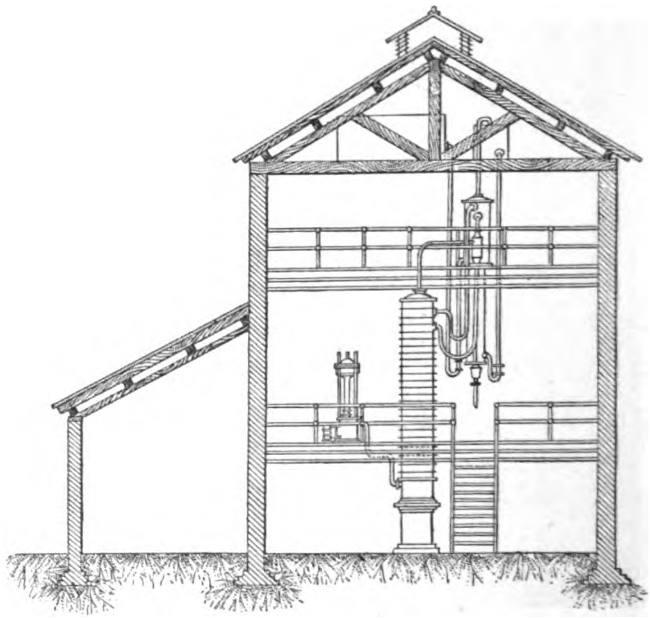
FIG. 244.



Manlove & Co.'s Rum Distillery.

water supply for the condenser is drawn from the water-tank on the overhead stage alongside the wash-tank. This tank is supplied by a small pump driven by an engine shown on the ground floor. This engine also drives a pump or pumps for raising molasses and other materials to the mixing vat, and also drives the agitators of the mixing vat. The wash on arriving at the bottom of the still column is heated by steam blown directly into the wash. The supply of steam is con-

FIG. 245.



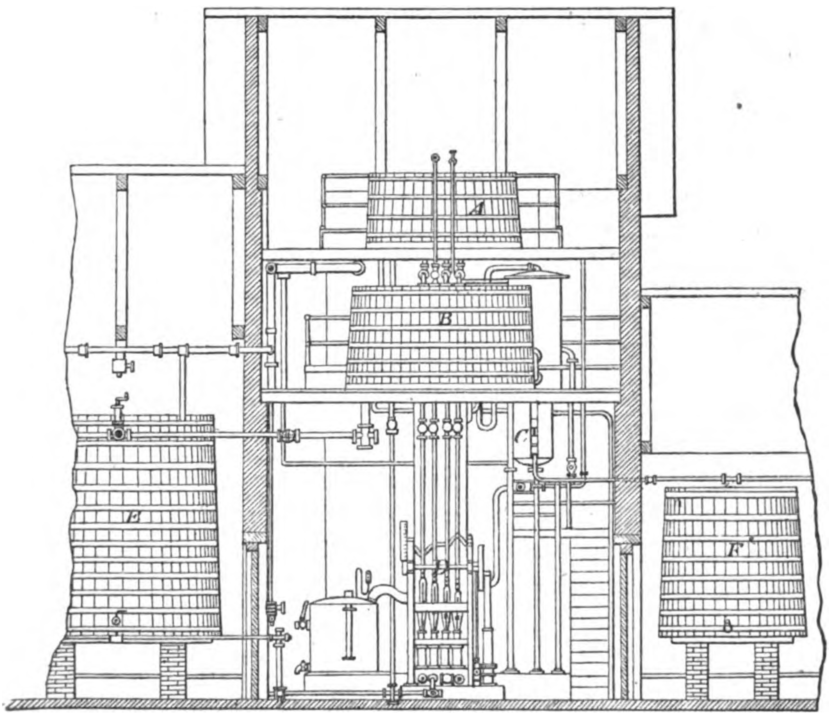
Manlove & Co.'s Rum Distillery.

trolled by the regulator or governor shown on the staging alongside the still column. The action of this governor is as follows :—

The lower vessel of the governor is connected with the base of the still, which is also connected to a special steam-regulating valve fixed on the lower part of the governor casing. The slight pressure in the lower part of the still forces the wash into the lower part of the regulator. If steam continues to be admitted, and the pressure in the base of the still increases, the wash in the base of the regulator is forced up the central pipe into the upper chamber of the regulator, where it raises a float and shuts off the steam supply to the still. On the pressure at the bottom of the still decreasing, the level of the wash in the regulator falls, the float follows and opens the steam valve, and the spent wash or "dunder" is run off from the base of the still.

Steam is supplied by a multitubular boiler, with a special grate arranged for burning megass.

FIG. 246.



Brazilian Still House.

Fig. 246 shows the arrangement of one still-house of six made for the Brazilian Central Sugar Factories, as designed and erected by Pontifex and Wood, Limited, of London. The still is capable of making 50 gallons of proof spirit per hour from molasses. The parts are: A, wash back; B, mixing vat; C, continuous still; D, pumps; E, fermenting vats; F, spirit store vats. The same firm design and erect distilling plant for making spirit from grain, fruits, wines, &c.

Purifying.—When new, rum is white and transparent, and has a peculiar, unpleasant flavour, which is generally understood to proceed from the aromatic essential oil contained in the rind of the cane; but apart from this, an empyreumatic oil appears to be generated during the fermentation of the wash, which Liebig ascribes to the interchange of the elements of sugar and gluten. This flavour is, however, exceedingly undesirable, and has to be removed before the spirit is fit for the market; this may be done by the use of charcoal and lime, the former to absorb, and the latter to combine with the oil, and to precipitate it in the form of a soap. A wooden box, about 2 feet long and 1 foot in diameter, with a division running down to within an inch of the bottom, is filled with coarsely powdered charcoal, through which the spirit is made to pass as it runs from the worm. The charcoal absorbs a considerable portion of the oil, and the rum consequently flows from the filter much purified. It is then conveyed to the rum butt (of about 300 or 500 gallons capacity), which is situated at a good elevation, and at once heated with a little caustic lime, and well stirred-up. After an interval of two days, the flavour may be tried, and if found satisfactory, the contents of the butt may be drawn off through a charcoal filter, similar to the first, into the colouring butt to be coloured. But if the lime used be not enough, a little more must be added, mixing the whole together again; and after two days it may be run off as noticed. At this period, the lime will be seen at the bottom of the butt in combination with the oil, forming together a kind of soapy precipitate.

When this process has been carefully conducted, quite new rum may be afforded the appearance and flavour of aged spirit. Pineapple juice is sometimes employed by the planters for the purpose of ageing new rum.

Colouring.—The next operation is to colour the rum, and this is a very important part of the process. It frequently happens that really good rum is quite spoilt by being badly coloured, and this should therefore be strictly attended to. The best description of sugar for boiling "colouring" is a well-grained muscovado, such as is commonly chosen in Jamaica. It is placed in a large copper or iron boiling-pan, to which heat is applied. The contents are well stirred up by means of a wooden oar or rake throughout the process. As the boiling proceeds bubbles rise, large and heavy at first, then small and more quickly, the colour of the mass changing from brown to deep black. The fire is then withdrawn, and some strong proof rum is added, the whole being stirred hard meanwhile. When quite cool, it is poured into a cask and allowed to settle. Good colouring is quite thick, clear, and bright; three pints should be sufficient to colour 100 gallons of spirit. When coloured, the rum is filled into hogsheads for sale or shipment.

Commerce.—Pure rum, as made in the West Indies, is not often met with in commerce. The spirit which is so largely drunk in England as rum, is in reality nothing more than mixtures of British spirit, or "silent" spirit, as it is called, with small quantities of genuine rum, and of "essence of rum," a butyric compound made for the purpose of preparing a fictitious rum. The greater portion probably contains no genuine rum at all, and consists merely of silent spirit, or beet spirit, flavoured with this volatile essence. The consumption of rum is steadily declining in England, its place being taken by gin. The duty on the genuine article, if imported direct from any of the British colonies, is 10*s.* 2*d.* per proof gallon; but if imported from any other part of the world, it is 10*s.* 5*d.*

per gallon. It is consumed in considerable quantities in the Royal Navy. It is often more profitable to re-distil the rum until it is simply proof spirit, or nearly pure alcohol, in which state it finds a good market in France, for the preparation of brandies.

ALCOHOL FROM BEET.—It will be interesting to many sugar planters to know something of the manufacture of spirit from the beetroot. Beet contains 85 per cent. of water, and about 10 per cent. of sugar, the remainder being woody fibre and albumen. The conversion of the sugar into alcohol is effected in several different ways, of which the following are the principal:—(1) By rasping the roots and submitting them to pressure, and fermenting the expressed juice; (2) By maceration with water and heat; (3) By direct distillation of the roots.

By Rasping and Pressure.—The spirit obtained by this process is much preferable to that obtained by the others, but it is considerably higher in price, as it requires a larger stock and much more labour. The process is adopted chiefly in the large sugar factories, where all the necessary utensils are always at hand, and the only additional expense incurred is the distilling apparatus. The roots are washed, rasped, and pressed exactly as in the manufacture of sugar. By this means, 80 or 85 per cent. of juice is obtained, but this proportion is much increased by permitting a stream of water to flow upon the rasping instrument. The utmost cleanliness is essential to these processes; all the utensils employed should be washed daily with lime-water to counteract acidity.

Before fermentation, the juice from the rasper and the press is brought into a boiler and heated by steam to about 28° C. (82° F.); at this temperature it is run off into the fermenting vats. Here it is necessary to add to the juice a small quantity of concentrated sulphuric acid for the purpose of neutralising the alkaline salts which it contains, and of rendering it slightly acid in order to hasten the process; this quantity must not exceed 2½ kilo. (5½ lb.) to every 220 gallons of juice, or the establishment of fermentation would be hindered instead of promoted. The addition of this acid tends also to prevent the viscous fermentation to which the juice obtained by rasping and pressure is so liable. Although the beet contains albumen, which is in itself a ferment, it is necessary, in order to develop the process, to have recourse to artificial means. A small quantity of brewers' yeast—about 5 grains per pint of juice—is sufficient for this; the yeast must previously be mixed with a little water. An external temperature of about 20° C. (68° F.) must be carefully maintained.

The fermentation of acidulated beet-juice sets in speedily. The chief obstacle to the process is the mass of thick scum which forms upon the surface of the liquor. This difficulty is sometimes obviated by using several vats, and mixing the juice, while in full fermentation, with a fresh quantity. Thus, when three vats are employed, one is set to ferment; at the end of four or six hours, half its contents are run into the second vat, and here mixed with fresh juice. The process is arrested, but soon starts again in both vats simultaneously; the first is now allowed to ferment completely, which is effected with much less difficulty than would have been the case had the vat not been divided. Meanwhile the second vat, as soon as the action is at its height, is divided in the same manner, one-half its contents being run into the third. When this method is employed, it is necessary to add a little yeast from time to time when the action becomes sluggish.

By Maceration.—The object of this process is to extract from the beets by means of water or spent liquor all the sugar which they contain, without the aid of rasping or pressure. Spirit is thus produced at considerably less expense, although it is not of so high a quality as that yielded by the former process. The operation consists in slicing up the beets with a root-cutter, and then allowing the slices to macerate in a series of vats at stated temperatures. It is essential that the knives by which the roots are cut should be so arranged that the roots are divided into slices having a width of $\frac{1}{2}$ inch and a thickness of $\frac{1}{25}$ inch, and a variable length; the roots are of course well washed before being placed in the hopper of the cutter. When cut, the beets are covered with boiling water in a macerator of wood or iron for one hour; the water should contain 2 lb. of sulphuric acid to every 1000 lb. of beets. After this, the water is drawn off into a second vat, in which are placed more beets, and allowed to macerate again for an hour. This is repeated a third time in another vat, and the juice, which has now acquired a density equal to that obtained by rasping, is run off into the fermenting vat.

When the first vat is empty, it is immediately refilled with boiling water and fresh beets; the juice from this operation is run into the second vat, when the contents of that one are run into the third. To continue the operation, the beets are completely exhausted by being macerated for an hour with a third charge of boiling water (acidulated as in the former case). The exhausted pulp is removed to make room for fresh slices; and the first vat is then charged with juice which has already passed through the second and third vats. After macerating the fresh beets for one hour, the charge is ready for fermentation. In ordinary weather the juice should now be at the right heat for this process, viz. about 22° or 24° C. (72° to 78° F.); but in very cold weather it may require some re-heating. The fermentation is precisely similar to that of the pressed juice, and calls for no special remark. It is usually complete in from 24 to 30 hours.

By Direct Distillation of the Roots.—This process, commonly called Leplay's method, consists in fermenting the sugar in the slices themselves. The operation is conducted in huge vats, holding as large a quantity of matter as possible, in order that the fermentation may be established more easily. They usually contain about 1300 gallons, and a single charge consists of 2200 lb. of the sliced roots. The slices are placed in porous bags in the vats, containing already about 440 gallons of water acidulated with a little sulphuric acid; and they are kept submerged by means of a perforated cover, which permits the passage of the liquor and of the carbonic acid evolved; the temperature of the mixture should be maintained at about 25° or 27° C. (77° to 81° F.). A little yeast is added, and fermentation speedily sets in; it is complete in about 24 hours or more, when the bags are taken out and replaced by fresh ones; fermentation declares itself again almost immediately, and without any addition of yeast. New bags may, indeed, be placed in the same liquor for three or four successive fermentations without adding further yeast or juice.

The slices of beets charged with alcohol are now placed in a distilling apparatus of a very simple nature. It consists of a cylindrical column of wood or iron, fitted with a tight cover, which is connected with a coil or worm, kept cool in a vessel of cold water. Inside this column is arranged a row of perforated diaphragms or partitions. The space between the lowest one and the bottom of the cylinder is kept empty to receive the condensed water formed by the steam, which is blown into the bottom of the cylinder in order to heat the contents. Vapours of alcohol are thus disengaged from the undermost slices, and these vapours as they rise through the cylinder vaporise the remaining alcohol, and finally pass out of the top at a considerable strength and are condensed in the worm. When all the contents of the still have been completely exhausted of spirit, the remainder consists of a cooked pulp, which contains all the nutritive constituents of the beet, except the sugar.

RECTIFICATION.—The product of the distillation of alcoholic liquors, termed "low wines," does not usually contain alcohol in sufficient quantity to admit of its being employed for direct consumption. Besides this, it always contains substances which have the property of distilling over with the spirit, although their boiling points, when in the pure state, are much higher than that of alcohol. These are all classed under the generic title of "fusel-oil": owing to their very disagreeable taste and smell, their presence in spirit is extremely objectionable. In order to remove them, the rough products of distillation are submitted to a further process of concentration and purification. Besides fusel-oil, they contain other substances, such as aldehyde, various ethers, &c., the boiling points of which are lower than that of alcohol; these must also be removed, as they impart to the spirit a fiery taste. The whole process is termed ***rectification***, and is carried on in a distillatory apparatus.

Heat is first applied gradually, in order to remove the most volatile impurities, and to concentrate them in the first portion of the distillate. When the spirit coming over possesses no objectionable odour, it is caught separately as long as it is of sufficient strength. The receiver is then changed again, and the remainder is collected apart, as weak spirit which contains much fusel-oil; the first and last runnings are then mixed together and re-distilled with the next charge. When a strong spirit is required, rectification may be repeated several times. It is customary, however, with the improved apparatus of modern times, to produce at the outset spirit containing but little fusel-oil and at least 80 per cent. of alcohol; this is then purified and concentrated in the above manner, and afterwards reduced with water to the required strength.

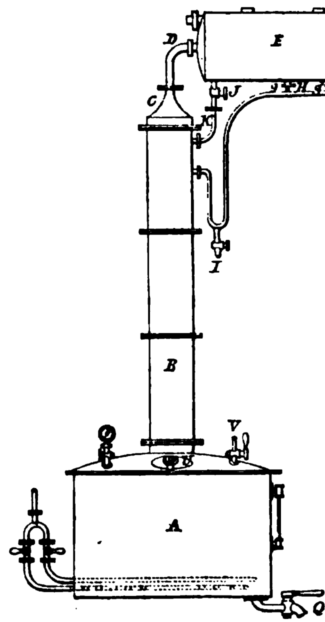
Another cause of the offensive flavour of the products of distillation is the presence of various acids, which exist in all fermented liquors; they are chiefly tartaric, malic, acetic, and lactic acids. The excessive action of heat upon liquors which have been distilled by an open fire has also a particularly objectionable influence upon the flavour of the products.

The first operation in the process of rectification is to neutralise the above-mentioned acids; this is effected by means of milk of lime, which is added to the liquor in quantity depending upon its acidity; the point at which the neutralisation is complete is determined by the use of litmus paper. In the subsequent process of distillation, the determination of the exact moments at which to begin and to cease collecting the pure spirit is very difficult to indicate. It must be regulated by the nature of the spirits; some may be pure 20 or 30 minutes after they have attained the desired strength; and some only run pure an hour, or even more, after this point. The product should be tasted frequently, after being diluted with water, or a few drops may be poured into the palm of the hand, and after striking the hands together, it will be known by the odour whether the spirit be of good quality or not; these two means may be applied simultaneously.

The process of rectification is usually carried on in the apparatus shown in Figs. 247 and 248. A is a still which contains the spirits to be rectified; it should be four-fifths full. The condenser E and the cooler G are filled with water. After closing the cocks F and I, the contents of the still are heated by steam, which is introduced slowly at first. The vapours of spirit given off pass above the plates *a* of the column B, and escape through C and D into the condenser E, where they are condensed on reaching the lentils *d d'*, and return in a liquid state through *f f'* and *g g'* to the upper plates of the column B. In these return pipes the liquid is volatilised, and constantly recharged with alcohol to be again condensed, until the water in the condenser is hot enough to permit the lighter alcoholic vapours to pass into the coil *c*, without being reduced to the liquid state. When this is the case, the vapours pass through F into the cooler G, where they undergo complete condensation.

Great care must be taken that the heat is not so great as to permit any of the vapours to pass over uncondensed, or to flow away in a hot state; and also to keep up a constant supply of water in the cooler, without producing too low a temperature; the alcoholic products should run out just cold. The highly volatile constituents of the spirit come over first,

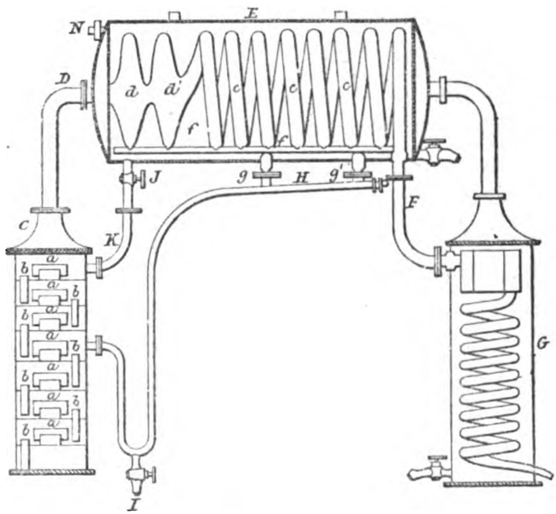
FIG. 247.



Rectifier.

that which follows becoming gradually pure until it consists of well-flavoured alcohol; after this, comes a product containing the essential oils. The more impure products are kept apart from the rest, and re-distilled with the next charge. Some hours generally elapse before alcohol begins to flow from the cooler. The purest alcohol is obtained while its strength is kept between 92° and 96° B., and the operation is complete when the liquid flowing through the vessel marks not more than 3° or 4° B.: it is better, however, to stop the still when the backing or "faints" indicate 10° B., because the product after this point contains much fusel-oil, and is not worth collecting.

FIG. 248.



Rectifier.

In order to cleanse the apparatus—which should be performed after each working—the still A is emptied of water by opening the cock C. The contents of the condenser are then emptied in like manner by opening the cock J, through which they flow upon the plates in the column B, and wash out essential oils which remain in them. These two cocks are then closed, and the door U is removed. The water in the cooler G is run by means of a pipe into the still A, so as partially to cover the steam-coil in the latter. After again securing the door U, a strong heat is applied, and the water in the still is well boiled, the steam evolved thoroughly cleansing all the different parts of the apparatus; this is continued for 15 or 20 minutes, when the heat is withdrawn and the still is left to cool gradually.

The capacity of the rectifying apparatus has a good deal of influence upon both the quantity and the quality of the spirit obtained. Besides being much more difficult to manage, a small apparatus will not yield so large a proportion of spirit as a more capacious one; nor will its products be of equally good flavour. The proportion of alcohol which may be obtained from a successful rectification is very variable; it depends upon the nature of the spirit rectified, the method of extracting the sugar, and the manner of conducting the distillation; it will also be in inverse proportion to the quantity of fusel-oil contained in the raw spirit. The average loss of pure alcohol during the process of rectification is generally estimated at about 5 per cent.

CHAPTER XXV.

PRODUCTION AND COMMERCE.

IN the following statistics relating to the production of and commerce in sugar, molasses, and rum, the term sugar must be taken to mean cane sugar or beet sugar, according to the tropical or temperate climate of the country affording it, unless otherwise stated. Figures having reference to the sugars of less importance will be found under their respective heads.

Abyssinia.—In 1877, this country sent us 1880 cwt. of unrefined sugar, value 2430*l.* In 1884, the figures were *nil.*

Argentine Republic.—Great progress has recently been made in the provinces of Tucuman and Salta in the production of sugar. Of late, large quantities of sugar-making machinery have been taken out from Europe. The crop of 1877 was estimated at 2250 tons, and that of 1878 was expected to be 30 per cent. greater. The machinery used is chiefly French. The sugar made has found its way to Rosario; it is of a light-brown colour, and said to be superior in flavour to Brazilian.

Australia.—It appears that the crop of sugar in Queensland amounted in 1879 (that is, 30th April, 1879, to 31st March, 1880), to about 18,200 tons, or about 4500 tons above that of the previous year. The approximate output of the four sugar districts was:—

	Tons.
Southern district	about 2200
Central ,, ...	,, 5750
Mackay ,, ...	,, 9500
Cardwell ,, ...	,, 750

The output for 1880 was estimated at 21,000 tons. Throughout Moreton Bay, previous to its separation in 1859 from New South Wales, and its formation into Queensland, the sugar-cane was cultivated in the gardens of several people, so that there was little doubt as to the possibility of its culture.

The first sugar known to have been produced in Queensland was made by Buhôt, of Barbados, from cane grown in the Botanic Gardens, Brisbane, in May, 1862. In 1863, Captain L. Hope had 20 acres under cane. By the end of 1867, there were 20,000 acres under cultivation for cane, and the 6 mills in existence manufactured 168 tons of sugar. At the close of the season of 1869, there were 28 mills at work crushing the cane from 1230 acres, out of over 5000 acres under cultivation. In 1875, the season turned out very bad, the cane, nearly drowned in wet, became unhealthy and died, giving next to no returns. In the course of time, the evil effects of 1875 passed away, and the sugar industry has been since then more or less of a success. The average yield of sugar per acre in Queensland, for the 10 years ending 31st March, 1879 (and including the rust year 1875) is as follows :—

	cwt.	qr.	lb.
Southern district	24	0	25
Central ,, ...	24	2	9
Mackay ,, ...	27	0	23
Cardwell ,, ...	30	1	2
Queensland ,, ...	25	3	0

These figures may be compared with the yield of other countries, as in the following table :—

Country.	Average yield per acre. lb.
Demerara	4480
Louisiana	1200
Mauritius	3500 to 5500
Jamaica	1344
Philippine Islands	2800*
India	896
Rio Janeiro	2100
Java	about 3360

* This has been stated as only 1680 lb.

Roth writes respecting these figures that according to Porter, virgin land used to give 5000 lb. of sugar per acre; and Edwards, in his 'History of the West Indies,' speaks of soil in Jamaica which with plant cane will produce 2½ tons (5600 lb.) of sugar to the acre. In Queensland, 3½ tons and over, or above 7840 lb. per acre, have occasionally been obtained from soils newly broken up, but such a yield is exceptional. The manufacture of rum has increased at the same rate as that of sugar. The total production since 1867 was 1,842,322 proof gallons. Up to 1876, the yield was at the rate of over 2 gallons of molasses fermented to 1 proof gallon of rum distilled. For 1877, it was at the rate of 1⅘ to 1, and in 1878, at the rate of 2 to 1.

The mean consumption of sugar in Australasia is greater than in any other part of the world. The consumption of sugar and molasses in England for 1878 was at the rate of 62½ lb. per head. Australasia, however, consumed 78·7 lb. per head, or 16 lb. per head more than England did. Of the colonies, Queensland is the greatest, and South Australia the smallest consumer, their consumption being 92·13 and 71·31 lb. respectively. Australia draws her supplies from various quarters. Of the 91,500 tons which went into consumption in 1878, one-sixth was produced by Queensland, and one-twelfth by New South Wales, thus one-fourth of the sugar consumed in Australasia is produced in Australia itself. The remaining three-fourths are imported chiefly from Java and the Mauritius, supplemented by small supplies from the minor sugar-producing countries.

