

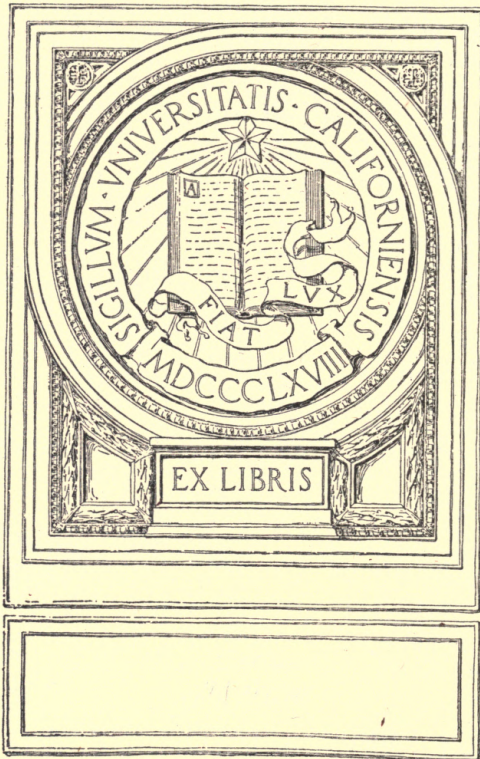
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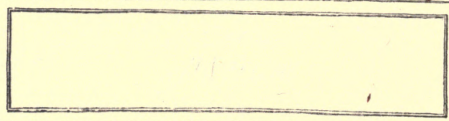
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SULPHITATION
IN
WHITE SUGAR
MANUFACTURE

FRANCIS MAXWELL



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MANUFACTURE

BY

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TO
MY RESPECTED FATHER