The sugar industry in Queensland is always increasing. During 1880 no less than 5500 tons of Queensland grown sugar were exported, besides large quantities of rum, treacle, and white spirits. A plantation on the Mackay River, containing 5000 acres, has been sold for 95,000*l.* cash. It was estimated to produce in the 1881–2 season 1200 tons of sugar

—an amount which can be increased to 4000 tons per annum.

The growing of the sugar-cane in New South Wales is an industry which, although only introduced on a practical scale about 10 or 12 years ago, has grown by degrees into proportions of considerable magnitude, and promises eventually to become the staple of the settlers on the rivers in the northern parts of the colony. In the year 1867, there were only 116 acres of land under sugar-cane throughout the colony; in the year ending on March 31st, 1877, the area of land devoted to sugar-cane was 6755 acres, of which 3524 were productive, the remainder being young plants not yet old enough to bear. In 1879, the area was 7778 acres. The principal seats of the sugar cultivation are on the banks of the Tweed, Clarence, Richmond, Macleay, and Manning Rivers; but sugar-cane has also been grown successfully on the Hunter, although on a small scale. On the rivers just named there are several mills where cane is crushed and sugar made. During last year there were no less than 70 sugar mills at work in various parts of the colony. The weight of cane crushed was over 1,150,000 cwt., which produced about 94,000 cwt. of sugar, besides a large quantity of molasses. The value of the sugar thus made was not far short of 150,000*l.* Sugar has been made in New South Wales from sorghum and beetroot. The returns from the sugar-cane, however, are so much more certain and profitable, that the cultivation of the other plants just mentioned is falling off, except in certain places where they are used as food for cattle. In the season 1877–8, the manufacture reached 150,744 cwt.

The exports of molasses from New South Wales to the United Kingdom were:—2021 cwt., 849*l.*, in 1876; none in 1877; 2392 cwt., 1260*l.*, in 1878; 5897 cwt., 2353*l.*, in 1879; 4525 cwt., 1628*l.*, in 1880.

Sugar-growing on a large scale has been initiated in the northern territory of South Australia.

Austro-Hungary.—The production of taxed beet (for sugar-making) has been as follows :—

Years.	Met. Centners (of 110¼ lb.).
1850–51	3,216,874
1860–61	7,949,676
1870–71	18,538,173
1876	24,329,277
1880	32,968,757

The exports assumed the following proportions, viz. :—

Years.	Refined Sugar.	Raw Sugar.
	met. cent.	met. cent.
1860	6,272	677
1870	174,028	377,328
1876	445,947	779,486
1880	675,000	1,624,000

Fiume shipped 462 tons of sugar, value 152,460 florins (of 2*s*.), in 1880; which figures had increased in 1885 to 2550 tons, value 61,720*l.* In 1884, Trieste shipped 579 tons of sugar, value 14,376*l.*, to India, and in 1885, 290 tons, value 6051*l.* The total sugar exports from Trieste in 1884 were 401 tons raw, value 9000*l.*, and 68,584 tons refined, value 1,810,628*l.*; and in 1885, 4531 tons raw, value 65,620*l.*, and 62,426 tons refined, value 1,298,400*l.* In 1883, the beet harvest in Austro-Hungary amounted to 41,969,760 metrical centners (of 110¼ lb.).

The tax on sugar amounted in 1877 to 18,514,919 florins, against 12,390,369 in 1876, more by 6,124,550 florins, or 49·43 per cent. This enormous increase is but a consequence of the altered law, which fixed the working capacity of the manufactories at a much higher rate. The drawbacks amounted in 1877 to 11,685,237 florins, leaving a net revenue of 6,829,682 florins. But here it must not be overlooked that the results of 1877 comprise the most considerable part of the manufacturing period of 1877–8. Still a great difference is to be observed in the results of 1876–77. In this period the tax did not amount to more than 10,870,823 florins, or less by

7,000,000 florins than in the year 1877. No alteration in the number of manufactories took place in 1876–77, either in Austria or in Hungary. The numbers were 210 and 17 respectively: total, 217 in the whole Empire, same as in 1875–76. 38,323 workmen and 19,808 women were employed in these manufactories. Bohemia, with 150 factories, 35,600 working people, and 8,212,768 florins of taxes, predominates in the produce of sugar.

Belgium.—Our imports thence have been:—

	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined, and Candy	68,368	35,775	81,799	89,401	108,313
„ Unrefined	578,931	489,256	496,156	338,329	493,349
Sugar: Refined, and Candy	107,417	62,739	123,681	122,258	155,340
„ Unrefined	621,945	588,338	510,580	338,680	540,241

The direct importation of raw sugars slightly exceeded in 1878 that of the previous year, but the large yield of beetroot sugar in Belgium during the next two years imparted feebleness to all transactions in cane sugars.

The following table shows the amount of raw sugars received at Antwerp during the year 1878:—

From—	Amount.
Havana	12,462 cases and 540 bags.
Bahia	13 cases, 6994 bags, and 17 barrels.
Alexandria	7640 bags.
Hamburg	104 cases, 8335 bags, 14 barrels, and 44 casks.
France	3803 cases, 374 bags, and 6 casks.
Great Britain ..	518 cases, 32,322 bags, 119 barrels, and 18 casks.
Holland	25,759 cranjangs.

The trade in beetroot sugar was in a very depressed condition during the year 1878, as was also that in refined sugars—a situation which was no doubt aggravated by the expiration of the International Convention of 1864. A certain amount of business, however, sprang up with England in respect of loaf sugar of the type termed *gros grains.* On the other hand, the exportation of *fins grains* loaf sugars to the north of Europe diminished.

The following statement shows the exports of refined and beetroot sugars by land and by sea during the first 11 months of the year 1878, in comparison with the corresponding period 1877:—

Year.	Refined Sugars.			Raw Beetroot Sugars.
	Loaf.	Crushed.	Candy.	
1878..	3,031,689	563,153	3,216,081	17,568,810
1877..	1,887,950	28,117	2,731,272	21,382,358

In 1884 the sugar exports from Antwerp to the United Kingdom reached 11,694 tons, and in 1885, 9646 tons. The total exports from Antwerp were 60,691 tons, value 1,060,303*l.*, in 1884, and 50,960 tons, value 890,538*l.*, in 1885.

Borneo.—In 1863, 200 acres were planted with cane; and in 1865, 10,000 dollars' worth of sugar was exported. The shipments from Sarawak in 1884 were 900 *piculs*, value 5135 dollars.

Bourbon.—The area under cane in 1874 was 43,672 hectares (of 2½ acres); the exports to France in the same year were 8,876,298 kilogrammes (of 2·2 lb.). We imported thence 14,750 cwt. unrefined sugar, valued at 16,880*l.*, in 1877, but none since.

The serious decrease in the yield of the sugar-cane is owing to the exhausted condition of the soil, and other causes, together with the low rate of exchange on home remittances consequent on the change of currency in the island, by which only French coins are permitted to circulate, which although favourable to the import trade, is highly prejudicial to the interests of the sugar planters.

While the 30,031 tons of sugar exported in 1884 fetched a value of 518,396*l.*, the 35,598 tons shipped in 1885 were only worth 448,940*l.*

On many plantations the plough has been called in to replace manual labour, and the beneficial results of this are seen in the fact that where it cost 26 fr. to produce 1000 kilos. of cane by employing men, the same crop is now obtained at half the cost by means of the plough. It is unfortunate that owing to the rocky nature of the soil, ploughing cannot be adopted all over the island.

Brazil.—The sugar-cane grows throughout Brazil, but chiefly in the provinces of Rio Janeiro, São Paulo, Bahia, Pernambuco, Parahiba, Ceará, Alagoas, and Rio Grande del Norte. Central factories are being generally established.

The Provincial Government of Bahia endeavours to maintain and to raise the cultivation of sugar, which at one time was its most important product (and of which, in 1852, 82,000 tons were shipped from this port), and towards whose support the Provincial Assembly has granted the guaranteed interest of 7 per cent. on the capital for the erection of six central sugar mills in different districts of the province. One has been erected by a French Engineering Company, with a capital of 700,000 to 800,000 reis. Its great advantage is the economical division of labour. The one in construction at Bom Jardim will grind the cane of the shareholders owning some 30 large plantations within its zone. The cane is to be paid for at the rate of 8 reis the ton; and after deducting the expenses of manipulation, the nett profits of the mill are to be divided amongst the shareholders in proportion to the capital of each.

The following calculation is made by the French engineer sent out by the above-mentioned company, based on the results obtained at the island of Guadeloupe with similar mills, upon a capital employed of 200,000 reis, grinding 120 tons of cane in 24 hours.

The produce to be obtained is in the proportion of—

White sugar	8·65
Muscovado	0·75
Total	9·40

EXPENSES.

	Milreis.
Calculating the cane purchased at 8 reis per ton, placed at the central mill per diem	960
Wages of 160 labourers at 1 reis	160
Inspectors	120
Coal, 4 tons	128
Wear and tear of materials, 10 per cent. in 100 days	160
General administration	240
Total	1,768

REVENUE.

	Reis.
White sugar, 8·65 per ton, at 24 reis	2,491
Muscovado 0·75 ,, at 20 ,,	180
Daily revenue	2,671
Expenses as above	1,768
Gross revenue	903
Commission of Superintending Engineer, 25 per cent.	225
Net revenue per diem	677
In 100 days' harvest work	67,740

Which, in relation to the capital employed on the central mill, is 34 per cent.

The sugar and molasses exports from Pernambuco in 1878–9 were:—

Destination.	Sugar.					
	White.			Brown.		
	Quantity.	Value.		Quantity.	Value.	
	kilos.	reis.		kilos.	reis.	
Great Britain	15,075	3,511	$643	36,927,655	5,055,480	$858
Germany	..	..		..	..	
Chile	5,786	1,400	329	..	..	
Argentine Confederation	6,575,232	1,505,309	072	524,002	72,793	958
Oriental States	3,245,568	775,529	715	189,834	33,886	743
United States	..	..		11,531,219	1,660,480	915
France	240	72	000	30,000	4,200	000
Italy	..	..		247,500	35,592	715
Spain	..	..		..	..	
Portugal	1,772,661	412,082	630	3,910,061	553,154	800
Russia	..	..		..	..	
Total	11,614,562	2,697,905	389	53,360,271	7,405,389	989
Total in sterling	..	£ 269,790 s. 10	d. 9⅜	..	£ 740,538 s. 19	d. 11⅛

Destination.	Molasses.	
	Quantity.	Value.
	litres.	reis.
Great Britain	..	..
Argentine Confederation	7,840	270 $240
Portugal	137,285	5,061 040
Total	145,125	5,331 280
Total in sterling	..	£ s. d. 533 2 6¼

The sugar exports from Maranham in 1885 were 12,414 tons, of which 9337 tons came to Great Britain. The exports from Paraiba in 1884 were 9,476,852 kilos., value 56,209*l.*, having fallen from 15,483,819 kilos., value 91,838*l.*, in the previous year. Ceará, in 1884, shipped 3,175,417 kilos., of which 2,697,248 kilos. reached Great Britain. The exports from Pernambuco in 1884 were 96,442,875 kilos. to foreign ports, and 40,450,009 kilos. to native ports. In the same year, Rio Grande do Norte sent 1950 tons, value 19,311*l.*, to Great Britain, and 10,120 tons, value 100,397*l.* to America. We received from Bahia in 1884 6,092,168 kilos., value 65,205*l.*, out of a total export of 50,372,152 kilos., value 520,584*l.* Altogether our receipts from Brazil in 1884 were 1,414,322 cwt., value 1,042,991*l.*

Canada.—Both beet and sorghum growing are attracting attention in Canada, where the climate is found to be well adapted to sugar raising. From experiments made on sugar-beet in Tilsonburg, Ontario, the following results were obtained. Total cost of raising, harvesting, and securing 34 tons of beets, 55 dollars—worth, for sugar refining purposes, 136 dollars; balance of profit, 81 dollars. The land under cultivation was 2⅜ acres; and, under more favourable circumstances, it was calculated that 54 tons might have been raised in the place of 34. Experiments at different places have all given favourable results.

Cape Colony.—Our imports thence show a steady increase:—

	1876.	1880.	1884.
	cwt.	cwt.	cwt.
Sugar, Unrefined	13,513	45,277	70,922
	£	£	£
Sugar, Unrefined	13,352	47,486	61,989

Cayenne.—The area under sugar-cane in 1874 was 235 hectares (of 2½ acres). The production of sugar has fallen to about 250,000 kilogrammes (of 2·2 lb.) annually.

Central America.—Our imports fluctuate remarkably, as the following figures show:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar, Unrefined	15,552	602	12,143	1,738	24,738
	£	£	£	£	£
Sugar, Unrefined	18,228	672	11,229	1,737	21,339

Chili.—British imports thence have been:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar, Unrefined	17,196	46,794	34,537	79,658	72,641
	£	£	£	£	£
Sugar, Unrefined	23,010	51,387	32,105	90,766	56,164

China.—The cultivation of the sugar-cane and manufacture of sugar are at the present time attracting considerable attention from the native inhabitants; and the statistics published by the Inspector-General of Customs at Shanghai show a decided increase of late years in the export of sugar to foreign countries.

The following method of cultivating the sugar-cane is employed by the Chinese. When the canes are cut, the tops are removed and bound in bundles, and the leaves of these tops are taken off; the cuttings themselves, which usually have 4 or 5 joints, are placed in a pond of fresh water, where they remain in soak for some 20 days; at the expiration of this time, the joints will have thrown out sprouts or buds, about 4 or 5 inches in length, when the cuttings are planted in rows about 2 feet apart, and at an angle of 60°. The cuttings, when planted, are slightly manured with bean-cake (i.e. the cake remaining after the expression of the oil from the beans of the soy plant, *Glycine Soja* [*Soja hispida*], the so-called "yellow China bean," which grows abundantly in the northern portion of the empire). It requires 10 months from the time of planting before the crop is matured and ready for harvest. From the roots (stools) of this crop, being well fertilised with the bean cake in a semi-liquid form, a second crop (1st ratoons) is produced; even a third is sometimes secured in this manner, but this is only when the soil is exceptionally rich. If the soil is not sufficiently fertile for a third crop (2nd ratoons), the roots are removed, the land is cultivated and manured as for the first crop, and cuttings are planted every 2 years.

The cane, when cut, is collected in bundles, and conveyed by men or boats, according to locality, to the mill or crusher; this consists of 2 granite cylinders about 3 feet in length by 18 inches in diameter, placed perpendicularly, the lower ends revolving in a stone socket, the upper in a frame of wood set into granite uprights; attached to or let into the upper end of these cylinders, are wooden cogs, and to the end of one of these cylinders is attached a strong wooden shaft or spindle, to the upper end of which is fixed a strong cross beam or lever, and to the outer end is attached the propelling power, which usually consists of 4 or 5 small oxen. The cane is passed between the cylinders, the juice running down into a small trench, which opens into a receptacle in the ground holding about 20 or 30 gallons; the juice is then conveyed in buckets to the boiling-pans near at hand, and the cane, after being crushed, is taken away to be used as fodder. It is sometimes dried in the sun, and is used for fuel (begass) for boiling the sugar. The boiling-pans are of cast iron, the greater part of those used being made at Fat Shan, about 15 miles from Canton. They are about 18 inches deep by 4 feet in diameter, and are placed in brickwork side by side, usually 4 in number, with arches for fuel underneath, all covered with a mat or thatched shed.

Three kinds of sugar are manufactured, viz. "rock-candy," "green sugar," and "clayed sugar." The rock-candy is made as follows:—The sugar is placed with a sufficient quantity of water in a large boiling-pan, similar to the ones already described, and boiled down to the proper consistency, which is ascertained by putting a small quantity into cold water; if it hardens at once, it is then time to run it off into earthen jars—these jars holding about 50 lb. each. They are always broken into 3 or 4 parts, and the parts are then bound together with a small quantity of lime-cement and a few bamboo or rattan hoops. The hot liquid is put into these broken jars, and a network of basket-splints is placed over each, the ends of the splints extending in different directions through the liquid to the bottom of the jar. If the temperature is low, the syrup will crystallise in about 15 days; if high, it requires from 25 to 30 days. As it crystallises, it adheres to the splints, the portion not crystallising settling at the bottom. The jars are then placed with the bottom part turned partly up over empty ones, to allow the molasses to run out. When sufficiently drained, the jars are removed, the hoops taken off, and with a small hatchet the parts are again broken asunder; the candy is then removed from the splints and spread out in the sun for a short time to purify or bleach. It is then assorted and packed into wooden tubs holding from 40 to 50 lb. each. Two qualities are always found in the jars; that at the bottom being darker and of less market value. The drainage from these jars is re-boiled, and a poorer quality of brown sugar is produced ; from the refuse remaining after this last process, a cement is made by mixing with lime.

The process pursued in the manufacture of "green" sugar is as follows :—The juice is boiled in the month of December ; as it is taken from the crushers in buckets in one of the 4 iron boiling-pans, a man is in attendance who pours the juice from one pan to the other. As soon as the liquid boils, a small portion of lime is put in, and the white of one or two eggs is placed in each pan. After a time, the dirt and refuse come on the surface, and are all skimmed off at intervals, while the sugar is boiling. When sufficiently boiled, it is run off into a wooden cooler, about 7 feet long, 4 feet wide, and 1 foot deep; and while in the hot liquid state a man begins to stir it about with a piece of wood about 1½ foot long and an inch thick, attached in the centre to a handle about 4 feet long. With this wooden instrument, the liquid is kept in constant motion until it begins to granulate and cool; and when cool enough, several men mix and rub it with their hands until all the lumps are bruised, and the sugar becomes all of one colour, which is a dark yellow. It is then put in baskets, and sold to sugar dealers, who put it up in mat bags, and bring it to market for sale to merchants for shipment.

The sugar principally exported to foreign countries is what is known as "clayed" sugar, and is made as follows :—When the juice is boiled to a proper consistency, the whites of two eggs are put into each pan, which serves as a clarifier; when sufficiently boiled, it is run off into conical-shaped earthenware jars, which are placed in rows either over trenches or empty jars. In the bottom of each jar containing the sugar, is a small aperture, in which is placed a wisp or bung of straw; when the sugar has become sufficiently granulated by cooking and an occasional stirring, the straw bung is slightly loosened, the portion not becoming sugar escaping into the trench or empty jars. When sufficiently drained, a thin layer of straw is placed over the sugar, and over this a thick layer of clay. The jars are then packed away in a dry place, where they remain for 30 to 40 days, according to the state of temperature. The coverings and straw bungs are then removed, and each jar will be found to contain three qualities or grades of sugar, the upper part being white, the next light brown, and at the bottom a dark brown. The drainings are sometimes used for distilling purposes, and also for making cement.

It appears that two distinct kinds of cane are grown in China, one being of a dark purple colour, and this is better for sugar than the other, which is green, and quite tender; the latter is principally sold in pieces about 8 to 10 inches in length, to the natives, who eat it in its raw state.

The total annual production is estimated at 200,000 tons. There are two refineries in Hong Kong, and a third at Swatow, drawing supplies from China, Cochin China, the Philippines, Straits Settlements, and Java. The raw sugar is usually packed in mat bags, weighing about $\frac{1}{3}$ picul each (1 picul = 133$\frac{1}{3}$ lb.); and the refined in double mat bags, of much superior quality, containing generally 1 picul each.

The following is a comparative table showing the export of sugar (brown, white, and candy), for the year 1879, from Canton:—

Year.	Newchwang.	Tientsin.	Chefoo.	Hankow.	Shanghae.	Nangpo.	Total to Coast Ports.	Hong Kong and Foreign Countries.	Grand Total.
	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.
1879 ..	569	52,451	760	58,250	9,431	1,451	122,919	31,114	154,033

The total amount of sugar imported at Chinkiang in 1879 was:—Brown sugar, 29,725,000 lb.; white sugar, 18,487,000 lb.; candy, 1,040,000 lb. The import of brown sugar increased since 1878 by nearly one-fourth. The other kinds remained stationary. The brown sugar is valued by the Custom-house at 15*s.* 7*d.* per 100 lb., the white at 26*s.* 3*d.* About three-fourths of the whole is classed as "foreign," the remainder as "native." In its origin, it is all Chinese alike, almost all of it being from Swatow, and the remainder from Formosa and Canton. The so-called foreign sugar is exported first to Hong Kong, where it obtains its foreign title; and thus, on arriving at Chinkiang, it is enabled to obtain the protection of transit passes, under cover of which it is distributed through the interior. One may note that, as coming from a foreign country, it has to pay full duty on entering Chinkiang, instead of the half-duty which is paid by the goods which come from other Chinese ports. The Customs authorities therefore receive a distinct benefit from the denationalising of the article, after which they cannot well decline to recognise its foreign character. About eleven-twelfths of the "foreign" sugar imported last year was thus sent up country. The white sugar is a partially refined article, which would be denominated anything but white in other countries. White sugar from the Hong Kong refinery has been introduced into Chinkiang by foreign merchants, but its quality is too good for the Chinese buyers, and the importers have suffered considerable loss by their venture.

Hankow, in 1879, imported from Japan and the Straits:—45,636½ piculs brown sugar, value 51,170*l.*; 1117½ sugar-candy, value 2249*l.*; 9031 white sugar, value 15,397*l.*

Kiukiang imported ("foreign") 17,117 piculs of brown sugar in 1877, 14,076 in 1878, and 15,174 in 1879; and of white sugar, 2533 piculs in 1877, 1911 in 1878, and 1280 in 1879. "Native" sugar, brown: 19,350 piculs in 1877, 25,904 in 1878, and 30,394 in 1879; white: 40,366 in 1877, 54,520 in 1878, and 75,946 in 1879; candy: 2196 in 1877, 2725 in 1878, and 2671 in 1879. The so-called "foreign" sugar, though coming partly from Manila and Cochin China, is to some extent of Chinese origin, and is called foreign from the fact that it passes through Hong Kong, and is there transshipped.

Kiungchow exported, brown sugar: 57,310½ piculs, value

47,884*l.*, in 1878; and 47,023½ piculs, value 44,391*l.*, in 1879; white: 15,872½ piculs, value 20,592*l.*, in 1878, and 17,225 piculs, value 23,832*l.*, in 1879.

Macao largely exports sugar (from Kwangsi and the island of Hainan) to the northern ports; the demand for Europe and America, which was brisk in 1877, almost entirely ceased in 1878. In the latter year, the export of white was 31,000 piculs, value 210,000 dollars; brown, 27,000 piculs, value 108,000 dollars.

Newchwang imported of brown sugar from Amoy and Swatow, nearly twice as much in 1879 as in 1878; besides 115,013 piculs brought in foreign vessels, nearly 300,000 piculs arrived in junks. The comparative imports of native sugars were:—

	1877.	1878.	1879.
	piculs.	piculs.	piculs.
Brown sugar	34,435	43,507	91,117
White ,, ...	8,909	17,879	16,820
Sugar candy	4,238	8,965	7,076

Ningpo imported as follows:—

	1877.	1878.	1879.
	piculs.	piculs.	piculs.
Brown sugar	8,723	21,491	25,040
White ,, ...	20,224	16,383	15,243.
Sugar candy	6,456	7,617	7,323

Shanghai received nett imports, in 1879, of:—Brown sugar, 550,995 piculs; white, 278,193; candy, 58,706; and exported: brown sugar, 386,723½ piculs; white, 352,779½; candy, 26,387¾.

Brown sugar is the staple export from South Formosa. The total amount exported in 1879 was 701,687 piculs, equal to 40,718 tons; of this, 25,029 tons were sent to foreign countries, by far the largest share being taken by Japan; the remainder was divided amongst the Treaty ports, principally Chefoo and Shanghae.

The prospects of the 1880 crop were particularly good. More ground was planted with sugar-cane than in any previous year; the weather had been very favourable, and the sugar was both good and fairly cheap. It was estimated that the export would in all probability reach 1,000,000 piculs, and that the trade would prove remunerative to exporters, and fairly so to the native producers.

White sugar, too, shows a very large increase over the previous year, namely, 63,614 piculs, as against 21,829 piculs, and there seemed every probability of the export for 1880 being even larger.

The following is a comparative table showing the exports of brown sugar from Taiwan for the years 1874 to 1879:—

Year.	Tientsin.	Chefoo.	Newchwang.	Shanghae.	Ningpo.	Amoy.	Total to Coast Ports.
	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.
1874	35,807	198,988	7,937	47,474	5,957	2,752	298,915
1875	8,772	119,575	..	27,363	..	1,807	157,517
1876	26,028	233,799	16,340	60,023	8,087	17,754	362,031
1877	35,918	91,442	..	8,586	2,594	5,561	144,101
1878	15,995	117,926	2,107	18,208	3,746	1,034	159,016
1879	35,487	159,984	4,850	62,225	1,947	5,922	270,415

Year.	Japan.	Australia.	London.	United States of America.	Valparaiso.	Hong Kong.	Total to Foreign Countries.	Grand Total to Coast Ports and Foreign Countries.
	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.	piculs.
1874	218,577	88,797	..	43,261	..	23,127	373,762	672,677
1875	223,946	72,323	..	19,500	..	8,658	324,427	481,944
1876	275,685	5,831	142,374	..	14,249	51,318	489,457	851,488
1877	242,421	79,264	18,500	73,077	..	10,219	423,481	567,582
1878	165,967	42,409	11,676	..	..	5,786	232,838	391,854
1879	284,663	139,799	..	..	..	6,807	431,269	701,687

Tientsin imported of native sugar as follows:—

	1876.	1877.	1878.	1879.
	piculs.	piculs.	piculs.	piculs.
Sugar, brown ..	201,523 04	118,202 70	151,886 27	162,606 96
„ white ..	140,695 25	73,894 68	78,913 23	83,184 88
„ candy ..	27,578 37	10,504 14	16,590 24	15,989 12

Wuhu imported sugars as follows :—

	1877.	1878.	1879.
	piculs.	piculs.	piculs.
Brown, native	9,484½	17,072¾	14,425½
White ,, ...	27,359¼	38,077	32,689
Candy ,, ...	368	877¼	581½
Brown, foreign	14,186¼	11,126	18,195½
White ,, ...	8,956½	9,648	19,436½
Candy ,, ...	98	41½	171¾

The sugar exports from Peking were 209,468,803 lb., value 1,021,315*l.*, in 1884, and 110,298,184 lb., value 498,899*l.*, in 1885. Canton shipped 216,213 piculs (of 133⅓ lb.) of brown sugar, value 493,937 taels (of 5*s.* 6*d.*) in 1884, and 113,438 piculs, value 263,476 taels (of 5*s.* 4*d.*) in 1885. The exports from Shanghae in 1885 were 22,640 piculs of candy, value 44,829*l.*, 635,916 piculs brown, 425,666*l.*, and 524,089 piculs white, 550,294*l.*

Our imports from China, including Hong Kong and Macao, have been :—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar, Unrefined	1,115,758	147,012	111,143	359,821	103,647
	£	£	£	£	£
Sugar, Unrefined	1,150,653	120,326	92,746	301,307	71,476

The Annamite sugar is a sort of cassonade, whose colour varies from deep-brown to clear-yellow, according to the preparation. It has a good flavour, and sweetens well.

The Loo-Choo islands owe whatever commercial importance they possess to the growth of sugar. The sugar-cane is stated to have been introduced into Loo-Choo from China in the year 1623. At present, it forms by far the most important product of the islands. Judging from the number of Government offices which are concerned in the cultivation of sugar, and in its collection as a portion of the revenue, the most accurate information in this respect ought to be obtainable; but this is not the case. In former years, the trade in sugar with the Loo-Choos was in the hands of the Satsuma Han, and it is doubtless in part owing to the existence of this lucrative monopoly that the Han attained such a flourishing condition. The sugar used to be conveyed to Kagoshima, from the Loo-Choos (a large proportion—that coming from Oho-sima and Yarabusima—being actually the property of the Han), and thence it was sent by Japanese junk to Osaka, where it was sold in large lots by the Satsuma agents at the Yashihi of the clan to the highest bidders by written tender. The merchants who purchased it then retailed it to smaller dealers, and it was in this way gradually distributed to different parts of the country. It is estimated that the value of the sugar which used to pass through the hands of the Satsuma authorities was not less than 500,000 yen. This estimate, however, judging by the present export of sugar from Loo-Choo proper, seems to be rather large. Of late years, since the abolition of the Han, the sugar has been bought by private merchants and trading companies at Kagoshima and Osaka, and no control over the trade is exercised by the Government.

The sugar plantations are owned by private landowners, the proprietorship not being restricted to any class. Each proprietor has his own sugar mills conveniently near to the plantations. These mills are of very primitive construction. In the centre of a circular space some 30 feet in diameter, are 3 cylindrical rollers arranged vertically side by side. The centre roller is higher than the two others, and is turned by means of a long pole, fastened to the top of the roller, and to the neck of a pony or bullock, who moves along a circular path on the outer edge of the enclosure. By means of simple cogs, made so as to fit one into another, the centre roller turns the two others. The mill is fed by two men, who sit one on each side, and each cane is crushed twice, being passed through between the centre and the right hand rollers only to return between the centre roller and that on the left. The juice, as it is expressed, falls into a trough underneath the rollers. Through this it runs into a tube, which, when full, is emptied into the ovens close by.

The ovens are round, open at the top, and built of earth. Each is protected from rain and wind by a thatched roof, which also affords shelter to the men who attend to the fire. The process of boiling the sugar is simple enough. Before lighting the furnace below, 3 shallow iron pans are arranged in the oven, in the form of a trefoil, and the spaces between them and round the sides of the oven are built up with a mixture of clay and straw. The liquid sugar is then poured into the pans, and, the furnace being lighted, is allowed to boil for five or six hours. During this operation, the burnt ash of a stone collected on the sea-shore is mixed with it in definite proportions. When the sugar is sufficiently boiled, the pans are removed, and placed in the open air. Here the sugar is stirred until it becomes cool, and it is then poured into tubs, where it forms a solid cake. Each tub holds about 120 catties (of 1⅓ lb.). Sugar is conveyed by coolies from the plantations to Nafwa, whence it is exported to Japan. The boiling season is during the cold weather, from November to February.

All the efforts of Europeans to cultivate the sugar-cane in Saigon (French Cochin China) seem to have resulted in complete failure, and abandonment of the enterprise. In 1878, the area recorded under sugar was:—11,397 acres in Saigon, 1912 in Mytho, 8960 in Viublong, and 4342 in Bassac; total, 26,611. The exports in that year were 1832 piculs, costing 3 dollars per picul, equal to 10*s.* a cwt., for unrefined.

Colombia.—The sugar-cane is grown in the province of Carthagena to a limited extent. Our imports from Colombia have been :—

	1876.	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar, Unrefined ..	31,772	28,742	56,612	16,640	17,919	25,349
	£	£	£	£	£	£
Sugar, Unrefined ..	31,567	34,193	55,887	17,334	20,277	20,892

Costa Rica.—Sugar cultivation is extending here, and small quantities of raw sugar are exported to neighbouring states.

Ecuador.—In 1884, the five existing sugar estates turned out some 23,200 quintals of sugar, valued at 24,000*l.*; but this production is not much more than half the local consumption.

Egypt.—Nearly 100,000 acres are under cane. The values of the exports in 1880 were:—320,554*l.* to Great Britain, 284,273*l.* France, 123,542*l.* Italy, 35,465*l.* Turkey, 700*l.* Greece, 22*l.* Austria, 11,196*l.* other countries; total, 775,752*l.* The crop of 1879–80 was estimated at 790,000 cantars, or 39,000 tons, and valued at 730,000*l.* In 1883 the total exports only reached a value of 404,175*l.*, and in 1884 but 376,617*l.* The shipments from Alexandria in 1885 were 101,430,857 lb., value 593,794*l.*

Our imports thence have been:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined, and Candy	37,485	9,820	..	59,474	—
,, Unrefined	192,371	229,082	143,637	195,217	192,827
,, Molasses	26,610	63,870	1,212	30,057	—
	£	£	£	£	£
Sugar: Refined, and Candy	64,440	12,761	..	78,645	—
,, Unrefined	282,982	227,522	138,005	229,381	141,411
,, Molasses	9,404	25,947	360	9,408	—

France.—The following are the official statistics of the home beetroot sugar production of France since 1838, when it began to be taxed. In the first year, 1838–39, there were 547 factories scattered over 51 departments, and producing 39,000,000 kilogrammes (of 2·2 lb.). In 1847, the sugar produced remained at or below this amount, but the number of factories had fallen in 1840, and thenceforward gradually diminished to 289, owing in great part to the burden of taxation falling too heavily on small concerns. The number of departments in which the industry was carried on at the same time decreased to 18. In 1858, the production had risen to 152,000,000 kilogrammes, the number of factories was 341, and the number of departments 17. In 1866, the amount produced was 274,000,000 kilogrammes, the number of factories 418, and of departments 19. In 1873, the production was 408,000,000 kilogrammes; and in 1876, 462,000,000 kilogrammes. The number of factories was 525, and of departments 24. The amount produced in 1877, owing to the bad beetroot crop, sank considerably from that of the preceding years, being 243,000,000 kilogrammes, while the number of factories fell to 498.

In 1879–80, the production was about 400 million kilogrammes; in 1880–1, 320 million. The French imports of sugar are about 180 million kilogrammes, of which, 85 million come from the French colonies, and 95 million from foreign countries. The indigenous production and the foreign supply therefore make a total of 580 million kilogrammes thrown on the French market. The local consumption is only about 270 million. There remain, therefore, 310 million which have to find a foreign market. The export consists of raw and refined sugars. Up to 1875, the export demand was sufficiently great to absorb all the sugar not consumed in France, but of late years the foreign demand has sensibly declined.

Recent exports have been:—From Calais: raw French, 60,914 kilogrammes in 1878, 11,614 in 1879; refined, not French, 386,645 in 1878, 108,709 in 1879; from Dunkirk: sugar, 15,689,947 kilogrammes in 1879, 15,014,370 in 1880, 20,719,173 in 1883, 8,824,431 in 1884; glucose: 2,722,048 in 1879, 70,473 in 1880; all to England; from Nantes: in 1879, 4,400,139 kilogrammes refined sugar to England, Senegal, Norway, Switzerland, Spain, and America; in 1880, 8,402,800 kilogrammes refined sugar to England, Spain, Turkey, Chili, and Switzerland; 236,274 kilogrammes treacle to Norway; in 1882, 4200 tons refined sugar and treacle; and in 1884 but 84 tons. Rouen exported 18,635,687 kilos. in 1883, and 17,890,017 kilos. in 1884. Our imports from France have been:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined, and Candy	2,069,543	2,313,676	1,624,605	1,586,416	1,047,501
,, Unrefined	442,884	281,621	176,940	115,298	44,095
	£	£	£	£	£
Sugar: Refined, and Candy	3,464,915	3,391,378	2,258,093	2,342,912	1,171,102
,, Unrefined	596,669	331,560	201,641	136,089	37,137

Dunkirk exported 2,672,835 kilogrammes of glucose to England in 1877, and 6,705,642 kilogrammes in 1878.

Sugar refining, formerly one of the principal industries of Nantes, is declining. There are but two sugar refineries for loaf sugar now in existence, and three smaller refineries principally occupied in the manufacture of sugar-candies, used to make champagne, whereas in the year 1830 they numbered about 20.

This decline is owing, firstly, to the competition of the large refiners in Paris, who appear determined to obtain control over the entire French market, having succeeded in doing so in England; and, secondly, by the treatment of their customers by the Orleans Railway Company, as if they were quite dependent on it for their business.

Two large refineries have lately disappeared: that of Massion and Co., which turned out on an average 60 tons per day, was consumed by fire; and the refinery belonging to a company known as Les Raffineries Nantaises, capable of turning out 120 tons daily, has been closed under liquidation.

The following quantities of raw sugar were imported at Nantes during 1878:—

	Kilogrammes.
Entered as for consumption—	
French colonial sugar, Foreign sugar	24,896,395
Beet-root	295,307
Entered as for temporary admission—	
French colonial and foreign sugar	21,929,989
Total	47,121,691
Quantity entered in 1877	40,606,512
Increase during 1878	6,515,179

Appended is a table giving an explanation of the system under which the sugar trade is worked in France.

Although this table clearly shows that considerable profit should be made under the system of granting drawbacks, the refiners of Nantes maintain that this profit does not fall to their share, but into the pockets of their sellers, and that it is undoubtedly to the prejudice of the French Treasury.

Category 3, classified for drawback by the numbers 10–13, is taken as the basis of operation at Nantes as elsewhere; but, contrary to the Paris market, the custom of this market is to add to or deduct from the classified qualities the difference existing between the custom-house duties and the value of the "Certificats de Sortie."

The duties on 0–7, 7–9, and 10–13, are 65 fr. 52 c. per 100 kilos.; and for 13–14 and 15–18, 26 fr. 64 c. per 100 kilos.

In order to arrive at the true amount of duty, the official yield is multiplied by the value of the "Certificat de Sortie." and the product is deducted from the duties.

The official yield fixed for numbers 7–9 is 80 per cent. Taking 74 fr. 50 c. as the normal value per 100 kilos. of the "Certificat de Sortie," the calculation is as follows:—

$$\frac{74 \cdot 50 \times 80}{100} = 59 \cdot 60, \ 65 \cdot 52 - 59 \cdot 60 = 5 \cdot 92;$$

therefore sugars classed 7–9 are worth 5 fr. 92 c. per 100 kilos. more than those classed 10–13.

Sugars classed 0–7, the yield of which is 67 per cent., are worth 15 fr. 60 c. per 100 kilos., more than the 10–13, and 9 fr. 68 c. more than the 7–9.

The duty fixed for sugars classed 13–14 is 68 fr. 64 c. per 100 kilos. The market price is therefore fixed as follows:—

	Fr.	c.
Therefore 10–30 selling at	49	00
Deduct therefrom the difference of duty	3	12
	45	88
To which is added	3	08
Consequently classification 13–14 are priced lower at	48	96

The official yield being 88 per cent., multiplied by 74·50, gives for the duty really paid 65·56, or a difference of 3 fr. 8 c.

TABLE SHOWING THE SYSTEM OF THE FRENCH SUGAR TRADE.

Category.	Analysis by the Saccharometer of Crystallisable Sugar per Degree per cent.	Numbers indicating Classification for Drawback.	Quantity of Refined Sugar to Export to clear the Raw Imported.	Amount of Duties per 100 kilos. of Raw Sugar not cleared for Exportation as Refined.
	per cent.		per cent.	fr. c.
1	76	No. 7	67	65 52
2	76 to 85	Nos. 7 to 9 inclusive ..	80	65 52
3	85 ,, 91	,, 10 ,, 13 exclusive ..	88	65 52
4	91 ,, 92	,, 13 ,, 14 inclusive ..	88	68 64
5	92 ,, 98	,, 15 ,, 18 ,, ..	94	68 64
6	Above 98	Above No. 18 ,, ..	100	70 20

Category.	Cost of Certificat de Sortie per 100 kilos. of Raw Sugar Imported, calculating the Certificate at 74 fr. 50 c. per 100 kilos. of Refined.	Difference to the Treasury as Bounty when the Raw Sugar is cleared at the Customs for Exportation as Refined.			
		Per 100 kilos. of Raw Imported.		Per 100 kilos. of Refined Exported.	
		Profit.	Loss.	Profit.	Loss.
	Fr. c.	fr. c.	fr. c.	fr. c.	fr. c.
1	49 91	..	15 61	..	23 29
2	59 60	..	5 92	..	7 40
3	65 56	0 04	..	0 04·2	..
4	65 56	..	3 08	..	3 50
5	70 03	1 39	..	1 48	..
6	74 50	4 30	..	4 30	..

On the Paris and Marseilles markets, the classifications of exotic sugars 10–13 and 13–14 are bought at one price under the designation of 10–14, the reason being that the price of sugar is always calculated with the duty. For example, classification 10–13, at 88 per cent., being quoted at 49 fr. per 100 kilos., with duty at 65·52 the 88 per cent., classification 13–14 or 15–18 with duty 68 fr. 64 c., will be quoted at 3 fr. 12 c. less per 100 kilos.

The difference of 3 fr. 12 c. on the 13–14 is, however, counterbalanced by the profit on exportation of refined, the "Certificat de Sortie" giving 3 fr. 8 c. profit. The prices of 10–13 and 13–14 are therefore equalised. By the same calculation it will appear that there is a loss of 3 fr. 12 c. per 100 kilos. on sugars classed 15–18, consequently they are never entered for temporary admission.

The refined sugar exported during three years from Nantes was as follows :—

Destinations.	1876.	1877.	1878.
Switzerland	123,100	184,875	195,750
Italy	10,858	800	1,090
England	4,686,169	3,301,191	3,920,773
Sweden	1,220,203	456,201	77,044
Norway	783,188	359,490	295,018
Denmark	60	34	..
Belgium	17,842	67	277,500
Spain	975,703	1,025,056	1,051,827
Algeria	105,039	11,583	..
French colonies	12,551	18,010	41,824
Other ports	299,161	394,842	282,397
Export from St. Nazaire	2,837	2,656	2,586
Total	8,236,711	5,754,805	6,145,729

A recent Consular Report says that the beet sugar industry, which was in former years so flourishing and proved such a source of wealth to the cultivator of the roots, the manufacturer of the raw sugar, and to the refiner, has, as regards the two first-named, completely altered in character, until it is to-day a source of actual loss instead of profit, and the French beet-growers and sugar manufacturers who, under the stimulus of very heavy bounties, first showed Europe the mine of wealth to be worked in the cultivation of that root, now find themselves put into the background by the more skilful modes of culture and manufacture of their German competitors, who have made it impossible for them to continue to compete with them except at the cost of the increased measures of protection which they have managed to get passed by their Legislature. Owing partly to the mode in which the duty on the sugar was levied, and partly to the over-sense of security which their state of prosperity induced, the beet-growers in France, unlike their German competitors, took no pains to increase the saccharine richness of the roots, so that while it does not take more than 9½ tons in Germany to produce a ton of sugar, it has required about 17 tons in France for the same purpose. The relative cost of production hitherto may be put on an average as follows: Rent of land in France per hectare (2½ acres), 125 fr.; in Germany, 187 fr. 50 c.; cost of cultivation in France, 555 fr.; in Germany, 481 fr. Price paid by manufacturers to farmers for roots in France, 20 fr. per ton; in Germany, 25 fr. to 30 fr. (In France, farmers who are not protected by contracts were in 1884 getting only from 10 fr. to 15 fr. per ton.) Average produce of roots per hectare in France, 45 tons; in Germany about 28½ tons. During a debate in the French Chamber it was stated that French colonial sugar cost to manufacture 52 fr. 77 c. per 100 kilos.; beet-root sugar in France, 48 fr.; in Germany, 38 fr. From reliable data compiled on the spot, a ton of sugar costs 22*l.* 8*s.* 6*d.*, duty included, or, deducting the drawback of 9*l.* a ton, 13*l.* 8*s.* 6*d.*, and adding the cost of freight to London, say about 13*l.* 19*s.* for what has been selling as low as 10*l.* In his speech on July 9, 1884, the French Minister of Agriculture is reported to have said that the German bounty amounted to 3 fr. per 100 kilos. on the whole crop, and 7 fr. on the amount exported. This is about the case. The duty is 80 pf. per cwt. of roots; the drawback 92 pf. If 10 per cent. of the sugar is produced this gives a bounty of 1*l.* a ton, but as the manufacturers nearly always obtain 13 per cent., it comes to quite 2*l.* 17*s.* The production in France for crop 1884-5 was estimated at 325,000 tons, the consumption at 360,000 tons. In Germany the crop was put at 1,150,000 tons, the consumption at 350,000; by the new law passed by the French Chambers, the system of levying the duty on the roots on the basis of a fictitious yield of sugar per 100 kilos. has been adopted, by which the manufacturer will profit by all the excess he can make, being free of duty, and thus, added to a surtax of 7 fr. per 100 kilos. on all sugar imported from European countries, the farmer will find it to his advantage to cultivate roots of a greater saccharine richness, and the manufacturer will be fully protected against his German rivals. The interests of the French colonial planter are also guarded by his being granted an allowance for waste of 12 per cent. The refiners gain nothing by the new law, and, indeed, those in Paris will rather suffer from its effects, but their profits have been hitherto so large that no great amount of pity seems to be felt for them. What the result will be in Germany, and still more in England, on whose markets the amount hitherto exported by the former country to France will in future be poured, remains to be seen, but one thing is clear—namely, that the unfortunate West Indian planter will find himself still more oppressed by this most unjust system of bounties, to which, direct or indirect, must now be added this increased measure of protection in France, and to which the present crisis in the sugar trade is almost, if not entirely, owing. At present prices, utter ruin stares him in the face, from no fault of his own, but solely from the unfair competition to which, with his hands tied behind his back, he is exposed. It is very difficult, on an estate producing both sugar and rum, to correctly calculate the exact cost of production of the first-named, but, speaking from a practical knowledge of sugar-planting in the West Indies, and taking the average results of the last ten years of an estate in Jamaica, unencumbered by debt, and both well and at the same time economically managed—the Consul considers it requires the sugar to fetch quite 15*l.* per ton to enable the estate to pay its expenses one year with another. There is a point, too, which is little thought of when the advantage of the cheapness of beet sugar is expatiated on, namely, that a certain deduction must be made for its sweetening power being less than that of pure cane sugar, thereby requiring a greater specific weight to be used. Any practical housekeeper will testify to this.

Germany.—The general statistics of the production of beetroot sugar in the year 1879–80 are as follows. The number of factories in operation was 328, of which 291 worked on the diffusion process, 28 by presses, 8 by maceration, and 1 by centrifugal. There were used, 4,628,748 tons of beetroot, of which 3,114,029 tons were grown by the factories, and 1,514,717 tons were bought of private growers. The average yield of roots per hectare (of 2½ acres) was 25·2 kilogrammes (of 2·2 lb.) of washed and topped roots. The yield of *masse-cuite* was 11·54 per cent., which, in sugar of all sets, yielded 8·52 per cent., and of molasses 2·73. From 100 kilogrammes of *masse-cuite*, 73·850 kilogrammes of sugar of all kinds were obtained, and 23·70 of molasses. To obtain 100 kilogrammes of sugar, 1174 kilogrammes of beetroot were required.

The beetroots in general were but of middling quality, owing to the rain and low temperature which prevailed in 1879. The price varied from 20 to 36·25 francs per 100 kilogrammes, according as the factory returned the pulp to the farmer or not.

Seasons.	No. of Factories.	Working by :—			
		Press.	Maceration.	Centrifugals.	Diffusion.
1871–72	311	216	25	18	52
1872–73	324	220	26	15	63
1873–74	337	214	31	12	80
1874–75	333	181	30	9	113
1875–76	332	137	29	9	157
1876–77	328	98	23	10	197
1877–78	329	81	16	8	224
1878–79	324	50	12	4	258
1879–80	328	28	8	1	291

The accompanying table shows the variation that has taken place in the processes of manufacture in the last nine years.

It will be noticed that the diffusion process is gradually superseding the older methods. The quantity of beetroot bought of private growers is also augmenting yearly.

GERMAN SUGAR STATISTICS.

	1871.	1872.	1873.	1874.	1875.	1876.	1877.
Tons of beet per acre ..	8·1	10·2	10·9	8·3	11·3	10·1	11·0
Production of sugar ..tons	186,441	262,551	291,041	256,412	358,048	289,422	378,009
Percentage diffusion works	16·7	19·5	23·7	34·0	47·3	60·0	68·0
Tons sugar per 100 tons beet	8·28	8·26	8·25	9·30	8·60	8·15	9·24
Tons beet for 1 ton sugar..	12·07	12·11	12·12	10·75	11·60	12·47	10·82
Tons sugar per acre	0·67	0·84	0·90	0·97	0·97	0·82	1·02
	1878.	**1879.**	**1880.**	**1881.**	**1882.**	**1883.**	**1884.**
Tons of beet per acre ..	11·6	10·1	13·1	11·8	13·8	11·9	11·3
Production of sugar ..tons	426,155	409,415	555,915	644,775	848,124	986,402	1,154,417
Percentage diffusion works	80·0	88·7	90·3	94·0	94·0	95·5	96·0
Tons sugar per 100 tons beet	9·21	8·52	8·79	9·56	9·55	10·54	10·3
Tons beet for 1 ton sugar..	10·86	11·74	11·37	10·46	10·47	9·42	9·70
Tons sugar per acre	1·07	0·86	1·15	1·32	1·35	1·25	1·16

The figures show that the yield of sugar per acre in 1882 was double that in 1871.

Season.	Number of Factories.	Acreage of Factories.	Roots raised by Factories.	Or, per Hectare	Total in Germany.		Yield of 100 Ko. of Roots.		Sugar Exported	Sugar Consumed in Germany
					Roots Raised.	Sugar Produced.	Sugar.	Molasses.		
		Hectares.	Tons.	100 Ko.	Tons.	Tons.	Ko.	Ko.	Tons.	Tons.
1873-4	337	88,877	2,420,909	272·4	3,528,764	291,041	8·25	3·00	21,655	298,339
1874-5	333	92,655	1,908,095	205·9	2,756,745	256,412	9·30	3·54	10,813	273,290
1875-6	332	96,724	2,836,307	293·2	4,161,284	358,048	8·60	3·22	56,121	323,180
1876-7	328	98,725	2,490,154	252·2	3,550,037	289,423	8·15	3·13	60,354	241,575
1877-8	329	104,783	2,872,775	274·2	4,090,968	378,009	9·24	3·00	96,778	290,114
1878-9	324	107,679	3,114,030	289·2	4,628,748	426,155	9·21	2·89	138,077	296,049
1879-80	328	113,003	2,850,586	252·3	4,805,262	409,415	8·52	2·73	134,485	281,514
1880-1	333	118,431	3,871,679	326·9	6,322,203	555,915	8·79	2·61	283,904	277,618
1881-2	343	121,256	3,431,754	283·0	6,271,948	599,722	9·56	2·40	314,410	291,045
1882-3	358	129,262	4,448,632	344·2	8,747,154	835,165	9·55	2·24	472,552	369,214
1883-4	..	..	..	..	..	925,000	..	..	606,351	..

Our imports of sugar from Germany have been :—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined and Candy	411,035	108,401	59,134	244,645	752,027
,, Unrefined	1,853,946	2,436,380	2,660,196	4,384,268	7,181,237
	£	£	£	£	£
Sugar: Refined and Candy	663,570	151,524	56,840	339,969	733,712
,, Unrefined	2,318,984	2,560,679	2,794,473	4,728,916	5,035,247

The receipts of raw sugar at Hamburg were :—

Whence received.	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Interior of Germany ..	1,500,597	1,548,745	1,977,488	2,467,966	4,379,716
Brazil	7	22,181	566	19,237	Seawards 127,946
Porto Rico	5	15,881	15,778	5,111	
Great Britain	12,146	16,928	7,078	9,649	
Cuba	4,822	..	..	..	
Holland (by sea) ..	12,320	29,666	9,739	3,185	
Dutch East Indies ..	23,584	67,436	32,042	53,902	
Other countries	14,500	9,878	3,042	4,412	

The exports of beetroot sugar from Germany, Austria, and Russia in 1878 were 25 per cent. larger than usual, having reached a total of 105,000 tons, as against 78,678 tons in 1877.

Guatemala.—The movement in sugar noticeable in 1878 may be attributed to an experiment which has not given satisfactory results, owing to the high rates of freight from the plantations to the port (San José), and necessarily high charges for wharfage and lighterage at the latter. It is, however, probable that the railroad from San José to Escuintla, the centre of the principal sugar-producing district, may provide, when completed, cheaper transportation, and thereby give impulse to an important branch of industry.

The exports of good sugar in 1879 were :—52,500 quintals (of 110 lb.) to England, 68,550 to California, 10,000 to S. America, 3000 to Central American States. Of common sugar, in the same year :—49,650 to England, 38,100 to New York, 53,700 to California. 19,900 to Central American States.

Totals, 134,050 quintals, 13,405 dollars (of 4*s.* 2*d.*); and 161,350 quintals, 5647 dollars.

Guiana.—The area occupied by sugar-cane in British Guiana in May 1881 was 40,877 acres in Demerara, 18,286 in Essequibo, and 15,294 in Berbice. The exports in 1880 were:—From Demerara, 69,682 hhds., 8228 tierces, 2321 barrels of sugar; 16,976 casks of molasses. Berbice: 1247 hhds., 37 tierces, 381 barrels, 34,895 bags of sugar; 25 puncheons of molasses. Our imports thence have been:—

	1876.	1877.	1878.	1879.	1880.
	proof gals.	proof gals.	proof gals.	proof gals.	proof gals.
Spirits, Rum	4,717,583	3,777,871	3,364,094	3,539,647	3,288,560
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined	..	11	..	3,567	16,338
„ Unrefined	1,569,893	1,249,087	1,215,069	1,500,058	1,327,084
„ Molasses	2,034	13,591	33,555	9,447	20,888
	£	£	£	£	£
Spirits, Rum	463,843	328,440	267,111	251,420	231,100
Sugar: Refined	..	19	..	4,459	22,851
„ Unrefined	1,920,769	1,848,925	1,572,521	1,886,237	1,778,481
„ Molasses	765	7,387	16,461	3,837	10,189

Holland.—Five years' commerce in raw and refined sugars in Netherlands lb. (of 2·2 lb.), have been:—

	1875.	1876.	1877.	1878.	1879.
	N. lb.	N. lb.	N. lb.	N. lb.	N. lb.
Imports, raw ..	62,700,000	69,900,000	58,500,000	59,000,000	43,000,900
Exports	17,556,000	29,000,000	16,000,000	18,800,000	21,300,000
„ refined ..	76,778,400	74,800,000	62,500,000	64,400,000	63,800,000

Of 45,852,681 N. lb. of refined exported from Amsterdam in 1879, 32,639,733 N. lb. came to England. Our total imports from Holland have been:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined and Candy	521,891	649,876	792,063	876,471	1,320,324
„ Unrefined	99,548	339,717	222,328	205,601	234,623
	£	£	£	£	£
Sugar: Refined and Candy	904,934	931,612	1,052,267	1,275,717	1,379,227
„ Unrefined	124,009	360,678	228,853	223,900	181,258

Rotterdam possesses four sugar refineries, and the total exports of their manufacture were :—

	Tons.
In 1879	16,750
" 1878	17,260
" 1877	16,250
" 1876	17,750

The annexed Table shows the exports of refined sugar from Holland, and their destination :—

To	1879. 11 months.	1878. 12 months.	1877. 12 months.	1876. 12 months.	1875. 12 months.
	tons	tons	tons	tons	tons
Germany and Switzerland ..	6,447	6,889	7,492	8,359	8,343
Belgium	6,127	6,905	6,587	2,465	2,563
Great Britain	39,120	34,649	27,311	33,489	28,536
Gibraltar	210	168	97	232	347
Italy	3,951	6,735	11,017	13,504	11,618
Turkey	809	1,462	1,569	3,457	6,676
Austria	..	..	40	5	..
Hamburg	701	863	844	869	554
Denmark	33	78	136	305	421
Russia	13	..	..	2,609	11,213
Sweden	2,206	2,656	3,015	3,369	1,904
Norway	715	823	1,027	728	625
Surinam	83	48	53	41	39
Rio de la Plata	2	104	6	542	1,679
Other countries	1,742	1,259	643	866	787
Total	62,159	62,639	60,437	70,840	75,305

Honduras.—Reliable experience proves that sugar can be easily produced in British Honduras for about 10*l.* per ton, and at the rate of 2 tons to the acre. One planter states that on actual experiment, 1 acre of picked canes yielded 4 tons of drained sugar. No artificial manure is required, nor any drainage, beyond mere surface drains, and hardly any cultivation beyond a couple of ploughings to clean the canes. Canes ratoon for ten or twelve years without deterioration, and instances have been quoted of some that have been ratooning for twenty years. The area under cane is over 10,000 acres. The exports were 177½ tons in 1862, 2203 in 1872, 2017 in 1876, 1932 in 1877, 1736 in 1878.

Our imports thence have been :—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined	24,432	15,405	24,412	18,207	26,514
	£	£	£	£	£
Sugar: Unrefined	29,807	14,717	19,930	18,273	17,599

India.—The exports of sugar have been as follows :—

	Cwt.	Rs.
1874–75	498,054	31,92,383
1875–76	420,762	25,39,374
1876–77	1,093,625	92,51,961
1877–78	844,125	74,58,513
1878–79	279,756	20,43,600

The trade of 1876–77 and 1877–78 was greatly stimulated by the failure of the West Indian crop, and deficiencies in the French beetroot crop, which caused a very active demand for England and France. But supplies from Mauritius and other places filled the markets, and prices having fallen, the export of Indian sugar diminished. The exhaustion of stocks caused by the unusually large exports of those two years raised prices in this country, and they were maintained at a high level by a very poor crop in the north-west. Hence the comparatively very small exports of Indian sugar, and the greatly increased imports into India of foreign sugar. The sugar exported is mostly of a very inferior quality, so inferior that in England it is said to be mostly used in brewing; it has been found unsuited to the American market, which, however, would be more cheaply supplied from local and neighbouring sources; and in Bombay, it is unable to compete with Mauritius sugar, the importations of which into India are quite equal to the total quantity of Indian sugar exported to foreign countries.

The manufacture of sugar ought to be a thriving industry in India. Sugar, like salt, is of universal consumption amongst the people of India, and may indeed almost be called a necessary of life with them. But the manufacture generally is roughly and wastefully conducted, and the introduction of improvement both in the expression of the juice from the cane, and in the conversion of the juice into sugar, is greatly needed. There are a few European sugar factories in India, as, for instance, the Rosa Works at Shahjehanpore (North-west Provinces), a factory at Cossipore, in the suburbs of Calcutta, and one at Aska, in the Ganjam district. But the products of these works find a ready sale in the country amongst the European population, and there is a practically unlimited field for the further development of this industry with a view to the economical preparation of sugars for native consumption, and to the improvement in quality of the article exported. An improved mill, manufactured by Thomson and Mylne, of Beheea, effects considerable economy in the expression of the juice. It is cheap, simple, and portable, and it is understood that it finds a ready sale amongst sugar cultivators. Attention might also with advantage be given to the preparation of date sugar, which as yet is exclusively a native industry, largely carried on for the foreign market only in Lower Bengal, although in the Madras and Bombay Presidencies there are districts where the industry might be followed with equal advantage.

The sugar-cane is generally believed to have originated in the Indian Peninsula, and is said to ripen all the year round in the varying climates and soil to be found in the vast expanse of land between Cape Cormorin and the Himálayas. So cheaply can sugar be produced in India, that Dr. Royle thought it might even be possible to use it for manure in less favoured lands; and, indeed, it is already manufactured there at a low enough cost to be used in this country for feeding and fattening cattle. It has, therefore, always appeared most singular that India, which might with ease supply the whole world with sugar, actually does not produce enough for its own requirements. Indeed, in 1876, the last year for which returns are available, it imported 30,657 tons, while it only exported 25,370 tons. It is nevertheless strange that, no sooner do the European markets rise beyond a certain price, than vast quantities of sugar immediately begin to be exported from India, though in the general way its produce is almost unknown in exterior markets. The universal cultivation of the cane in India, and the great quantity of sweets eaten by its peoples, indeed, make it evident that the sugar production of the empire must be immense. No country has a soil or climate better adapted to the industry, or more abundant supplies of cheap labour, while the growth of a fresh great export trade would be of very high importance not only to India but to ourselves. The reason why Indian sugars are unknown or despised in the markets of the world, though so much of them is produced, certainly appears a subject for inquiry. On this question the following statistics are available:—

ASCERTAINED AREA UNDER SUGAR CULTIVATION IN BRITISH INDIA; AVERAGE YIELD PER ACRE; AND ESTIMATED PRODUCE AND PRICE.

Presidencies or Provinces.	Approximate Extent of Cultivation in Acres.	Average Produce per Acre in Cwts.	Estimated Yield or Out-turn, in Tons.	Price of Produce per Cwt.
Assam (excluding the Hill Districts)	85,738	12	52,476	Not stated.
North-West Provinces ..	703,163	No information.		
Oudh..	203,538	5	54,952	6*s.* 1*d.* to 15*s.* 4*d.*
Punjab	391,630	10	193,400	36*s.* 6*d.* first quality.
Central Provinces	107,805	4	22,542	10*s.* 10*d.* to 24*s.* 7*d.*
British Burmah	4,271	11	2,123	25*s.*
Madras	33,000	No information.		
Mysore	14,737	5	3,313	10*s.* 8*d.*
Hydrabad (assigned districts or Berars)	5,594	No information.		
Bombay	49,849			
Scinde	4,058			
Total	1,603,383			

N.B.—These figures are for the year 1876–77, with the exception of Assam, which is for the year 1875-76.

It will be seen that the above table gives no information as to the sugar acreage of Bengal, but its area is, roughly, double that of the North-West Provinces; and supposing that the cultivation of the cane in the former is proportionally great (perhaps a moderate estimate, as it contains the alluvial delta of the Ganges), the acreage under sugar in Bengal would be 1,400,000 acres. This would make the acreage under sugar, in that part of India under direct British rule, 3,000,000 acres in all. The area of native feudatory states is 60 per cent. of the area of British India, but their population is only 25 per cent. of that under our rule. Assuming that the acreage of sugar in the native states is only one-quarter what it would be in a similar extent of British India, it would amount to 750,000 acres. This would, at a moderate estimate, give the sugar acreage of all India as 3,750,000 acres, and the production of sugar, at the average of 8 cwt. per acre, shown by the above table, would be 1,500,000 tons per year.

Our imports from India have been:—

	1876.	1877.	1878.	1879.	1880.
Sugar: Unrefined.. ..	cwt. 456,161	cwt. 891,801	cwt. 298,141	cwt. 186,006	cwt. 512,907
Sugar: Unrefined.. ..	£ 440,889	£ 939,757	£ 252,173	£ 146,066	£ 376,924

The native method of "refining" (or, more correctly, "curing") the raw sugar deserves a short description. The product of the first boiling of the juice is either "raab" or "goor," the former being a semi-solid syrup, while the latter has been boiled till it will assume a solid concrete state. Both consist of varying proportions of both crystallisable and uncrystallisable sugar, with the ordinary organic and other impurities.

The raw material is purchased during the cane-pressing season (from middle of November to end of March or April), and stored in dry godowns. As much as 3000 maunds of goor are bought by an average well-to-do refiner during the season for one evaporating pan. While the buying season continues, nothing is worked up but goor. Molasses are reboiled during the rains, and until another season comes round.

In one pan or evaporator, 30 kutcha maunds are worked off daily (= 18¾ Calcutta maunds of 82 lb., or about 13⅔-cwt.). The goor "chuckees" or cheeses are broken up and put into the pan with 30 ghurrahs (earthenware vessels holding about 3 gallons) of clean water (= 90 gallons). The firing is begun gently. It requires 100 maunds (nearly 4 tons) of firewood to work up 100 maunds goor. The wood chiefly used is "mahooa," costing Rs. 25 per 100 maunds split and cut up ready for burning, or mango at a cost of Rs. 20 per 100 mds. Coal would cost here not less than 12 annas or a rupee per maund, i. e. 20 to 27 Rs. per ton. As soon as the contents of the pan have become heated, fresh cows' milk is added in the proportion of 4½ pucca seers or 9 lb. weight of milk mixed up in 5 ghurrahs (15 gallons) of water. The milk acts as a coagulum, drawing all the impurities to the surface, when it is skimmed off as often as any appears. This is the only and most thorough defecation during the whole process. The skimmings are collected in an earthenware vessel fixed near the evaporating pan, and amount to about 18 ghurrahs (54 gallons.)

The goor syrup from the moment it is put into the pan to the time when taken off, continues to be defecated and heated up to boiling-point for 4 or 5 hours. It is then strained through a filter of cloth covering a willow basket placed over an earthen vessel. The cloth should be the ordinary country-made stuff, but regular in texture.

As soon as the evaporating pan has been emptied, and while the syrup is being strained, the 54 gallons of skimmings are poured into the pan, 30 gallons of water are added, and the whole is reboiled without any clarifying or defecating process. This liquor is ready in an hour to be poured into the filter mentioned above.

The evaporating pan being now empty, it is carefully cleaned out, and the work begins of evaporating the defecated juice down to the crystallising-point. It will be noted that there are two distinct processes—the first, to defecate or clarify the goor-syrup; the second, now to be described, to boil it down for crystallising. The amount of dirt in the filter weighs about 8 kutcha maunds, or 410 lb. (i. e. 5 pucca mds. of 82 lb. each). It is composed of begass, leaves, soot, or mud, and when dried is used for fuel.

The defecated or cleaned juice or syrup, of which there would be about 40 ghurrahs (= 120 gallons) is now dealt with, but not in bulk: only 1 ghurrah, or 3 gallons, are boiled down each time, as a small quantity is more under command than a large quantity. Three gallons of juice being poured in, it is boiled down, and when nearly ready, is treated with castor-oil-seed water, which is said to have the after effect of making the molasses run off the sugar crystals quickly and cleanly. The standard solution of castor water is made by pounding finely 1 lb. of dry castor-oil seeds and mixing it up in 1 ghurrah (3 gallons) of cold water. To 1 ghurrah (3 gallons) of the syrup, when nearly evaporated to the finishing-point, is added 1 chittack (Calcutta capacity) = 2 oz. of the castor seed solution.

By evening, the whole 40 ghurrahs (120 gallons) of defecated juice is worked off. As soon as one of the 40 ghurrahs is sufficiently evaporated, it is taken away to another building, and put into a cooler or "naad," which contains about 24 or 25 gallons of evaporated crystallisable syrup. These naads have a hole in the bottom, into which a plug is put from below; and over the hole, from the inside, is placed a little piece of mat, 9 inches by 9 inches, to prevent sugar passing through along with molasses.

After a naad or strainer is full, it is left untouched for 12 or 13 days. This is to allow crystallisation to go on. No syrup or molasses is allowed to drain off through the bottom hole at this period. After the lapse of 12 days, the contents are cut out in layers 3 inches thick, broken up, and turned over into a separate naad or strainer, supplied as before with a plug-hole. Before each layer is cut into, it is slightly sprinkled over with lukewarm water, which is said to facilitate the after draining of molasses. The contents being transferred from one cooler into another, it is allowed to drain in the latter for 5 days, when the bulk of the molasses drains off through the plug-hole, the intervening mat preventing the passage of any solid sugar. After 5 days, the surface of the sugar, which is now like dry muscovado, is broken up finely, and ultimately mixed up to the depth of 1½ inches, so as to present a loose and uniform body when subjected to the action of the "sewar" or weed described hereafter.

On the 6th day, after turning over from one strainer into another, the fresh wet weed to a depth of 1½ inches is applied on the surface. On the 7th day, nothing is done; on the 8th fresh sewar is added; on the 9th, nil; on the 10th, again fresh sewar. Each time fresh sewar is added, the preceding sewar (now withered) is put above the fresh sewar to prevent the latter from withering rapidly. Up to this time, no sugar is taken out. On the 12th day, fresh sewar is added for the fourth time; and on the 13th day, 1½ inches of beautifully white and fine sugar is scooped off the surface. The process having been started at the surface, with four applications of sewar, it is only necessary to add fresh sewar every second day, and on intervening days to cut out 1½ inches of sugar each time.

Before sewar is added a fifth time, and on subsequent occasions, the surface of the remaining muscovado in the strainer must, as at first, be dug up and loosely mixed to a depth of 1½ inches, to allow the mysterious action of the sewar to have full effect.

It will take 25 days from the first scooping out (or scraping off) of clean sugar, to work at the bottom of each naad, of which probably there are 200 for each evaporating pan.

As the sugar is taken off the surface, it is spread on a thick cloth and dried in the sun; a man goes to and fro spreading it out to whiten it, by crushing the small crystals against each other.

The molasses which leaks out through the plug-hole during the time of draining, runs along gutters into a reservoir dug under the floor of one of the houses. It is worked up into a second quality of sugar during the rains,—which is obtained by reboiling 9 gallons of molasses diluted with 3 gallons of water. No defecation with milk, or treatment with castor-seed water, takes place, nor is much scum taken off.

The following are the average results of refining 100 maunds goor:—

	mds.		per md.	at par exchange.
1st class "Chinî," called "Rás" ..	33,	valued at	15 rs. =	about 40*s.* per cwt.
2nd " " " "Doma" .	15	"	8 rs.	" 21*s.* "
Molasses, after 2nd boiling	30	"	8 as.	" 1*s.* 4*d.*
Refuse, cane trash, soot, mud, and evaporation	22,	the solid portion being used for fuel.		
	100			

Before the introduction of portable iron-roller cane-mills, the refuse amounted to as much as the first sugar, viz. 30 per cent.

Raab would not give better results than goor, and would require more complicated arrangements for carrying, purchasing, and storing; hence its disuse in favour of the more portable and handier chuckees of goor or concrete.

The sewar weed before mentioned must be had fresh from adjoining streams or rivers. It is carried sometimes a distance of 10 or 15 miles, and may be obtained from the edge of most perennial streams in this quarter. Its botanical name is *Vallisneria spiralis.* Montgomery Martin states that when it cannot be procured, the *Serpicula verticillata* of Dr. Roxburgh, and several *Potamogetons*, are used.

The daily operations of the native process of refining may be contrasted with the use of centrifugals, thus :—

NATIVE PLAN, USING GOOR.	
1st day	Buy goor, and store it.
2nd day	Pound goor, dissolve, defecate, filter, concentrate, and put into coolers or strainers to crystallise.
3rd to 14th day	Allow contents to remain untouched.
15th to 19th day	Cut out contents, and transfer to separate strainers to drain off molasses.
20th to 28th day	Apply sewar four times, and scoop out 1½ inches of surface sugar at a time.
29th to 45th day	The gradual cleansing of the entire bulk of sugar in the cooler or naad.

Total—1½ month to obtain 33 per cent. of No. 1 "Chînî" or muscovado, which sells at an average of 14 rs. per maund, or £1 18*s.* per cwt.

CENTRIFUGAL PLAN, USING RAAB.	
1st day	Buy raab, and store it.
2nd to 9th day..	To settle if it has been newly made.
10th day	Charge turbine, and take out turbine sugar.

Total—10 days to obtain 45 per cent. of turbine sugar, which sells at an average of 10 rs. per maund, or, say, £1 7*s.* per cwt.

Our imports of raw sugar from India in 1884 were 854,109 cwt., value 470,614*l.*, from Madras ; 56,739 cwt., 46,503*l.*, from Bengal and Burma ; and 5166 cwt., 3246*l.*, from Bombay and Scinde.

An Indian factory, that belonging to Mr. Minchin, at Aska, must be credited with having been the first to make a success of the diffusion process for cane.

Italy.—We imported 4023 cwt. of unrefined sugar from Italy in 1880, valued at 3636*l.*

The quantities of sugar entered for consumption were, according to the Custom House tables, in 1877 and 1878 respectively :—

	1877.	1878.
	kilos.	kilos.
Refined	3,875,901	615,686
Non-refined ..	37,001,409	38,648,519

But the German and Austrian sugars, coming by land, do not figure in these tables, as they pay duty at the land frontier.

The great feature of the year 1878 was the crushing effect the increased production of the local refinery had upon the import of refined sugars. This establishment (the Ligure Lombarda), under the protection of existing duties, and further assisted by the facilities accorded by the Government of paying these duties only at the expiration of 6 months, acquired the supply of the whole market, and annihilated foreign competition in the qualities it produced. The increased import of raw sugars was entirely due to the purchases of this establishment, which in the year 1878 turned out 35,000 tons of sugar. The qualities imported have been chiefly Guadeloupe, Mauritius, and Egyptian sugars, and beet sugars from Germany, Austria, and France.

Japan.—The Japanese provinces where sugar is mostly grown are Isé, Owari, Totomi, Suruga, Aki, Ku, Awa, Sanuki, Tosa, Hizen, and Satsuma. Sanuki has the name for producing the best kind of white sugar, and Satsuma for the better quality of the darker description. Sugar-cane, which is obtained from seed, is said to attain to a height of about 10 feet in Japan. It is not known to bear any flower. The mode of cultivation is as follows:—At the commencement of the cold weather, small bundles of sugar-cane roots are planted in rows, stem down and roots upwards, on a slope of about 45 degrees. The following spring they are taken up, and about 2 inches of cane, both above and below the joint, having been cut off, they are planted out in proportion of about 900 lb. weight of cane to ¼ acre of ground. The soil is well looked after in the spring, and a number of small holes are dug here and there. Into these the lees of oil are poured, and they are then filled up with earth, in which the cane-slips are now planted out, that is, so soon as the cane-slips show signs of budding or of having taken root. When planted, a little liquid manure is applied. After the lapse of 15 days, the slips or roots will have attained a growth of about 7 or 8 inches. At this stage, fish manure, mixed with the lees of oil, is applied. In droughty seasons, the ground is also watered. There are three kinds of insects which do much harm to the sugar-cane in Japan, and against the ravages of which some precaution has to be taken.

During the winter, the canes that have attained the highest growth are either broken off just above the roots, or are cut with a sickle. The canes are then stripped of their leaves, and are made up in bundles, each of about 80 lb. weight. A quarter of an acre of ground will produce about 10,800 lb. of cane, and this quantity of cane will turn out from 6 to 7 piculs of sugar. The sheds in which the cane is crushed are generally about 24 feet square, and in each there are three crushers worked by oxen. The teeth of the crushers are kept constantly fed with canes, about 4 or 5 being inserted at a time. A workman stands behind on the watch for any canes that may slip through the crusher without being caught in the action of the mill; and canes that have so passed are handed to a third man who feeds the mill from the opposite side. The mill having a reverse action, it thus results that not one cane is lost. The cane juice is now removed to a separate place in quantities of about 200 lb. weight at a time, and the mill is cleansed after each such removal. The syrup then goes through no less than four refining processes, and is afterwards removed to where it is to be made into sugar. The working up of about 2220 lb. weight of cane is considered a fair day's work. As regards the further process with the syrup, about 133 lb. weight are poured into two tubs, each tub containing half of the above quantity. Fires are then lit under the boilers, and the contents of one tub are poured into the boiler. A small quantity of lime is then mixed with the syrup, which is skimmed when at boiling-point. The clearness of syrup will be the test of its having been sufficiently boiled. If the syrup is thick, or in any way impure, it shows that either too much or too little lime has been put in.

The syrup is now placed in a tub, called by the Japanese "sumashi oke," in which it is allowed to settle, fresh syrup is again poured into the boilers, and boiling goes on as before. As soon as the syrup is once more at boiling-point, that which has been already boiled is poured in and mixed with it, the white froth being skimmed off and placed in an empty tub. The syrup is now divided between the two boilers, and allowed to simmer for about two hours, being constantly skimmed during this time. In order to ascertain the amount of boiling which the syrup has undergone, a bamboo is inserted, and in withdrawal the drops are allowed to fall into a saucer containing water. If the drops congeal rapidly, the fires are at once withdrawn from the boilers, the syrup is promptly poured into coolers arranged in sets of four, and constantly stirred. So soon as it has sufficiently cooled, it is poured into tubs, one man attending to each tub. To make the very best quality of sugar, a picul of ordinary sugar is divided into nine parts, and each is wrapped in a hempen cloth; they are then placed in receptacles, pressed down with heavy weights, and are thus sweated for one night. On the following morning, the sugar thus sweated is placed on a table, and kneaded for about two hours, after which it is again wrapped in cloths, and the same process is gone through for three successive days and nights. On the fourth day it is placed in clean receptacles, and is now termed first quality sugar. To obtain a superfine quality, the sweating and kneading are gone through for an extra day. A picul—or, say 133 lb. of ordinary sugar—will thus be made to yield about 50 lb. of first quality sugar; the remaining 80 lb. are, of course, not wasted, but from it are obtained about 40 lb. of a sugar known to the Japanese under a particular name, and the residue also finds its way to market. Second quality sugar is known as "jui-mai," and is made by sweating a certain quantity of coarse sugar.

Sugar is generally known to the Japanese under three headings, white, black, and candied, but the two former are again known under a variety of names. A good deal of black sugar is produced in the Loo-Choos, in Sakurajuna, Araki, Hanaoka, and Jaramidzer. Any marked difference as to good or inferior kinds of black sugar depends on the quality of the cane and the skill of the workmen, but the above-mentioned places have always well sustained a reputation for providing the best sugars. Sugar candy is made by boiling down a certain quantity of best quality sugar and adding the white of egg. Split pieces of young bamboo about an inch in length are then put into the syrup, which crystallises around them. A good deal of sugar candy is made in Osaka. Either Japan sugar cannot compete with that produced in China, or the supply is not equal to the demand, for China sugar is always an important item in the import returns.

Java.—The area under cane is about 70,000 acres. The following figures show the production from 1876 to 1885:—

	Piculs.		Piculs.
1876	3,717,716	1881	4,606,780
1877	4,048,574	1882	4,809,322
1878	3,700,630	1883	5,348,867
1879	3,843,470	1884	6,493,248
1880	3,593,404	1885	6,259,355

From this table it will be seen that the production has taken great strides since 1880, caused by the yearly erection of new mills during the prosperous years of 1881–83. The yield of 1884 was an unusually abundant one, owing to the exceptionally fine weather which prevailed, and the decrease in 1885 was owing to a generally smaller yield of sugar per acre, and not to any reduction in the acreage planted.

The 1886 crop was about equal to that of 1885, and for 1887 the acreage planted was about the same as in 1885 and 1886, so that the production of that year will only differ from that of its predecessors as it may be influenced by climatic or other unforeseen causes. No new mills are at present being erected; and the production at the moment is stationary, and will probably remain so for, in any case, another couple of years.

The question as to the price at which sugar can be produced here is a very vexed one, in view of the varying circumstances under which mills work in the different districts of the island.

Mr. Van den Berg, the president of the Java Bank, who has a wide reputation for the interest he takes in the welfare of this and other industries in the colony, lately collected statistics bearing on this point from all the districts of the island, and came to the conclusion that the crop of 1885 cost on an average 8 fl. per picul of 136 lb. English, or about the equivalent of 11*s.* 6*d.* per cwt., free on board, for No. 14.

The present crop will, it is said, cost less, owing to further economies having been introduced in the manufacture of the sugar.

Turning from the average cost of production over the whole island, to that of some individual mills, in several well authenticated instances, this does not exceed 6 fl. per picul, or about 8*s.* 9*d.* per cwt., free on board; while a cost of 7 fl. per picul, 10*s.* 3*d.* per cwt., free on board, is by no means rare.

These figures include an export duty of 9 c. per picul, or 1$\frac{13}{28}$*d.* per cwt.; and there are other taxes weighing exclusively upon this industry, which vary in different districts, but may be taken as running from 50 c. to 75 c. per picul, or 8$\frac{1}{4}$*d.* to 1*s.* 0$\frac{3}{8}$*d.* per cwt. Agitation is being carried on by the planting community for the removal of these burdens.

The exports of the 1879 crop were:—2,356,530 piculs to Channel for orders, 329,053 to Holland, 328,967 to Australia, 284,458 to America, 161,971 to France, 35,975 to the Persian Gulf, 35,125 to Singapore, 19,088 to Lisbon for orders, 12,133 to China, 10,403 to Cadiz for orders, 2164 to Siam: total, 3,575,867.

Our imports from Java have been:—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined	1,316,095	1,514,469	1,550,845	1,763,522	3,253,653
	£	£	£	£	£
Sugar: Unrefined	1,923,796	1,839,556	1,766,285	2,226,225	2,899,620

The exports of the 1878 crop were:—428,351 piculs to Holland, 2,098,043 to the Channel for orders, 162,816 to France, 8996 to Gibraltar for orders, 11,000 to Sweden, 258,757 to America, 406,837 to Australia, 38,249 to the Persian Gulf, and 32,988 to Singapore; total, 3,446,037.

The gradual diminution of Government assistance hitherto granted to sugar planters in Java on certain fixed conditions in the form of compulsory labour, commenced during 1879, the area treated under Government supervision during the year being one-thirteenth less than in 1878; official assistance will be withdrawn annually to this extent, so that in 1891 the Government will have entirely ceased to provide labour in connection with sugar cultivation. The result of this policy is as yet problematical. Thus far, owners of so-called "free mills," i. e. those working without Government aid, have found it no slight undertaking to contend, unassisted by the authorities, with the natural laziness of the Javanese; their experience, however, is on the whole, not discouraging, and although the measure in question is condemned by the present planter interest, there are, on the other hand, cogent arguments used in favour of a law which tends to the abolition of forced labour.

Madagascar promises to become a great sugar-producing country, the alluvial lands being eminently suited to cane, the climate favourable and free from tornadoes, and labour abundant and cheap.

Madeira.—According to the best calculations, it is estimated that the sugar-cane crop of 1879 yielded about 950 tons of sugar and 305,280 gallons of spirit, showing a considerable decrease from the crop of 1878, which gave 1320 tons of sugar and 595,000 gallons of spirit.

Mauritius.—A combination of unfavourable circumstances has tended to the decline of the sugar industry in this island, despite the fact that its mechanical appliances are far superior to most of the colonies, and that its sugar is particularly esteemed. In 1876, the export of home-made sugar was

115,801 tons; in 1877, 136,292; in 1878, 128,329. Our imports thence have been :—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined	1,205,354	626,934	451,861	120,516	338,495
	£	£	£	£	£
Sugar: Unrefined	1,747,147	782,434	486,295	137,021	234,439

The comparative table below gives the amount of sugar exported to various countries from 1st July in each year to the end of March in the following year :—

Countries to which Exported.	1883–4.	1884–5.	1885–6.
	tons.	tons.	tons.
United Kingdom	6,682	9,639	12,397
France	756	43	7
Australia	36,841	25,871	15,319
New Zealand	9,432	7,030	5,654
Bombay	30,856	47,743	39,538
Cape of Good Hope	4,492	3,533	2,515
America	7,099	7,353	5,278
Other countries	971	1,812	3,615
Total	97,129	103,024	84,323

It will be seen that the exports to Australia, which amounted to 36,841 tons in 1883–4, fell to 25,871 in 1884–5, and to 15,319 tons in 1885–6. The Australian markets, which are already supplied by home produce, also derive their supply from America, Fiji, Java, and from China, where the sugar-cane is much cheaper than at Mauritius. On the other hand, there is an increase in the exports to Bombay.

Mexico.— Our imports thence of unrefined sugar were 30,560 cwt., value 32,532*l.*, in 1876; 94,879 cwt., 98,113*l.*, in 1880; 19,695 cwt., 17,957*l.*, in 1884. The sugar trade of Mexico is gradually being developed. The American Consul at Tampico states that the total value of the sugar raised in the republic is 1,775,000*l.*, representing a product of nearly 300,000,000 lb., or a little more than the product of the

Hawaiian group. Of the total above given, the export equals 53,775*l.* in value, or 6,959,100 lb. It seems probable that sugar production on the western coast of Mexico has a great future before it. If this should prove to be the case, San Francisco will benefit by it, as it is sure to become the principal market for West Mexican sugar.

In Paris, Cerralvo, Agualeguas, Puntiaqudo, and Sabinas, in the state of Nuevo Leon, towns situated within 90 miles of Guerrero, and along the bottoms of the Rio Grande, as far as Matamoras, there is a considerable amount of sugar produced, but the true sugar country is situated at the towns lying along the foot of the northern declivity of the Sierra Madre, namely, Victoria, Linares, Montemorelos, Cadarrita, and numerous other towns, extending as far as the Gulf of Mexico on the South, and to the North as far as the borders of the State of Coahuila, in Lampasas, Villadama, San Buenaventura, Santa Rosa, and San Fernado. Consul Winslow, of Guerrero, says that from the cañons in the Sierra issue numerous streams which unite to form rivers, and at the heads of these rivers, where the banks are low, and irrigation can be used, are situated the haciendas of sugar-cane and corn. The inhabitants of a town and owners of land, who so desire, form a company, and request permission from the Government to draw off water from the river. This being granted, the river is dammed up, and a large canal is made, which is called *el saco de agua,* or sack of water, and leading from this are smaller canals, called *sequias,* which conduct the water to the different haciendas. The *saco* of water is divided up into many shares, and each person takes as many shares as his means will permit, or each one puts so many men to work to make the dam and the canals, and according to the labour he employs is his share in the *saco* of water. The *dia de agua,* or water day, consists of 24 hours, or from sunset or sunrise of one day to sunset or sunrise of the next, once every month, and a man of moderate means may own but one or two days of water, while the richer haciendero may own several days, or one haciendero may be the exclusive owner of one saco of water. When a person owns one day or more of water, he has the exclusive right to the whole water for the time belonging to him, the sluice gates being shut down in the mean time from the other canals. From the same river there may be several sacos of water, but the number is limited to the size of the river. The labourers on the haciendas are, says Consul Winslow, literally worse than slaves. Their wages are generally about 16*s.* to 20*s.* a month, and one peck of corn and some beans every week. The tortilla, with some red pepper and beans, and an occasional piece of meat, and some coffee, are the sole subsistence for themselves and families. Their bed is a sheep-skin and a cheap Mexican blanket. Besides these labourers, or *peons*, there is another class, called *arrimados*, who live on the hacienda with their families, and are allowed to plant or to raise stock on condition that they assist in the labour of the hacienda when required, or give a portion of their crop. The *medieros* are those who plant a field and give half the product to the owners. These two latter classes are much superior to the peons. If, however, it were not for the peons, no sugar-cane could be raised, as day labourers are scarce, and not to be depended upon. In the preparation of sugar, wooden mills of a rude description are generally used, although in the larger haciendas iron mills are coming into use. These iron mills are worked by water power from the canals that water the haciendas. The cane-juice is transferred from the tub to large iron boilers, which are placed over a fire in holes dug in the ground, and is boiled, being constantly stirred until it is sufficiently condensed, and is then poured into conical earthen moulds, which contain 1 lb. each. The sugar loaves, or *piloncillos*, are then wrapped in cane leaves, and are tied with fibres from the leaves of the bayonet palm; 150 of these loaves are packed in an oblong sack. The sugar from the different haciendas is not of uniform quality, some of it being of a yellowish-white colour, and resembling maple sugar in taste, and some of a dark brown, of a disagreeable taste. No clarifying materials are used in the preparation of the *piloncillo*. It is stated that Mexico can produce sugar at a lower price than any other country in the world. In Cuba, the lb. of sugar costs the planter nearly 1½*d.*, in Central America a little over 1*d.*, and in the Sandwich Islands a little over 1½*d.* In the fertile lands of Mexico the production does not cost more than ½*d.* per lb. at the most. There are two kinds of sugar cane planted, one called the *cana criolla*, or creole cane, which is about ½-inch thick, of a light green colour, thin bark, short joints, and very sweet. The other, called *cana pinta*, or painted cane, of a reddish colour, 1 inch thick, with a tough bark and longer joints. The latter is mostly planted, as it yields more juice than the former. The *cana criolla* produces a much whiter and harder sugar, and of a better quality; when stripped of its bark, and ground, a very white sugar is made, which is sometimes mixed with aniseed and kernels of walnuts. This class is extensively eaten as a delicacy. Consul Winslow says, in conclusion, that there are a few sugar refineries in the neighbouring State of Neuvo Leon, but from the scarcity of refineries in Mexico generally, it would be a profitable enterprise to establish them in that country.

Natal.—Sugar has a history in Natal similar to that of most other cane-growing countries. The beginners had neither the practical knowledge requisite, nor the necessary capital. Fifteen years ago Natal planters thought that only flat lands were suitable, now the bulk of the crop is grown on hill lands. The planting season is September to November. The first crop is ready about 21 months after being planted. The cotton crops follow at intervals of 15 to 18 months; generally at least 3 crops are taken from the same plants. On some few rich alluvial flats, as many as 10 or 12 crops have been taken without the land being replanted. First crops on good land, if with ordinary favourable season, and if the weeds be kept down, are calculated to give 2½ tons (5600 lb.) per acre, besides treacle, which is afterwards distilled into rum. Succeeding crops (first or second ratoons) are expected to yield not less than 1½ tons (3360 lb.). These figures are below the average experience of planters in good seasons, 3½ tons of sugar per acre for first plant cane having often been obtained. The terms of sale in Durban are prompt cash. The average value, taking the average by shipments, is between 22*s.* and 23*s.* per cwt.; white crystal sugar realises 28*s.* to 30*s.* per cwt.; yellow crystallised, 24*s.* to 25*s.* per cwt.; heavy syrup sugar, 17*s.* to 18*s.* per cwt.

The Central Mill system has been at length successfully introduced at the Usine Centrale, in Victoria county, where growers of cane deliver their crop (by rail or by wagon), and, after the juice is extracted, the value of sugar contained therein is ascertained by testing the density of the juice. The grower can receive his payment for the proportion coming to him (calculated at about two-thirds of the value of the sugar at existing prices) without delay, the manufacturing company making a profit on the cost of manufacture out of the other third. The mill has cost about 70,000*l.*, and will turn out 15 to 20 tons of white crystallised sugar per day. A mill capable of making 2 tons of sugar per day can be erected for about 5000*l.* to 6000*l.*, including all good buildings. The 1881 crushing season is said to have given the largest crop yet produced in the colony, and is estimated at 15,000 tons—worth over 300,000*l.* As with coffee, the lane seems to have turned, so with sugar; the losses of the past, which have been very heavy, and from many causes, seem likely to be compensated for in the immediate future, not, though, in many instances, to those who suffered the loss, but to others who have purchased estates which the former owners could not retain. Manuring the land for sugar-cane has only been resorted to as yet in very few instances in Natal.

Our imports thence have been :—

	1876.	1877.	1878.	1879.	1880.
Sugar: Unrefined	cwt. 22,189	cwt. 60,595	cwt. 20,752	cwt. 15,095	cwt. 31,405
Sugar: Unrefined	£ 22,027	£ 73,722	£ 18,573	£ 13,111	£ 29,234

New Zealand.—Efforts are being made to secure the establishment of a beetroot sugar manufactory in the Waikato, and to induce the settlers to cultivate the beet. At a meeting of settlers it was announced that a Hamburg company were willing to furnish seed of the best quality for the cultivation of 500 tons of beet, send out a plant capable of manufacturing 10,000 tons per annum, and skilled labour to work it, and to take about 6000*l.* money interest in the undertaking, if the settlers would grow that quantity of beet, and provide the remaining capital required—some 24,000*l.* The nett profit for the working of a plant of this kind was expected to be not less than 30 per cent. per annum on the paid-up capital. Notwithstanding the fact that the soil and climate in Waikato are very suitable for the growth of beetroot, the settlers appear indisposed to undertake its cultivation; but in order to prevent a failure of the scheme, J. C. Firth, a wealthy landowner, and the possessor of many thousands of fertile acres at Matamata, has undertaken to grow 500 to 700 acres of beetroot per annum for a long term of years. Should the necessary capital be found, therefore, sugar may form an article of export from Auckland ere long.

Pacific Islands.—Fiji produces a native sugar-cane called *vico*, which may or may not be a species of *Saccharum.* Both climate and soil are well adapted for sugar-cane. The soil in most places is rich alluvium on the banks of the rivers, loam on gentle slopes or hillocks, and volcanic soil of the richest kind. The cane lands are found in all parts of the group: in the far interior of Viti Levu, at the mouths and on the banks of the Rewa, Sigatoka, and other rivers, in many localities of Vanua Levu, Tadiuni, Rabi, and even Ovalau and some of the smaller islands.

In the Sandwich Islands, several estates have yielded 12,000 lb. of sugar per acre of plant canes per annum from large tracts; ratoons give 3 to 4 tons. Fiji might reckon upon an average of 5000 lb. an acre; about 3000 acres are now under cane here, as against 1838 in 1879. Tahiti has about 300 acres in cane. The Sandwich Islands produce yearly about 30 million lb. of sugar, and 500,000 gallons of molasses. The Hawaiian Islands in 1879 exported 49,020,972 lb. of sugar, 87,475 gallons of molasses, and 2184 gallons of rum.

Peru.—Among foreign introductions, the sugar-cane is the most important. Better than guano or salitre, it is destined to be the surest and most inexhaustible source of the wealth of Peru. The annual yield of sugar and spirits is estimated at 20,000,000 dols. The recent rise in the price of sugar has given a new impulse to its cultivation, and the prospect is that Peru will ere long be a formidable rival of Cuba and the other West Indies. The usual cane crop in the West Indies is 1,130,000 tons; in Java, 200,000; in Brazil, 170,000; in Louisiana, 75,000; in Egypt, 40,000. In 1875, Peru exported 60,000 tons; in 1876, over 70,000. That amount will be greatly increased, provided labourers can be obtained. But thousands of acres are lying idle for want of hands. The Celestials outbid and outdo the mongrel races along the coast, and the mountaineers cannot endure the lowlands. But Chinamen must be better treated than they have been. Even now, great as is the demand for foreign labour, the natives, as in Trujillo, would persecute the Asiatics and drive them from their shore.

In no other country, save Egypt, is the cane crop so sure as in Peru. Occasionally, as in 1871, the crop may suffer by drought from want of the supply of water from the sierras;

but in the course of 10 years, the decrease would not amount on the average to more than 25 per cent. As the cultivation is regulated by irrigation, as in Egypt, Peru has an advantage over Cuba, where planters depend on the weather. At present, Peru can compete with any other country, save Egypt, since she can grow the cane without intermission. The slave labour of Cuba cannot produce it so cheaply. The cane grows more slowly than in Louisiana. The amount of juice to the cane is about 65 per cent., and its average density is 10° B. In Northern Peru, 2 tons of cane give 400 gallons of juice, each gallon yielding 1·35 lb. of sugar. The best season for planting the cane is November, and the yellow variety (originally from India) is preferred to the red, being richer. The first planting takes 15 months to mature; after that, the crops (ratoons) ripen every 12 months. This is true only of Northern Peru, where the soil is thinner but more tropical than at the south; in Cañete, for example, it takes fully 2 years for the first crop to mature. Some 3 or 4 crops are obtained before re-planting is necessary. The green and ripe cane are seen in the same field; there is cutting at one end and planting at the other; so that the ground is never idle. The actual time spent in the manufacture of sugar is 8 months; the rest of the year is occupied in repairing acequias, &c. From the small establishments, the sugar is exported in the crude "concrete"; in the larger mills, it is first refined. For inland transportation, Western Bolivia being supplied from Peru, it is put up in conical loaves, weighing 45 lb. each. Under the present American tariff, refined sugar goes by New York to Europe, the law favouring the New York refiners without benefiting the consumer or the Government revenues. Then, too, the Hawaiian Reciprocity Treaty, allowing free importation of sugars from the Islands, tends to turn the sugar of Peru across the Atlantic.

The sugar-cane is cultivated on both sides of the Andes, but it does not grow at a higher altitude on the western slope than 4500 feet, while on the eastern side its limit is 2000 feet higher. In the Marañon region, as at Moyobamba, Tarapoto, Aipena, and San Regis, and also in the Urubamba Valley (Upper Ucayali), it grows luxuriantly, but will not give crystallised sugar; so it is turned into aguardiente. There the cane ripens in 6 or 7 months after planting. Considerable sugar of excellent quality is manufactured at Abancay on the Apurimac, but rudely purified with clay: it is mainly consumed in Cuzco, where it brings forty cents a lb.

The Pacific slope of Peru, particularly of Northern Peru, is the great sugar district; there it is fast taking the place of cotton and rice. The whole coast presents a series of alternating arid wastes and fruitful valleys. Nothing is wanting but water to convert the entire coast into a garden 1200 miles long. But it is worthy of remark that wherever the railroads run from the coast into the mountains, they seem to have changed the meteorological character of the lowlands, rains being more frequent on the coast terminus than formerly.

Every port above Callao exports sugar, those of Talaverry and Eten taking the lead. All told, there are about 120 large sugar estates on the coast. Lambageque and Chiclayo contain 18, of which, that of Patapo is the chief and probably the largest in the country. It guarantees 5000 dols. a month freight to the railroad. The Pacosmayo Valley has 15, of which the Lurifico is the most important. The rich valley of Chicama near Trujillo is crowded with sugar plantations: its 24 mills produce to the value of 1 million soles (of 3*s.* 9*d.*) per month. The machinery is English. The Casa Grande of Sr. Albrecht is the most complete. Further south, near Chimbota, in the Valley of the Santa, are two large establishments, Puenti and Viuzos; the former has American machinery precisely like that of Lurifico, only the charcoal process is not used. Choncay, just above Lima, has 15 estates, of which Palpa is the largest; while around the capital are more than 20, among them the well-furnished establishment of Santa Clara. In the valley of Cañeta, are the extensive plantations of the late Henry Swayne, 2500 acres being under cultivation. There are also numerous cane estates in the departments of Ica and Arequipa, but they yield comparatively little sugar.

The Lurifico works are capable of turning out per day 35,000 gallons of juice, requiring 175 tons of cane, or nearly 50,000 lb. of muscovado. The production of rum is 1400 gallons daily at 40°. The length of the process from pressing the cane to bagging the sugar is two days, including one for cooling. In the field and mill, there are 939 Chinamen, who get two rations of rice per day, one sol (3*s.* 9*d.*) a week, and two suits of clothes a year. They all live within a small enclosure called Galpon, adjoining which is an excellent hospital under the charge of Dr. Heath. They work 10 hours a day—5 hours before breakfast, and 5 hours in the afternoon. On Sunday, which is pay day, they work but 4 hours. In less than 4 years, the majority will be free, as their term of servitude will expire: some will re-contract for a year or two at higher wages, but many will set up for themselves, for the great ambition of the more intelligent Chinamen is to keep a shop or fonda. The labour question is therefore constantly revived, and is the uppermost topic at the sugar haciendas of Peru.

Our imports thence have been:—

	1877.	1878.	1879.	1880.	1884.
Sugar: Unrefined ..	cwt. 1,108,510	cwt. 1,109,263	cwt. 1,382,077	cwt. 1,000,987	cwt. 374,767
Sugar: Unrefined ..	£ 1,424,494	£ 1,211,792	£ 1,380,622	£ 1,128,062	£ 316,591

Philippines.—The sugar-cane is grown in Negros, Panay, Cebu, Luzon, and nearly every part of the Archipelago; the best sugar is from Pampanga and La Laguna, the worst from

Taal or Batangas. The exports in 1880 were 1,581,188 piculs (of 139½ lb.) from Manila, 1,004,394 from Yloilo, 321,574 from Cebu; total 2,907,156 piculs, 2,620,000*l.* In 1884, 122,128,325 kilos., value 1,375,000*l.* Our imports thence have been :—

	1877.	1878.	1879.	1880.	1884.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined ..	1,058,907	717,322	1,194,501	1,175,140	623,801
	£	£	£	£	£
Sugar: Unrefined ..	1,154,117	618,426	983,997	983,590	395,265

The principal trade of Yloilo is the export of sugar, which, during the year 1879 was as follows :—

Destination.	Superior.	Current.	Total.	Value.
	piculs.	piculs.	piculs.	£
United States	553,475	..	553,475	422,024
Great Britain	42,560	103,871	146,431	90,879
Spain	375	..	375	300
China	24,362	..	24,362	18,880
Manila	21,738	15,623	37,361	25,363
Total	642,510	119,494	762,004	575,446

During three years the total exports were :—

	Piculs (of 139½ lb.)
1877	556,495
1878	629,964
1879	762,004

Showing a steady increase each year. The 1880 crop was estimated at 950,000 piculs, for a quantity of fresh land had been enclosed and cultivated; and, as the financial state of the sugar planters is good, within a few years the trade of this port should largely increase. From the above table, it will be seen that the greater portion of the sugar shipped hence in 1879 went to the United States, and consisted entirely of superior sugar. In previous years, some shipments of current have been made; but owing to the scale of duties in force in America, and to the quality of the sugar, it has not been found remunerative, and the trade may be considered to consist entirely of superior sugar. To England, on the other hand, current sugar is generally sent; but, during the past year, two cargoes of superior were shipped thither, which is exceptional. To Spain, besides the 375 piculs mentioned in the above table, a large portion was shipped viâ Manila; and the greater part of the 21,738 piculs superior entered as shipped to Manila was ultimately destined for Spain, although a fair quantity of it was for China. The demand for Spain is limited, and is entirely for the higher qualities of superior sugar. Of the 24,362 piculs shipped to China, the greater portion was for Chinese use and for the refinery; but 8000 piculs at least were probably intended for transhipment to the United States. The 15,623 piculs current sent to Manila were for transhipment to the United Kingdom, for it is sometimes convenient for the Manila merchants to draw supplies of current hence, when the corresponding Manila wet sugar (which comes from Taal) runs short. A fair quantity of sugar used to go hence to Australia, but during 1879 none was sent.

The exportation from Manila for 1879 exceeded that of 1878 by about 16,000 tons, the excess being entirely in dry sugars.

The 1880 crop was variously estimated at from 175,000 to 200,000 tons; even the lower figure would mean an excess of more than 40,000 tons over 1879.

Annexed are tables of exports, giving destination, quantity, and total values.

It is satisfactory to note the increased improvement in the preparation of sugar, which is shown by the large excess in dry sugars.

There seems a tendency to create larger sugar estates, and to import more machinery. The difficulty hitherto has been that in small cultivations the machinery has always been defective, and the sugars coarse. The steady increase of production during the last 10 years, making allowance for bad harvests, has been most marked:—

	Tons.		Tons.
1870	78,213	1875	126,198
1871	87,464	1876	130,831
1872	95,526	1877	122,868
1873	89,337	1878	118,235
1874	103,861	1879	134,287

The years 1877, 1878, and 1879 were unfavourable with regard to crops, from want of rain when required, and also from locusts, whereas 1875 and 1876 were exceptionally good years; with this explanation, the steady increase of production will be more apparent.

The following table will show the increase in dry sugar and decrease of unclayed or wet sugar:—

Countries.	Sugar, dry.			Sugar, unclayed.		
	1877.	1878.	1879.	1877.	1878.	1879.
Great Britain	17,912	7,429	34,173	34,768	39,199	35,289
Australia..	..	1,562	..	..	181	..
China and Japan ..	229	2,486	6,295	..	354	588
United States.. ..	51,710	45,386	52,735	803	1,651	..
California	9,179	16,892	2,839	..	..	..
Continent of Europe	5,249	3,086	2,168	1	..	200
Totals	84,279	76,841	98,210	35,572	41,385	36,077

Increase in dry of 1879 over 1878, 21,379 tons; decrease in wet for the same years, 5308 tons: a plain proof that the importation of machinery, to the yearly value of nearly 100,000*l.*, is making its effects felt.

The value of the crop may be estimated at about 2,200,000*l.* in 1879, against about 1,483,000*l.* in 1878: an increase of 717,000*l.*

The exports in 1879 were:—Dry: 34,173 tons to Great Britain, 6295 to China and Japan, 52,735 to the United States, 2839 to California, 2168 to Europe; total, 98,210 tons; value, 1,839,230*l.* Wet: 35,289 tons to Great Britain, 588 to China and Japan, 200 to Europe; total, 36,077 tons; value, 360,770*l.*

During 1878, the exports from Manila were 4832 tons less than in 1877, and the decrease in value was 675,739*l.* There was a considerable deficiency in the crop, which was caused by want of rain when it was required, and by too much of it when it was not wanted. The crop for 1878–79 suffered from the same cause, and also from locusts; but was nevertheless considerably in excess of that of 1877–78. The sugar shipped was composed of the following descriptions:—

	Tons.	Tons.
Manila—		
Unclayed	22,561	
Superior (No. 7, D.S.)	17,758	
Extra (Nos. 8–10, D.S.)	19,899	
White (Nos. 14–16, D.S.)	2,312	
Yengarie	467	
		62,997
Yloilo—		
Unclayed	7,616	
Superior (Nos. 7–9, D.S.)	31,756	
		39,372
Cebu—		
Unclayed	11,534	
Superior (Nos. 7 and 8)	3,923	
		15,457
Total		117,826

Of the above shipments, Great Britain got 46,597 tons, Australia 1677 tons, and Hong Kong 2518 tons, or, say, rather more than one-third of the entire shipments. The average price of these descriptions was as follows:—

	Per ton. £	s.	d.
Unclayed	11	10	0
Cebu, superior	14	0	0
Yloilo „	15	0	0
Manila „	16	0	0
Extra	17	10	0
White	22	10	0
Yengarie	25	0	0

Laid down in England, the above sugars would cost from 3*l.* to 4*l.* per ton more.

The principal staple of the Cebu trade is sugar. The crop for 1878 turned out 14,210 tons, or in Spanish piculs of 137½ lb., equal to 227,356 piculs, as compared with, during the previous year, 240,388 piculs, or a decrease of 13,032 piculs.

The price of current unclayed sugar opened at 2 dol. 75 c. per picul in November 1877; the highest price paid was 3 dol. 56¼ c. per picul in July following, and the last of the crop was disposed of at 3 dol. per picul.

Dry or superior sugar—a description resembling in colour No. 8 Dutch standard, but of a bolder and duller grain—opened at 3 dol. 50 c. per picul, and gradually advanced to 4 dol. 15⅝ c. per picul.

During the last quarter of 1878 vast swarms of locusts settled down on the growing cane, and did immense damage. The cane, where attacked, was stripped of leaves, and, though ready for cutting, had to be left standing to recover its foliage. This calamity reduced the crop available for 1879 from 15 to 20 per cent.; and the quality also suffered, as the product of cane bitten by locusts is always inferior.

Most of the land adjoining the capital, suitable for the cultivation of the sugar-cane, has been taken up; and, as the soil never receives any manure, little increase can be expected in the yield in the island of Cebu; but the natives are extending the cultivation of the cane in Bohol, and that coast is becoming an important feeder to Cebu.

Russia.—The following particulars of the Russian sugar industry are extracted from a report published by the Russian Administration of Indirect Taxes.

The total revenue arising from the tax on sugar was in 1886 20,650,022 roubles, an amount much in excess of that of preceding years, as a reference to the following statement will show.

Produce of the duties on sugar:

Years.	Excise.	License.	Fines.	Repayment of Bounties.	Total.
	Roubles.	Roubles.	Roubles.	Roubles.	Roubles.
1876	4,850,809	76,037	66,151	..	4,992,997
1877	6,616,048	68,385	91,387	..	6,775,820
1878	4,972,553	58,755	63,511	..	5,094,819
1879	4,537,814	48,395	48,267	..	4,634,476
1880	4,169,537	51,409	36,355	..	4,257,301
1881	3,590,772	63,190	40,581	..	3,694,543
1882	7,962,258	85,411	7,378	..	8,055,047
1883	8,783,177	89,079	5,967	..	8,878,223
1884	12,252,953	96,217	46,594	..	12,395,764
1885	13,676,172	109,409	77,011	..	13,862,592
Average for 10 years..	7,141,209	74,629	48,320	..	7,264,158
1886	18,942,243	141,794	65,472	1,500,513	20,650,022

The rapid increase of revenue since 1882 is explained first by the increase in the production of sugar, and also by the new method of collection of the excise, and by the increase of the duty from 50 copecks to 65 copecks, and then to 85 copecks per poud; further, the repayment of bounties granted on exportation under the head of loans has yielded in the year 1886 more than 1½ million roubles.

In order to estimate the influence of the new method of collection of the tax introduced on the 1st August, 1881, and based on the real production of the factories, it is necessary to compare with the results of 1886 (repayments not included) those of the period between 1876 and 1881, when the system of collecting the tax according to the normal production of the apparatus and the normal yield of the beets, was still in operation. The average result for the six years 1876–81 is only 4,908,326 roubles, giving for the year 1886 a revenue higher by 14,241,183 roubles. And if it be taken into consideration that the old system of the assessment of the tax gave to the exporters of sugar a disguised bounty of from 50 to 55 copecks per poud, the actual growth of the revenue will be found to be further augmented.

Estimating the population of the Empire at 101,500,000 inhabitants, the tax on sugar would amount to 20·34 copecks per head.

The following statement illustrates the progress of the sugar industry:—

Years.	Number of factories.	Production in Pouds (of 36 lb.)
1875–76	254	9,507,105
1876–77	260	12,669,594
1877–78	245	10,602,918
1878–79	240	11,101,063
1879–80	239	12,544,628
1880–81	236	12,399,897
1881–82	235	15,936,714
1882–83	237	17,537,890
1883–84	244	18,859,739
1884–85	245	20,958,120
Average for 10 years	..	14,211,767
1885–86	241	20,039,594

The plantations of beets which provide the factories with the raw material, extended over an area of 291,730 desiatines (of 2·7 acres) in 1884–85, and 299,574 desiatines in 1885–86. The quantity of beets worked was 246,312,380 pouds in 1884–85, and 336,699,730 pouds in 1885–86; the quantity of sugar produced, determined by the excise was, according to the preceding table, 20,958,120 pouds in 1884–85, and 29,039,594 pouds in 1885–86; moreover, there were 8,427,759 pouds of molasses in 1884–85 and 11,384,582 pouds in 1885–86.

The sugar produced is principally white (25,193,086 pouds in 1885–86, or 86·75 per cent. of the total production).

The quantity of refined sugar produced in the refineries attached to the factories, including that produced in the independent refineries working exclusively raw sugar which has already been subjected to duty in the factories, was 15,199,346 pouds in 1884–85 and 16,762,634 pouds in 1885–86.

The crop of beets taken by the factories in 1885–86 from the 299,574 desiatines under cultivation was 340,881,710 pouds, or on the average 1138 pouds per desiatine. In 1884–85 the 291,730 desiatines then under cultivation only yielded 249,957,650 pouds, or on the average 857 pouds per desiatine, or a proportion of 32·8 per cent. The juice of the beets contained in 1884 12·63 per cent. of sugar, and in 1885 12·66 per cent.

The exceptional production of 1885–86 is then solely explained by the abundance of the crop, and not by its saccharine richness.

Quantities of beets worked :—

Up to 300,000 pouds	6 factories.
From 300,000 to 600,000 pouds	19 ,,
From 600,000 to 1,000,000 pouds ..	55 ,,
From 1,000,000 to 2,000,000 pouds ..	122 ,,
From 2,000,000 to 3,000,000 pouds ..	30 ,,
More than 3,000,000 pouds	9 ,,

Duration of the working or number of days worked :—

Up to 30 days	1 factory.
From 30 to 45 days	1 ,,
From 45 to 60 days	5 factories.
From 60 to 75 days	16 ,,
From 75 to 90 days	24 ,,
From 90 to 105 days	51 ,,
From 105 to 120 days	61 ,,
From 120 to 150 days	70 ,,
Above 150 days	12 ,,

Quantity of beets worked during one working day :—

Up to 4000 pouds	6 factories.
From 4000 to 6000 pouds	11 ,,
From 6000 to 8000 pouds	30 ,,
From 8000 to 10,000 pouds	31 ,,
From 10,000 to 12,500 pouds	52 ,,
From 12,500 to 15,000 pouds	52 ,,
From 15,000 to 20,000 pouds	38 ,,
From 20,000 to 30,000 pouds	20 ,,
Above 30,000 pouds	1 factory.

Quantity of sugar obtained :—

Up to 25,000 pouds	15 factories.
From 25,000 to 50,000 pouds	45 ,,
From 50,000 to 75,000 pouds	54 ,,
From 75,000 to 100,000 pouds	52 ,,
From 100,000 to 150,000 pouds	56 ,,
From 150,000 to 200,000 pouds	17 ,,
From 200,000 to 250,000 pouds	5 ,,
Above 250,000 pouds	1 factory.

In the majority of the factories diffusion is used for the extraction of the juice; it was used in 1885–86 in 219 factories possessing 2716 diffusors of a total capacity of 336,799 vedros (of 2·7 gal.); there were only 22 factories working with presses.

The extraction of sugar from molasses is carried on by the three known processes: osmose, elution, and by the action of strontian.

The number of workmen employed was in 1885–86 more than 90,000 (78,479 men, 12,000 women, and 2079 children).

The exportation of sugar under the influence of direct bounties of, at first, 1 rouble, afterwards reduced to 80 copecks per poud, granted to exporters under the head of loans during the year 1885–86 (from the 12th July, 1885, to the 1st July, 1886) amounted to 7,582,351 pouds, of which 7,323,932 pouds were exported by the European frontier, and only 258,419 pouds by the Asiatic frontier.

After the 1st July, 1886, when the direct bounties on the exportation of sugar into the European countries were abolished, this export almost ceased on the European side, between the 1st July, 1886, and the 1st January, 1887, 3939 pouds only being exported on this side; but the exportation by the Asiatic frontier, further stimulated by the continuation of the direct bounties of 80 copecks per poud, rose to 392,656 pouds. The quantity of sugar exported in the course of the year 1886 amounted in the aggregate to 3,871,377 pouds.

The importation of foreign sugar into Russia was very small in 1886, as in previous years; 4825 pouds only were imported, 252 pouds by the European frontier and 4573 pouds by the Asiatic frontier, the latter being principally Chinese candied sugar.

Respecting the present situation of the sugar industry, the following is quoted from the Russian *Herald*:—

"The situation of the Russian sugar industry has considerably improved since manufacturers have formed a syndicate. They have organised at Kiev a central bureau, specially devoted to regulating the prices of sugar, and the results obtained seem encouraging.

"The beet plantations have at the present time an area of 245,825 desiatines, as compared with 223,507 during the 1887–88 season. The average production during the preceding decennial period rose from 950 to 1100 pouds of beetroots per desiatine. Last year there were produced 254,352,722 pouds of beetroots, or 1140 pouds per desiatine. As the crop of this year will probably be a medium or good one, it may be fixed approximately at 1100 pouds per desiatine, or, on 240,000 desiatines, 264 millions of pouds. If the crop should reach 1140 pouds per desiatine, that will give 273,500,000 pouds of beetroots. On the average, a poud of beets yields 3·53 lb. of sugar. The production of the year 1888–89 should, therefore, be about 24 millions of pouds of sugar. Of this quantity more than 23 millions pouds are intended for home consumption."

San Domingo.—The officially recorded exports in 1880 were:—Sugar: 3138 tons to the United States, 134 to the West Indies, 25 to Great Britain; total, 3297 tons; molasses: 172,440 gallons to the United States. The actual total exports were at least 5000 tons, and cane-culture is spreading. In 1879, the exports of sugar were 5,770,000 lb. to the United States, and 152,000 to the West Indies, total, 5,922,000; and of molasses, 93,700 gallons to the United States. In 1878, 3,039,000 lb. of sugar went to the United States, and 195,000 to the West Indies.

St. Helena.—We imported 1000 cwt. of unrefined sugar, valued at 781*l.*, in 1879.

Servia.—A Russian company is about to introduce the culture of beet and manufacture of sugar. The climate promises success.

Siam.—Naconyhaisi and Petno are the chief sugar districts, but the cane is also grown at Poklat, Bangpasoi, Chantibon, and Petchabure, to a considerable extent. The exports were 101,307 piculs (of 133⅓ lb.) in 1870. Our imports of unrefined were 20,107 cwt., 23,140*l.*, in 1877.

Spain.—The cultivation of the sugar-cane in the 37th degree of north latitude would appear very remarkable to any one unacquainted with the peculiar climatic conditions which render it practicable. That portion of the coast of Andalusia which permits of the growth of the sugar-cane is comprised between the 36th and the 37th degrees of north latitude. The main development of the cultivation is along the coast from Estepona to Almeria. At a certain distance from the sea, a chain of mountains runs parallel to the coast, and forms a shelter from the north winds. The evil effects of a short frost, which occurs once in 7 or 8 years, are avoided by cutting the cane somewhat earlier in the season than usual. The geographical position of this part of Andalusia enables it to command a great amount of solar heat. As, in addition to a warm climate, a certain degree of humidity is requisite for the growth of the cane, artificial irrigation is resorted to when the natural sources fail. Of the three varieties of cane, that known as American is the best, and is fast superseding the others in all the new plantations. From 7 to 8 years constitute the productive life of the sugar-cane. The planting is performed by cutting slips from sound canes of the previous year, and placing them horizontally end to end in two rows at the bottom of broad furrows. This operation takes place in May. In October the cane turns yellow; in the following February it arrives at maturity; and it is harvested in the 3 succeeding months.

Irrigation is indispensable during the dry season, which lasts for 3 or 4 months; and as nearly 1,000,000 gallons of water are required for each acre of land, the construction of reservoirs is frequently necessary. The sugar-cane is a very exhausting crop, so that proper manuring of the soil is a subject of great importance. Farm-yard manure, mixed with the refuse of the last crop, is used when the harvest is annual; but when biennial, guano is preferred for the second year. About 12 tons of farm manure per acre is the quantity used. The annual crop per acre averages 20 tons, the biennial 30 tons. The selling price is 36*s.* per ton.

Those engaged in cultivating the sugar-cane in Andalusia are well aware of the limited area upon which it can be grown, and have recently turned their attention towards the introduction of beetroot, as a substitute for the more delicate and susceptible plant. Some experiments have been made with a view to its acclimatisation; so that by causing the crops to come to maturity at different times of the year, the working plant and factories would be utilised to a maximum.

On a large cane estate where the juice is extracted by 2 mills, and evaporated in a triple-effect and vacuum pan, the yield of sugar amounts to 10 per cent. on the weight of the canes; whereas, in Cuba, a yield of 8 per cent. is considered very good.

Straits Settlements.—Our imports thence have been :—

	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined ..	101,219	177,885	93,096	127,467	195,527
	£	£	£	£	£
Sugar: Unrefined ..	83,762	177,385	80,640	110,943	159,155

Surinam.—The area occupied by sugar-cane was 4132 hectares (of 2½ acres) in 1887, 4369·2 in 1878, and 4389 in 1879.

The production was:—Sugar: 8,471,320 kilogrammes (of 2·2 lb.) in 1878, and 11,023,130 in 1879; molasses: 1,330,268 litres (of 1¾ pint) in 1878, and 2,501,928 in 1879; rum: 1,012,935 litres in 1878, and 758,135 in 1879. The exports were:—Sugar: 7,823,342 kilogrammes in 1878, and 11,633,892 in 1879; molasses: 1,311,472 litres in 1878, and 1,936,802 in 1879; rum: 718,748 litres in 1878, and 920,119 in 1879.

Our imports thence have been:—

	1877.	1878.	1879.	1880.	1884.
	proof gals.	proof gals.	proof gals.	proof gals.	proof gals.
Rum	114,916	113,255	111,623	77,910	..
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined	92,636	62,130	106,974	74,959	79,292
,, Molasses	1,510	1,802	1,744	2,307	..
	£	£	£	£	£
Rum	8,963	8,778	7,805	5,267	..
Sugar: Unrefined	122,802	68,090	113,738	86,069	80,009
,, Molasses	548	589	491	846	..

United Kingdom.—No sugar is at present produced in the United Kingdom, but beet sugar was largely made at Lavenham, Suffolk, a few years since, and the industry will probably be revived at no distant date.

Following is an abstract of a report by Prof. Church on the cultivation of sugar beet in England in 1884.

The effect of the last year's drought told unfavourably, as regards regularity and yield, but still the results of this first year's experience prove encouraging. If the weight of the crops has been small in some instances, yet a yield of about 12 tons per acre has been secured on a large proportion of the farms, whilst the average quantity of sugar in the roots nearly reached 13 per cent., corresponding to a production of 1½ tons of crystallisable sugar per acre. Whilst the yield per acre in a few cases has been less than 5 tons, in others it has exceeded 15, or been as high as 20; and the whole 640 acres have produced a total of about 6850 tons of roots, or over 10 tons per acre. Two conditions of successful sugar-beet growing, are, (1) as close planting as possible, and (2) that the roots do not average in weight more than something below 1½ lb. a piece. By observance of these rules good results, both as regards quantity and quality, are secured, other things being equal. To have as close a plant as possible is, indeed, termed by the author the "golden rule" for the sugar-beet grower. Small roots and many of them are best, both for the grower and the sugar maker, for the smaller the root the richer it is in sugar, the less saline matter does it extract from the land or the manure, and the easier it is to lift. Moreover, when the roots are near to each other the bulbs are not so much exposed, and the proportion of leaf to root is smaller; they are also less likely to grow fanged and forked. The following table shows the advantage of a close plant :—

(*a*) Distance between the drills.
(*b*) ,, ,, ,, single plants in the rows.
(*c*) The number of roots per acre.
(*d*) The yield per acre, assuming each root to weigh 1 lb.

(*a*)	(*b*)	(*c*)	(*d*)
15 in.	6 in.	69,696	31 tons 2 cwt.
18 ,,	9 ,,	38,720	17 ,, 0 ,,
18 ,,	12 ,,	29,040	12 ,, 19 ,,
18 ,,	15 ,,	23,232	10 ,, 7 ,,
21 ,,	18 ,,	15,004	6 ,, 12 ,,

With regard to the question of suitability of manures, when the strontia process is used, by which the sugar is directly precipitated from the beet-juice, then superphosphate of lime, nitrate of soda, and other artificial manures, suitable for sugar-beets, may be employed, for the increase thus caused of saline matter in the roots no longer interferes with the extraction of the sugar. Farm-yard manure should never be applied directly to the sugar-beet crop, but to that which precedes it. Where it has been used, especially in the spring, the roots have been uneven in size, coarse in quality, and much fanged. In light soils and dry seasons, farm-yard manure may help to secure a tolerable yield, but at the sacrifice of almost every desirable character in the root. Another condition of importance is cleanness of the land, i. e. freedom from weeds, amongst which especially couch grass is very prejudicial. Besides "thick sowing," it is also very important that early thinning and careful singling be observed; moreover, earthing of the exposed part of the roots; cutting off any "bolted" or runaway stems; selecting the proper time for pulling the crop; drawing without wounding the roots; with many other minor details of cultivation. Despite the scepticism amongst well-informed and even scientific men, as to the production in this country of a crop of sugar-beet having a high proportion of sugar, the author adduces proof of the soundness of the position assumed by the advocates of English sugar-beet growing, in the recital of experiments made on the large scale in 1884, in Surrey, Berks, Oxfordshire, Middlesex, Northamptonshire, Lincolnshire, Staffordshire, Worcestershire, Warwickshire, Suffolk, Norfolk, Cambridgeshire and Essex, and also County Wexford, Ireland, which show perfectly encouraging results, although the year cannot be regarded as a favourable one in point of weather and other natural conditions. Though it is stated that a hot dry summer is the only one suited for the sugar-beet growth, this statement cannot be taken without modification, and it becomes the reverse of the truth with a shallow and gravelly soil, and when the spring rains have not sufficed for the regular germination of the seed.

Touching the best time for gathering; in the Cirencester experiments of 1870 and 1871; during the former year the increase of sugar continued up to and even after the middle of October; during the latter it practically ceased a week earlier. In both years, during the first half of November, the amount of sugar remained practically stationary, but afterwards a decided diminution of the percentage became apparent. Although observations of rainfall and temperature during the latter part of the autumn serve in guiding to a judgment as to the probable saccharine ripeness of the crop, it is by far the best to take a fair sample of roots, and ascertain the exact content of sugar by determinations of the specific gravity of the juice, or by analyses with the polariscope. There are various kinds of sugar-beet, and there are several improved sorts now at disposal. It is evident—and this is a matter worthy of the consideration of all the farmers in the country—that under normal conditions, sugar-beet must pay better than wheat does, at present prices. However, to ensure success, and to compete successfully with Continental producers, growers in this country must bestow their best land and their best care; they must learn that practically the selling value of the crop is to be regulated by the yield of sugar per acre, and this is the correct light in which to view the subject.

As regards hardiness in times of drought, the sugar-beet stands better than the ordinary mangolds, which have been almost a failure last year, even on heavy lands. In many fields, in which mangolds and sugar-beets were sown side by side, the mangolds did not appear, whilst the sugar-beets yielded a fair plant.

Most satisfactory have been the experiments on using sugar-beet refuse as cattle food, and chemical analysis explains the superiority of sugar-beet over other roots, for feeding purposes; whilst mangolds usually contain 90 per cent. of water, and swedes and white turnips often more, sugar-beets generally average about 81 per cent. A crop of sugar-beet, although its gross weight may not be much more than half that of other kinds of roots, will contain quite as much solid nutritive matter. It presents the further advantage of containing less of those saline matters which, without being useful in animal nutrition, tend by their removal from the soil, towards the exhaustion of the latter.

Starch sugar and brewing compounds are largely manufactured in London; and extensive sugar refineries exist in London, Bristol, Greenock, &c.

Our imports in 1880 were:—

	cwt.	£
Refined and candy:—		
France	1,586,416	2,342,912
Holland	876,471	1,275,717
Germany	244,645	339,969
Belgium	108,313	155,340
United States	103,396	161,384
Other countries	116,833	161,550
Total	3,036,074	4,436,872

	cwt.	£
Unrefined:—		
Germany	4,384,268	4,728,916
British W. Indies	2,578,971	2,738,322
Java	1,763,522	2,226,225
Brazil	1,484,924	1,512,709
British Guiana	1,327,084	1,778,481
Philippines	1,175,140	983,590
Peru	1,000,987	1,128,062
Spanish W. Indies	640,810	770,673
Belgium	493,349	540,241
Madras	487,048	349,803
China	359,821	301,307
Holland	205,601	223,900
Straits Settlements	195,527	159,155
Egypt	195,217	229,381
Mauritius	120,516	137,021
France	115,298	136,089
Mexico	94,879	98,113
Chili	79,658	90,766
British S. Africa	76,682	76,720
Dutch Guiana	74,959	86,069
Danish W. Indies	52,113	63,859
Bengal and Burma	25,851	27,113
Honduras	18,207	18,273
New Granada	17,919	20,277
Other countries	33,262	32,898
Total	17,001,613	18,457,963

	cwt.	£
Glucose, solid or liquid:—		
Germany	218,745	213,166
United States	100,467	91,063
France	70,151	69,733
Other countries	16,397	13,775
Total	405,760	387,737

Molasses:—	cwt.	£
United States	92,000	39,685
British W. Indies	42,476	16,937
Egypt	30,057	9,408
British Guiana	20,888	10,189
Germany	3,515	1,571
Mauritius	3,475	1,379
Other countries	19,130	7,082
Total	211,541	86,251

Our exports in 1880 were:—

Refined and Candy:—	cwt.	£
Portugal, Azores, and Madeira	28,031	36,815
Malta and Gozo	17,103	23,338
Channel Islands	15,411	22,666
Australia	13,039	19,470
Argentine Republic	8,742	12,972
Gibraltar	7,635	10,663
Turkey	5,218	7,590
France	3,712	4,581
Roumania	3,426	5,108
British S. Africa	3,221	5,210
Norway	2,166	3,323
Persia	2,005	2,754
Morocco	1,456	2,130
China	1,157	2,703
Italy	1,149	1,540
Other countries	11,771	16,924
Total	125,242	177,787

Unrefined Beet Sugar:—	cwt.	£
Portugal	12,132	17,020
Other countries	2,842	3,738
Total	14,974	20,758

Cane and other sorts:—	cwt.	£
Denmark	71,108	82,703
Portugal and Azores	60,977	71,465
Sweden	41,312	53,371
United States	38,960	42,634
Belgium	21,581	24,705
Holland	19,935	22,558
Germany	15,554	17,947
Italy	10,949	14,916
France	9,200	12,049
Other countries	9,085	11,337
Total	298,661	353,685

	cwt.	£
Glucose:—		
Australia	23,075	21,800
Other countries	770	807
Total	23,845	22,607

	cwt.	£
Molasses:—		
British N. America	13,457	9,165
Norway..	9,938	5,015
Other countries	15,631	9,435
Total	39,026	23,615

The annexed figures show approximately our imports, consumption, and export of sugar for a few recent years:—

Year.	Imported into United Kingdom Raw and Refined	Home Consumption Raw and Refined.	Exported.	
			British Refined included in Home Consumption.	Raw and Foreign Refined.
	tons.	tons.	tons.	tons.
1871	688,000	702,000	38,900	17,400
1872	774,000	715,000	31,600	11,200
1873	833,500	786,000	34,800	8,500
1874	844,000	836,000	46,500	26,300
1875	953,800	928,000	48,600	37,500
1876	918,500	925,000	59,400	49,500
1877	1,003,000	900,000	55,900	32,500
1878	910,000	950,000	52,100	21,600
1879	1,037,000	970,000	44,800	27,500

The figures for Home Consumption and Stocks since 1874 are only estimated.

The imports since 1879 have been: 1880, 1,032,749 tons; 1881, 1,106,327; 1882, 1,161,845; 1883, 1,221,331; 1884, 1,236,303.

United States.—Besides maple, melon, and sorghum sugars, whose statistics are given under their special heads, the United States produce considerable quantities of cane sugar (mainly in Louisiana) and beet sugar (in New York, Maine, and other States), as well as various kinds of glucose.

The sugar and molasses production of Louisiana has been as follows:—

SUGAR.

Year.	Crop.	Average Value per Hogshead.	Value of Crop.
	lb.	dol. c.	dollars.
1859–60	225,100,000	82 00	18,200,000
1876–77	194,964,000	95 50	15,646,000
1877–78	149,469,000	72 00	9,007,000
1878–79	251,088,860	67 00	13,182,000

MOLASSES.

Year.	Crop.	Average Value per Hogshead.	Value of Crop.
	lb.	cents.	dollars.
1859–60	17,858,100	35	6,250,000
1876–77	11,117,190	43½	4,836,000
1877–78	13,576,374	30½	4,141,000
1878–79	14,814,024	26¼	3,889,000

Florida, in 1879, produced 601,203 gallons of sugar-cane syrup, and 963,910 lb. of sugar.

The total quantity of foreign sugar received at the port of New York during the year 1880, including 6239 tons of melado, was 561,792 tons. In addition to this, 11,222 tons of domestic sugar was received, making a total import of 573,114 tons, against 505,685 tons in 1879—an increase of 67,429 tons. The consumption of the country in 1880 was 9·04 per cent. in excess of that of the previous year—the result principally of the general prosperity of the country, enabling farmers and labouring classes the better to supply themselves with the staple articles of food, but attributable also to the unprecedented increase in population from immigration. New York continues to be the most important receiver and distributor of this article of commerce, importing as it does the bulk of the foreign supply, and manufacturing by far the largest proportion of refined sugar.

The imports in 1880, compared with those of the previous year, exhibit a falling off in the receipts from Cuba, Porto Rico, Barbados, Martinique, and Guadeloupe; while there has been an increase from Demerara, British and other West

Indies, Brazil, Manila, and China. The largest and most notable increases are those from Brazil (about 50,000 tons), Manila (over 18,000 tons), and China (over 11,000 tons). The large increase in the crop of Brazil will account for the enlarged supply received from that country, and the increase from China and the Philippine Islands has no doubt been due to the profitable prices obtained in this market compared with other consuming countries. A gratifying increase is also observable in the quantity of sugar imported last year from Demerara, notwithstanding the harassing uncertainty which prevailed in regard to the basis on which the dutiable value would be assessed. The receipts from Demerara in 1880 were nearly 16,000 tons, compared with 4000 tons in 1879.

An adulterated article, called "new process" sugar, made by mixing yellow refined sugar with about 25 per cent. of grape sugar or glucose, made its appearance during 1880, and the sales were so large as to deserve notice. The colour of the sugar is made white by this "new process," but the saccharine properties are stated to be materially weakened. It is difficult to distinguish the adulterated from the pure article, and, while profitable to the seller, it is certainly not so to the consumer.

The total production of beetroot sugar in the country is estimated at 2000 tons, and there are no indications of a steady increase. The crop of maple sugar is estimated at 10,000 tons, but there are no reliable data for ascertaining the true yield of this description of sugar.

In regard to prices, the average quotation for Cuba, fair to good refining, for the year, was 7·87½ dollars per 100 lb., which was 94½ cents higher than the average of 1879, and 62½ cents higher than two years ago. The prices of other grades have likewise shown the same steadiness and narrow fluctuations, there being the same relative difference between this year and the last.

The efforts to obtain a revision of the present complicated tariff have, thus far, been without any practical result. Opposing interests are represented by two Bills before Congress, one known as the Tucker Bill, which provides for duties on the following schedule :—

	Cents.
Tank bottoms, syrup of sugar, cane juice, and melado ..	1⅞
Not above No. 7 Dutch standard	2⅝
Above No. 7, and not above No. 13	2¼
Above No. 13, and not above No. 16	2·81
Above No. 16, and not above No. 20	3·17
Above No. 20	3·67

And the other, known as the Carlisle Bill, which classifies the duty as follows :—

	Cents.
Tank bottoms, &c.	1½
Not above No. 13, Dutch standard	2
Above No. 13, and not above No. 16	2¼
Above No. 16, and not above No. 20	2·65
Above No. 20	3½

During the year 1880, the total imports of foreign molasses into the port of New York were 10,393,585 gallons, compared with 12,373,660 gallons in the previous year. Of domestic molasses from Louisiana, there were received 4,382,595 gallons, and from other coastwise ports, 73,580 gallons, making the total importation 14,849,760 gallons, or 31·55 per cent. of the whole imports of the United States.

A few years ago, molasses imported for this market passed into consumption as it was received ; but it is stated that very little of the pure article now finds its way to the table of the consumer. Pure molasses is now chiefly used either for boiling to obtain the bastard sugars which they contain, or for mixing with glucose or other adulterants in order to obtain the article largely sold at retail. This adulteration is done so skilfully as to deceive even the practised expert.

The manufacture of glucose has considerably increased during the past few years, and the article is largely in demand for brewing purposes, and as a substitute for cane molasses and sugar syrups. Next to the refining of raw sugar, the reboiling or refining of foreign molasses has become one of the most important industries connected with cane products. The bastard sugar thus obtained is chiefly used by refiners for producing their low-grade yellow sugars.

The imports of foreign molasses in 1880 show a falling off, compared with the previous year, of 1,300,000 gallons from Cuba and 600,000 gallons from Porto Rico, with correspondingly reduced quantities from other ports, the diminished yield of the sugar crop of Cuba and other West Indian ports necessarily lessening the amount available for export.

The average price of Cuba molasses in 1880 was 35 dollars per 100 gallons, the highest price being 40 cents per gallon during the month of March, and the lowest 28 cents per gallon in October. The same relative difference obtained for other grades.

There are at present in operation in the United States 15 factories for the manufacture of corn glucose, and it is estimated that the production has already reached the large quantity of 180,000 tons per annum.

Glucose was first manufactured on Long Island in 1867, but for some years it was not a commercial success. Processes have, however, since materially improved, whereby the product has been made much better and cheaper; and there is now a large demand for it. The business is stated to be exceedingly remunerative, experienced manufacturers being able, at present prices, to realise from 30 to 45 cents profit on each bushel of corn worked. The article is now sold by them at about 3½ cents per lb. It is used for a variety of purposes, and largely for mixing with sugar, the colour of which it whitens, but diminishes the saccharine properties. It is a practice extremely difficult to detect. The adulterated article is called "new process" sugar.

In the State of New York, there are three manufactories of glucose, viz.: one at Buffalo; one at Glen Cove, Long Island; and one at Hudson. There are factories also at

Chicago (two): Danville, Freeport, Sagetown, and East St. Louis, Illinois; Davenport and Des Moins, Iowa; Philadelphia, Pennsylvania; and Leavenworth, Kansas. There are others being built or contemplated at several other points, so that there is a probability of the production being largely increased, and, possibly, of reduced prices to the consumer.

The home-growth of cane-sugar, in 1870, was stated at 80 million lb. The imports at New York, in 1880, were:—

From	Hogs-heads.	Tierces.	Barrels.	Boxes and Cases.	Bags, Mats, and Baskets.	Total Tons of 2240 lb.
Cuba	463,692	6,125	344	12,120	145,271	331,323
Porto Rico	13,154	629	1,538	..	6,857	8,739
Demerara	12,859	253	2,510	..	26,710	15,738
Barbados	3,214	247	950	..	4,728	2,608
St. Croix	968	..	201	..	..	604
Martinique and Guadeloupe ..	21,017	117	3,253	..	3,419	12,578
Trinidad Island, Jamaica and other British West Indies ..	18,482	3,950	11,071	..	5,910	14,916
Other West Indies, Peru and Mexico	5,410	1,489	5,386	527	81,058	13,556
Brazil	185	..	37	..	1,073,304	71,996
Manila	..	..	..	..	2,024,868	59,281
China	..	..	..	..	197,606	11,322
Java	..	..	..	..	30,862	6,647
Other East Indies	..	..	..	..	51,251	3,432
European and other foreign ports	908	..	..	..	19,580	2,813
Total receipts of foreign direct	539,889	12,810	25,290	12,647	3,671,424	555,553
Add receipts of melado ..	14,309	799	397	..	..	6,239
	554,198	13,609	25,687	12,647	3,671,424	561,792
Texas	1,820	..	16	..	..	895
Louisiana	10,561	..	752	..	..	5,260
Other coastwise ports	6,008	19	657	6,255	..	5,167
Total receipts	572,587	13,628	27,112	18,902	3,671,424	573,114

The range of prices for sugar was:—

	dols.	cents.
New Orleans, refining grades	6	91½
Cuba, fair to good refining	7	87⅛
Porto Rico, refining grades	7	62¼
Havana, white	9	30
,, brown, Nos. 10 to 12	7	98⅛
Manila	7	19
Brazil, Nos. 9 to 11	7	55⅛
Melado	5	20¼

The receipts of molasses at New York, in 1880, were:—

From	Hhds. and Puncheons.	Tierces.	Barrels.	Total Gallons.
Cuba	44,062	4,226	8	6,265,370
Porto Rico	15,061	413	30	1,989,255
Barbados	4,684	70	217	524,900
Demerara	1,340	..	..	159,192
Trinidad Island	2,844	22	58	315,680
St. Croix	1,195	128	..	161,325
Martinique and Guadeloupe	873	..	..	103,713
Antigua	2,688	..	70	365,680
Nevis	..	..	..	..
St. Kitts	2,059	..	200	273,670
St. Domingo, Surinam, and other foreign countries ..	1,775	36	75	234,800
Total receipts of foreign direct	76,581	4,895	658	10,393,585
Received from Louisiana ..	..	..	97,391	4,382,595
„ „ other coastwise ports	332	..	676	73,580
Total	76,913	4,895	98,725	14,849,760

The range of prices of molasses at New York for three years has been:—

	Average.					
	1880.		1879.		1878.	
	dol.	c.	dol.	c.	dol.	c.
New Orleans, prime to choice	52	50	36	$16\frac{3}{8}$	41	50
Porto Rico	42	25	32	54	35	90
Cuba muscovado, refining 50 test	35	00	26	$13\frac{1}{8}$	33	35
English Islands	36	16	27	$29\frac{1}{4}$	32	83
French	Nominal		23	$94\frac{7}{8}$	31	75

The first year's report of the Maine Beet Sugar Company at Portland, addressed to the 1700 farmers who raised the beets, says that the average crop from 100 acres was 9½ tons; in some cases the return was not enough to pay cost of seed and fertilisers; the other extreme was 30 tons per acre. For 9000 tons delivered at the factory, $56,000 were paid; for storing and pitting, $6000; fuel, $10,000; labour and other expenses, $37,000; total, $107,000. The product, 900 tons of sugar and molasses, brought $110,000, leaving $3000 towards machinery and fixtures that cost $60,000, to which must be added the State bounty. The company wish to continue the experiment, and invite the growers to renew their contract for at least one acre each. They say, however, that they cannot afford to increase the price per ton, except for early deliveries, which can be worked up before freezing weather, and thus save expense of pitting.

Our imports from the United States have been :—

	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar, Refined	220,286	282,507	100,077	439,914	103,396
,, Unrefined	19,836	7,832	4,623	7,056	14,796
Molasses	263,822	104,833	287,503	511,699	92,000
	£	£	£	£	£
Sugar, Refined	341,913	521,305	164,233	624,670	161,384
,, Unrefined	16,138	10,599	5,056	8,007	14,466
Molasses	135,003	64,006	135,593	186,219	39,685

Venezuela.—The 1873 crop of cane sugar was about 5,000,000 lb. The exports from Puerto Cabello, in 1879, were 38,760 kilogrammes (of 22 lb.) to Holland.

West Indies.—In consequence of the meagre and inaccurate accounts which formerly reached this country of the yield of sugar in the West Indies, it was determined at the commencement of 1876 to obtain from all the islands as correct a yield of the crop as it was possible to procure. This return shows that the crop on Barbados for 1876 was 37,400 hhds.; Trinidad, 59,000 hhds.; Grenada, 3800 hhds.; St. Vincent, 9000 hhds; Tobago, 4000 hhds.; Santa Lucia, 10,200 hhds.; Martinique, 75,000 hhds.; Dominica, 3700 hhds.; Guadeloupe, 35,088,944 kilogrammes; Antigua, 7700 hhds.; St. Kitts, 10,600 hhds.; Porto Rico, 140,030,000 lb.; and Jamaica, 29,074 hhds. In consequence of the disturbed state of Cuba, no trustworthy estimate of the yield there could be obtained.

In connection with the export of sugar, it is necessary to add that Barbados yielded 23,000 puns. of molasses; Trinidad, 20,000 puns. molasses; Grenada, 800 puns. rum; St. Vincent, 1650 puns. rum; Martinique, 78,000 litres of molasses and 6,324,500 litres of rum; Guadeloupe, 479,470 litres of molasses and 1,437,244 of rum; Antigua, 3200 puns. molasses and 300 puns. rum; St. Kitts, 3700 puns. molasses and 1500 puns. rum; Porto Rico, 4,625,500 gals. molasses, and Jamaica, 22,048 puns. rum.

The areas occupied by cane are stated at 47,565 acres in Jamaica, 35,000 acres in Barbados, and 19,314 hectares (of 2½ acres) in Martinique.

Our imports from the various West Indies have been as follows:—

	1877.	1878.	1879.	1880.	1884.
BRITISH—	proof gals.	proof gals.	proof gals.	proof gals.	proof gals.
Rum	2,971,715	2,453,934	2,616,598	2,420,297	..
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined ..	2,352,072	2,620,739	3,242,034	2,578,971	1,428,611
„ Molasses ..	28,455	93,592	137,405	42,476	..
	£	£	£	£	£
Rum	360,625	272,034	278,729	263,303	..
Sugar: Unrefined ..	3,128,909	2,701,343	3,056,564	2,738,322	1,101,517
„ Molasses ..	13,399	44,625	56,385	16,937	..
DANISH—	proof gals.	proof gals.	proof gals.	proof gals.	proof gals.
Rum	21	391	18	974	..
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined ..	8,517	28,254	21,007	52,113	43,822
	£	£	£	£	£
Rum	40	83	6	87	..
Sugar: Unrefined ..	11,440	37,594	24,710	63,859	32,494
FRENCH—	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Refined	..	..	..	..	..
„ Unrefined ..	116,993	24,174	11,878	..	..
	£	£	£	£	£
Sugar: Refined	..	..	..	..	..
„ Unrefined ..	169,739	30,594	11,562	..	..
SPANISH—	proof gals.	proof gals.	proof gals.	proof gals.	proof gals.
Rum	162,796	165,414	218,465	209,421	..
	cwt.	cwt.	cwt.	cwt.	cwt.
Sugar: Unrefined ..	581,910	841,637	2,260,193	640,810	460,861
„ Molasses ..	7,013	5,809	4,990	156	..
	£	£	£	£	£
Rum	11,737	14,824	19,943	20,819	..
Sugar: Unrefined ..	801,161	922,661	2,299,764	770,673	352,841
„ Molasses ..	2,842	2,978	1,935	35	..

There are at present 385 estates and plantations of all kinds in Porto Rico. The majority of the large sugar plantations use mills worked by steam machinery, which for the most part is of British manufacture. A few mills are worked by water-power, and on the small properties mills worked by oxen are still in use. There are five establishments having in operation improved plant and apparatus for the manufacture of sugar. One of these works is on a large scale, well mounted and complete in every respect; it is equal to the working-up of 30 tons of sugar per day. This establishment, and three other similar ones on a somewhat smaller scale, are furnished with French machinery; on the other estate American machinery is used.

In the central factory first mentioned, a system of railway is employed for the conveyance of the canes to the works, and for the carriage of the sugar to the port, which is giving very satisfactory results in regard to the reduction of the cost of labour. In this and another establishment, triple-effect apparatus is used, and a superior kind of sugar is produced, which is sold for home consumption at three times the price of ordinary sugar. The molasses is also worked up into sugar. These central factories are yet in their infancy in the island, and upon their success or failure will probably depend the fate of sugar cultivation in Porto Rico. The majority of the planters complain that at present prices sugar is grown and manufactured without any profit, and even at a loss. In a very few instances is it admitted that there is any profit, and these admissions are of course made by planters whose estates are unencumbered. That any business, especially agriculture, can pay when money is borrowed at 12 or 18 per cent. per annum may well be doubted.

The following valuable data on sugar growing in Porto Rico would seem to be quite trustworthy.

As the bases of calculation, an estate is taken which in normal times and under ordinary circumstances produces on an average 500 hogsheads or 6000 quintals of sugar, and 200 hogsheads or 22,000 gallons of molasses, which are estimated to be worth the following prices, viz.:—Sugar, good refining, 3⅝ dol. per quintal; molasses, 12 c. per gallon.

GROSS PRODUCTION.

		dol.
500 hogsheads, equal to 6,000 quintals, of sugar, at 3⅝ dol. ..		21,750
200 hogsheads, equal to 22,000 gallons, of molasses, at 12 c. ..		2,640
		24,390

Value of each hogshead of sugar, 43·50 dol.
" " molasses, 13·50 dol.

EXPENSES.

	dol.	
Cost of cultivation, as explained in Table A	8,500	
Cost of manufacture, as explained in Table B	2,430	
General expenses, as explained in Table C	14,370	
		25,300
Deficit		910

In this account nothing is charged as commission for the sale of produce, insurance, extraordinary expenses, overflow of rivers, storms, earthquakes, fires, &c., and nothing for the maintenance of the owner of the plantation.

If from the above amount given as total expenses (25,300 dol.), the value of molasses sold be deducted, viz.: 2640 dol., there remains as the cost of the production of 6000 quintals of sugar, 22,600 dol., which makes the cost of the sugar 3·766 dol. per quintal, or 45 dol. 19 c. per hogshead; so that, at the price of 3 dol. per quintal, there is an apparent loss of 9 dol. 19 c. per hogshead, which certainly affords a very unsatisfactory prospect for the planter. It can hardly be supposed, in fact, that sugar making can be continued in this island upon former principles. On the other hand, while common muscovado sugars are thus produced at a loss by the ordinary methods of manufacture, crystallised centrifugal sugars are made at the central factory above referred to at a total cost, delivered in the market, of 8*s.* per cwt., and such sugars bring an average net price of 16*s.* per cwt., thus affording a large balance of profit.

For the establishment of central factories, however, capital or credit is required, neither of which Porto Rico enjoys to a very large extent.

Sugar cultivation in this island will probably continue to decline, and its place be taken, wherever practicable, by tobacco, the cultivation of which is steadily increasing, and which is very remunerative. That there is room, however, for improvement in the manufacture of even the ordinary kinds of sugar, may be readily believed. No one but an intelligent practical sugar-planter can conceive the enormous waste in producing cane sugar here. The plant itself is almost in its wild state, for little or nothing has been done towards improving its natural conditions—in augmenting the saccharine richness of its juice, &c.

Sugar-cane disease does not appear to be on the increase here, though it still exists in the infected districts. Thus far the Spanish Government would seem to have done nothing in regard to carrying out the suggestions of the Commission, whose report was published in June 1878. Dr. Grivot Grand-Court, an English gentleman from Mauritius, lately settled in Porto Rico, has, however, with indomitable energy and at great private expense, introduced new varieties of seed cane from all parts of the world, which have been planted at Mayaguez with most satisfactory results. It appears thus to be an established fact that the remedy for the sugar-cane disease consists in the introduction of new seed, combined with an improved state of cultivation.

TABLE A.—EXPENSES OF SUGAR CULTIVATION IN PORTO RICO.

Under ordinary circumstances the production of an acre of cane during the last five years is on an average 30 quintals of sugar and one hogshead of 110 gallons of molasses. In order to obtain this result, it is necessary to cultivate the land in the following manner:—

50 acres of new or seed cane.
150 acres of ratoons of first, second, and third cutting.

200 acres of cane plantation, in regard to which the following expenses are necessary:

1. 50 acres of new cane.—Expenses of cultivation—

	dol.	c.	dol.
Cutting, cleaning, and preparation of land, per acre	5	00	
Three ploughings—first, 2 dol. 50 c.; second, 2 dol.; third, 2 dol.	6	50	
Raking, &c.	1	50	
Forming ditches and paths, &c., 8 dol.; with 18 drains, at 25 c., 4 dol. 50 c.; and banking the ground, 1 dol. 50 c.	14	00	
Planting, preparing ground for plants, watering, and filling in same	10	00	
Replanting	2	00	
Three weedings, at 4 dol.	12	00	
Removing suckers and cleaning	4	00	
Trashing	7	00	
Cane cutting	6	00	
Total per acre	68	00	
Which equals per 50 acres—50 × 68 =	..		3,400
Ratoons, 150 acres—			
Picking straw, 1 dol. 75 c.; opening and changing beds, 2 dol.	3	75	
Raking of same	0	75	
Banking	1	50	
Replanting	2	00	
Trashing	14	50	
Picking withered leaves	3	50	
Cane cutting	4	00	
Cleaning of trenches and draining	4	00	
Total per acre	34	00	
Which equals per 150 acres—150 × 34 =	..		5,100
Total expenses of cultivation of 200 acres	..		8,500
Average per acre, 42 dol. 50 c.			

TABLE B.—EXPENSES OF THE MANUFACTURE OF SUGAR AND MOLASSES.

For the manufacture of 500 hogsheads of sugar giving 200 casks of molasses, working with a single battery or copper wall, 120 days are supposed to be employed.

Workmen employed in the buildings:—Engineer, 1; sugar boilers, 4; firemen, 2; cane carriers and feeders, 7; cartmen, 12; and one other employed carting wood, straw, &c.; green begass, 5; dry begass, 4; otherwise employed, 2.

	dol.
Total—38 workmen at 50 c. are 19 dol., for 120 days	2,280
Filling 500 hogsheads of sugar at 25 c.	125
Filling and loading 200 casks of molasses	25
Total expenses of manufacture	2,430

TABLE C.—GENERAL EXPENSES OF A SUGAR-CANE ESTATE producing 500 Hogsheads of Sugar and 200 Casks of Molasses Yearly.

	dol.	dol.
For one meal to 70 labourers during 240 days, and to 38 during 120 days—21,360 meals at 6¼ c. each		1,335
Salary of manager	1,000	
Salary to two overseers at 360 dol and 240 dol.	600	
Salary of ganger for carts and bulls	200	
Keep, at 10 dol. per week, of above	520	
		2,320
Packages.—For 500 empty sugar casks at 4½ dol. each	2,250	
Cooperage.—Refilling, heading, nails, and repairs to hogsheads	125	
		2,375
For taxes on land, income tax, municipal taxes, and direct and indirect taxes..		2,500
Carriage, freight, or transport of 700 casks to market, average 3 dol. each		2,100
For one ratter and feeding dogs		200
For one stableman, one cook for the labourers, and general man, at 7 dol. per week		364
For two cattle tenders and one boy for 50 yokes of bulls, cows, and other cattle, at 9 dol. per week		468
For carpenter and smith's work		350
Repairs to works and machinery, partial mounting of copper wall, &c...		700
Agricultural implements, ploughs, rakes, chains, cutlasses, hoes, carts, &c.		308
Replacing bulls, &c.		750
Oil, kerosene, lime, hemp, paints, bricks, yokes, ropes, &c., *ad infinitum*		600
Total of general expenses		14,370

The exports of sugar, molasses, and rum from Porto Rico have been:—

Destination.	Sugar.	Molasses.	Rum.
	quintals	gallons	gallons
To United States	826,551	4,961,580	12,017
,, Great Britain and provinces ..	793,108	67,160	..
,, France	9,053	..	..
,, Spain	19,491	..	22,032
,, Germany	7,928	..	..
,, Italy	..	..	..
,, Other countries	3,388	..	5,198
Total, 1878	1,659,519	5,028,740	39,247
,, 1877	1,246,540	3,880,775	7,946
,, 1876	1,376,788	4,518,535	4,934
,, 1875	1,662,664	5,773,955	15,548
,, 1874	1,601,233	5,597,577	8,343

The quantity of sugar, rum, and molasses, exported in six years from Antigua is as follows :—

Year.	Sugar.	Rum.	Molasses.
	hhds.	puns.	puns.
1874	6,132	418	1,735
1875	14,667	692	7,391
1876	8,330	305	3,507
1877	10,009	210	4,690
1878	10,745	209	5,363
1879	14,730	211	7,159

The exports from St. Vincent have been :—

Year.	Sugar.	Rum.	Molasses.
	hhds.	puns.	puns.
1870	12,948	2,155	1,638
1871	13,318	2,655	953
1872	11,342	1,908	1,610
1873	9,326	2,558	764
1874	10,254	1,131	887
1875	11,514	2,202	1,336
1876	9,102	1,791	789
1877	8,611	1,715	1,548
1878	8,601	1,789	1,371
1879	10,276	1,525	1,049

The following statement shows the quantities of sugar products exported in three years from St. Lucia :—

	1877.	1878.	1879.
	lb.	lb.	lb.
Sugar, Muscovado	10,772,500	11,385,450	14,705,600
,, Usine	1,624,080	1,281,400	1,987,510
	gals.	gals.	gals.
Molasses	155,800	146,500	292,000
Rum	25,678	15,825	7,506

The exports from Barbados in 1878 were :—

Countries.	Sugar.		Rum.		Molasses.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	hhds.	£	gals.	£	puns.	£
United Kingdom	29,738	446,077	..	..	25	112
United States	12,140	182,107	15	1	12,682	57,071
British North America ..	1,406	21,097	60	4	18,277	82,251
Bermuda	218	3,268	..	..	52	235
British West Indies ..	4	63	..	..	..	..
Foreign West Indies ..	2	28	..	..	..	..
Total	43,508	652,660	75	5	31,036	139,669

The comparative exports for 1876-77-78 (exclusive of re-exports) were :—

Years.	Sugar.		Rum.		Molasses.		Total Value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	hhds.	£	gals.	£	puns.	£	£
1876	37,848	567,723	103	7	24,001	108,015	675,745
1877	47,260	705,907	2,036	152	31,644	142,398	848,357
1878	43,508	652,660	75	5	31,036	139,669	792,334

Cane cultivation is rapidly declining in Grenada, and less sugar made from year to year. Many sugar estates are changing hands, and the metayer system is becoming more general than it has hitherto been.

The following is a return of the principal items of produce exported during two years :—

Produce.	1877.	1878.
	lb.	lb.
Sugar, unmanufactured ..	27,849,981	5,424,881
	gals.	gals.
Rum	89,931	47,360
Molasses	9,128	7,448

The exports from Dominica have been :—

Year.	Sugar.		Molasses.		Rum.	
	Cwt.	Value.	Gallons.	Value.	Gallons.	Value.
		£		£		£
1872	61,418	51,558	105,282	1,921	24,630	1,543
1873	69,300	51,927	95,613	2,081	16,282	1,140
1874	65,903	54,727	70,849	2,312	32,498	2,280
1875	74,446	56,105	88,140	4,797	17,041	1,443
1876	61,734	61,474	98,449	5,421	18,912	1,512
1877	57,751	60,729	78,679	3,029	7,660	624
1878	66,404	59,728	117,946	3,753	10,076	704

The exports of sugar products from Jamaica for ten years are shown in the following table :—

Exports.	1869.	1870.	1870–71.	1871–72.	1872–73.
	hhds.	hhds.	hhds.	hhds.	hhds.
Sugar	29,268	30,744	37,010	35,353	28,428
	puns.	puns.	puns.	puns.	puns.
Rum	15,270	16,897	19,376	20,113	16,584

Exports.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.
	hhds.	hhds.	hhds.	hhds.	hhds.
Sugar	28,398	27,847	29,074	30,569	26,066
	puns.	puns.	puns.	puns.	puns.
Rum	19,350	21,359	22,048	20,648	18,115

The sugar exported from St. Jago de Cuba was:—

	1879.	1878.
	hhds.	hhds.
To United States	9,695	12,422
British Provinces	686	145
English Channel	597	668
Spain	62	420
Coastwise	498	592
Total	11,538	14,247

The rum exported was:—

	1879.	1878.
	puns.	puns.
To Spain	1,830	2,305
British Provinces	250	397
Bremen	554	540
Sundries	444	760
Coastwise	940	1,236
Total	4,018	5,238

The lack of reliable statistics on sugar in Cuba is directly traceable to two causes. Firstly, to the absenteeism of the planters and the little attention they bestow on their estates, owing to which the management is left in most cases almost entirely in the hands of mayorals and administrators, who are, as a general rule, opposed to any system of figures which may put a check upon the pickings, often considerable, to which long impunity has led them to consider themselves entitled; and, secondly, to the suspicion and jealousy with which the planters themselves view any attempt to investigate their working expenses, fearing it may be made the basis for a new contribution.

A detailed statement of the average working expenses of sugar plantations in Cuba that would serve any useful end, is unattainable, owing to the immense variety of circumstances attending the cultivation of the cane on different estates, and in different districts. For example, the yield of cane varies on different soils and under different circumstances, from 400 to 1200 tons per caballeria (about 33⅓ acres); the labour employed is in some cases that of slaves, which may be estimated to cost about 10 dol. per head a month; while in others almost all the labour has to be hired at from 20 dol. to 30 dol., if the cost of maintenance is included. The item of fuel, no inconsiderable one on some estates, is often not taken into account at all, except in those cases where it has to be brought from outside, the planters failing to see that the labour employed in drying and preparing the cane refuse employed for that purpose, represents an outlay in money similar in nature—though not perhaps in extent—to the other. The basis of product also on which the contributions, both municipal and general, are leviable, is often estimated in a very capricious, not to say unjust, way; and cases have been known of planters having to pay in taxes an amount equal to, if not greater than, the whole of their net profits. But it is in the machinery and management that the greatest variety of results is attained, and as the nature of the first can only be ascertained by an inquiry into that in use on every individual estate, and that of the second by no possible means, the attempt to arrive at anything like a correct average of the cost of production, taken in detail, must be considered as hopeless.

A fair average estimate of the production of sugar to the caballeria of cane, on estates where centrifugal apparatus is used, is 80 hogsheads of 60 arrobas each of first sugar, 15 hogsheads of second sugar, and 15 hogsheads of molasses. The proportion of sugar extracted from a similar amount of cane by the Jamaica train process is 60 hogsheads of sugar and 55 hogsheads of molasses. The yield of cane on which these estimates are based is 800 cartloads of 100 arrobas each per caballeria, and is taken to represent a mean, though probably a rather high average of the produce obtained from all land, old and new.

According to the Government estimates, the cost of production is reckoned at 65 per cent. of the gross product, and the remaining 35 per cent. is made the basis of the municipal and general taxation, which varies in amount from 7 per cent. to 8 per cent., according to the locality.

Of the different kinds of sugar manufactured in the island of Cuba, a short notice may prove interesting:—

1. The simplest form of manufacture in use is the Jamaica train, where the juice is evaporated in the open air, and then passed into shallow tanks to crystallise, after which it is placed in hogsheads with perforated bottoms to drain the molasses. This is known as muscovado sugar, and is classed and quoted in the market as "common," "fair," and "good refining." It is shipped in hogsheads, and pays an export duty of 4 dol. 66 c. each hogshead of 620 kilos., and about 75 c. for every 100 kilos in excess of this figure.

2. Clayed sugars are manufactured by the same process with the exception that the "guarapo," or cane juice, after evaporation, is placed to crystallise in moulds, and is covered with a layer of clay. The molasses is allowed to drain off at the bottom, and, when this is accomplished, the sugar is taken out and dried in the sun, or by artificial heat. It is classed and sold by colour, according to the Dutch standard. It is shipped in boxes, and pays as export duty 2 dol. 1 c. per box of 16 arrobas. This sugar was generally made in Cuba

until the invention of vacuum pans and centrifugal apparatus, and was exported in large quantities to Spain, until the duties there became practically prohibitive. To-day, centrifugal sugar is found to be more profitable, and is rapidly taking its place.

3. Centrifugal sugar. The cane juice is first defecated and evaporated in Jamaica trains, or by steam, in the open air. It is then concentrated in vacuum-pans, by which great economy in fuel and labour, as well as a higher class sugar, is obtained, and next passes into the crystallising tanks. After the crystals are formed, it is passed into the centrifugals, and by the quick rotatory motion is freed of its molasses, and is then ready for the market. It is sold, as a general rule, according to the number it polarises, and it is owing to this, and the fact that the duties in the United States are leviable by colour, that suspicions (in some cases well grounded) have been aroused among the Customs authorities there that high class sugars have been coloured, so as to appear as of lower class, and get in at a lower rate of duty, as it is to the manifest advantage of the shipper that they should.

The sugar is shipped in boxes and hogsheads, and sometimes (though not so much now as formerly) in bags, and pays the same duty respectively as muscovado or clayed, according to the package in which it is contained.

4. Complete apparatus. By this process, all the elaboration is conducted by means of vacuum-pans; and the cane juice is filtered twice through animal charcoal, which makes it lose its dark colour, and produces white sugar. Most of the sugar made in this way is consumed on the island.

5. The molasses, the residue of these different processes, is sometimes boiled over again, to extract all the crystallisable sugar possible, but is more often sold as it is. It is shipped in hogsheads averaging 1000 kilos. in weight, and pays 1 dol. 75 c. duty per hogshead.

The following statement, compiled from the most reliable sources, will show the production of sugar and molasses in Cuba for the past five years :—

TOTAL PRODUCTION OF MOLASSES (all exported).

	hhds.		hhds.		hhds.
1875 ..	186,643	1877 ..	151,913	1879 ..	205,108
1876 ..	225,257	1878 ..	162,727		

SUGAR.

	1875.	1876.	1877.	1878.	1879.
	tons	tons	tons	tons	tons
Exported	669,900	542,000	475,553	500,598	650,033
Home consumption ..	30,000	30,000	30,000	30,000	30,000
Total production ..	699,900	572,000	505,553	530,598	680,033

The number of portable railways now in use on sugar estates in the island, according to reliable information, is as follows :—There are actually on the island 118 sugar estates provided with portable railroads in running condition; the number of wagons belonging to the same is 6413, and the tracks include 116 miles of fixed and 218 miles of movable rails. The crop of 1887–8 was 647,861 tons, being an increase of 21,441 tons, or 3·42 per cent. over 1886–7. The molasses reached 125,400 tons, or an increase of 6550 tons (5½ per cent.).

World.—The annual production of the sugar of the world is shown in tons in the accompanying tables, pp. 897,898.

The latest estimates of the Continental beetroot crops, by Mr. F. O. Licht, of Magdeburg, as compared with ascertained productions of previous years, are as follows :—

	1887–88.*	1887–88.†	1886–87.	1885-86.
German Empire ..	1,000,000	887,500	997,962	838,130
France	550,000	400,000	488,299	298,407
Austria-Hungary ..	500,000	425,000	523,060	377,032
Russia and Poland ..	450,000	400,000	480,000	537,860
Belgium	100,000	100,000	91,120	48,421
Holland, &c.	50,000	50,000	50,000	37,500
Total	2,650,000	2,262,500	2,630,441	2,137,350

In tons of 1000 kilos.

* First estimates, per Circular of 19th March.
† Estimated production, per Circular of 24th December.

CANE SUGAR.—I. British Possessions.

	1871.	1872.	1873.	1874.	1875.	1876.	1877.
West Indies :—	tons	tons	tons	tons	tons	tons	tons
Barbados	48,409	35,168	33,735	42,560	58,511	34,063	42,534
St. Vincent	11,983	10,205	8,492	9,228	10,363	8,191	7,751
St. Lucia	5,767	6,032	5,391	5,971	6,622	4,383	4,752
Grenada	5,257	4,217	3,618	3,780	4,373	3,153	2,793
Tobago	3,824	3,835	2,066	2,348	5,155	3,801	3,274
Virgin Islands	10	2	1	9	6	4	1
Dominica	3,311	3,071	3,463	3,295	3,722	3,087	2,888
Montserrat	1,850	1,510	1,806	1,748	2,474	1,917	1,380
Antigua	11,163	6,495	8,085	5,145	12,317	6,968	9,029
Nevis	3,541	1,683	3,913	1,975	3,055	2,496	1,588
St. Kitts	11,365	5,526	7,476	5,923	7,388	7,268	5,365
Trinidad	53,592	46,023	59,593	44,526	57,947	51,304	45,854
Jamaica	31,458	30,221	24,164	24,138	23,670	24,713	25,984
Bahamas	94	220	634	663	18	336	2,336
Total	191,625	154,208	162,437	151,309	195,621	151,684	155,529
British Guiana	93,879	80,119	85,773	89,073	84,544	107,453	100,041
Honduras	1,961	2,203	1,348	1,498	2,316	2,018	1,933
Natal	8,741	7,096	7,065	6,833	7,771	7,574	9,108
Mauritius	118,843	122,288	111,718	93,388	87,448	115,801	136,292
Fiji	..	..	..	..	153	388	482
Queensland	551	1,197	1,416	4,228	2,443	444	4,606
India (export)	17,265	20,964	33,583	16,873	27,963	25,370	57,223

	1878.	1879.	1880.	1881.	1882.	1883.	1884.
West Indies :—	tons	tons	tons	tons	tons	tons	tons
Barbados	39,159	51,437	48,763	46,968	48,325	42,505	..
St. Vincent	7,749	9,122	8,291	7,324	8,175	9,255	..
St. Lucia	5,039	6,872	5,952	4,233	7,506	7,630	..
Grenada	2,096	1,954	1,659	910	1,478	1,850	..
Tobago	3,172	3,243	3,326	3,623	2,518	2,543	..
Virgin Islands	25	7	5	2	25	19	..
Dominica	3,320	3,461	3,285	2,265	3,421	3,421	..
Montserrat	1,580	2,426	1,126	1,631	2,314	1,484	..
Antigua	9,018	12,345	12,398	8,642	12,670	10,436	..
Nevis	1,446	3,578	2,013	2,047	4,176	} 13,142	..
St. Kitts	9,771	8,803	9,041	9,682	12,488	}	..
Trinidad	52,048	66,819	53,285	43,608	55,326	54,496	..
Jamaica	22,156	24,778	27,300	17,898	32,634	30,783	..
Bahamas	941	184	766	..	906	313	..
Total	157,520	195,029	177,207	148,833	191,962	177,877	..
British Guiana	77,468	95,078	97,682	92,309	124,102	116,636	..
Honduras	1,736	2,003	2,807	1,930	2,572	2,021	..
Natal	7,428	3,010	11,705	8,589	4,141	6,336	..
Mauritius	128,287	103,542	108,439	108,762	115,242	113,976	..
Fiji	548	785	593	684	1,731	..	..
Queensland	3,381	8,216	7,560	6,631	5,841	..	..
India (export)	45,411	18,427	18,662	32,226	49,417	71,418	..

CANE SUGAR (*Continued*).—II. FOREIGN COUNTRIES.

	1871.	1872.	1873.	1874.	1875.	1876.	1877.
	tons	tons	tons	tons	tons	tons	tons
Cuba..	547,441	711,795	796,179	617,655	661,058	537,748	460,568
Porto Rico	103,304	89,559	87,639	71,755	72,128	70,016	62,340
Martinique	41,821	39,699	37,515	43,441	50,526	38,845	40,502
Guadeloupe	38,434	31,786	35,845	34,854	48,032	35,470	43,122
Brazil	143,975	157,809	126,395	153,937	102,509	148,732	134,464
Dutch and French Guiana	12,178	12,546	12,810	11,163	8,972	10,135	10,971
Peru	..	..	..	..	60,000	70,000	70,000
Java	201,928	207,842	167,298	214,780	206,612	205,155	235,231
Manilla	87,400	91,701	82,942	103,860	126,198	129,188	122,851
Réunion	23,533	33,100	30,450	36,353	32,176	35,450	34,542
Egypt	15,863	20,359	41,884	40,577	40,118	47,600	53,200
Louisiana	64,231	69,600	59,300	49,224	64,277	79,280	66,127

	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	tons	tons	tons	tons	tons	tons	tons
Cuba..	474,427	623,934	495,831	449,067	538,388	460,397	..
Porto Rico	84,347	76,411	57,057	61,715	80,066	60,000	..
Martinique	44,218	46,869	38,593	42,090	47,888	42,000	..
Guadeloupe	48,118	47,634	41,321	42,275	57,511	60,000	..
Brazil	120,918	161,788	218,582	194,516	131,397	150,000	..
Dutch and French Guiana	7,823	11,634	10,609	8,988	9,794	12,000	..
Peru	80,000	80,000	50,000	35,000	30,000	30,000	..
Java	217,000	182,844	235,178	249,393	295,083	270,000	..
Manilla	118,141	128,748	181,520	210,160	153,780	175,000	..
Réunion	40,610	33,032	21,176	27,373	25,059	40,000	..
Egypt	37,512	33,616	34,755	32,000	26,377	..	..
Louisiana	112,093	108,114	88,822	121,867	71,373	110,000	..

BEET ROOT SUGAR.

	1871–2.	1872–3.	1873–4.	1874–5.	1875–6.	1876–7.	1877–8.
	tons	tons	tons	tons	tons	tons	tons
Germany..	186,442	262,551	291,041	256,412	358,048	289,423	378,009
France	288,000	408,609	396,641	450,711	462,263	243,182	397,870
Austro-Hungary	182,000	214,000	202,000	222,000	209,000	247,000	330,792
Russia	105,000	90,000	150,000	150,000	222,000	245,000	220,000
Belgium	55,000	72,000	76,600	70,000	70,000	68,000	63,075
Holland	14,000	16,000	22,000	26,000	20,000	26,000	25,000
Total Beet Sugar ..	830,442	1,063,160	1,137,682	1,175,123	1,341,311	1,118,605	1,414,746

	1878–9.	1879–80.	1880–1.	1881–82.	1882–3.	1883–4.	1884–5.
	tons	tons	tons	tons	tons	tons	tons
Germany..	426,155	409,415	555,915	599,722	835,165	986,000	1,100,000
France	432,636	277,912	333,614	393,219	423,194	473,000	400,000
Austro-Hungary	455,000	406,375	411,000	473,000	435,000	445,000	525,000
Russia	215,000	275,000	250,000	270,000	250,000	310,000	340,000
Belgium	70,000	58,000	69,000	73,000	83,000	106,000	90,000
Holland	30,000	25,000	30,000	30,000	35,000	40,000	50,000
Total Beet Sugar ..	1,628,791	1,451,702	1,649,529	1,828,941	2,061,359	2,360,000	2,505,000

From the above it will be seen that the estimates of the present crop, which were originally 2,650,000 tons, have now been reduced to 2,262,500 tons, and even these figures may still require some slight modification. In round numbers the deficiency of the crops of the present campaign, as compared with those of the past, may be stated at 400,000 tons.

Supplies from cane-sugar-producing countries appear to be on much the same scale as during last season, except as regards Brazil and Louisiana, which promise a surplus, the former of about 40,000 tons, and the latter of about 50,000 tons, as compared with the previous year. The total cane crops, exclusive of India, China, and Australia, are estimated at 2,295,000 tons, against 2,210,000 tons in 1886, and 2,186,000 in 1885. The British West Indies continues to increase its manufacture of crystals for the London market, where an expanding consumption for good bright qualities admits of a ready sale being made. At anything like present prices of 19*s.* to 21*s.* for such sugars, prosperity would again return to estates which during the last few years have been struggling for existence.

Sugar Consumption.—People of every country and race are fond of sugar—when they can get it. But as a matter of statistics, it is a curious fact that the greatest consumers of sugar in our time are the peoples of Gothic and Teutonic stock, and beyond all others, the English and their offshoots. Thus this group consumes 2,460,000 tons yearly, of which the English-speaking countries alone take 1,850,000 tons, while the Latin group (supplying Italy, Brazil, Spain, America, and a few omissions) does not appear to consume more than about 465,000 tons, nor the Slavonic more than 265,000 tons. But for overloaded customs and excise tariffs, the people of the European continent would probably use two or three times as much sugar as they do, and yet be far behind England and North America. While the 32,000,000 of the United Kingdom take 900,000 tons, the 268,000,000 of the European continent appear to use no more than about 1,280,000 tons of sugar yearly, being only 42 per cent. more for eightfold the number.

Following are approximate statistics of consumption in various countries:—

	Year.	Aggregate Consumption.	Lb. per Head.
		cwt.	
United Kingdom	1875	18,374,543	62·80
Holland	1874	8,000,000	25·03
Belgium	1874	1,000,000	23·19
Hamburg (imports)	1873	2,223,733	..
Germany	1874	6,120,000	16·60
Denmark	1873	533,831	33·30
Sweden	1873	630,741	16·90
Norway	1873	193,086	12·70
France	1874	5,000,000	15·50
Austria and Hungary	1874	3,400,000	15·10
Switzerland	1873	381,295	15·90
Portugal	1874	300,000	8·40
Spain	1873	81,817	0·54
Russia and Poland	1874	4,000,000	5·40
Turkey	1874	500,000	3·80
Greece	1871	86,800	6·60
Italy	1873	865,350	3·60
United States	1873	13,040,500	37·80
British America	1875	1,721,386	51·40
Brazil	1874	642,857	8·00
Peru	1874	570,000	5·61
River Plate States	1874	1,000,000	43·90
Other S. and Central American States	1874	500,000	..
W. India Islands (British and Foreign)	1874	1,000,000	..
N. and S. Africa	1874	1,000,000	..
Australia	1874	1,713,142	85·90
India, China, and the Eastern and Pacific Islands	..	25,000,000	..

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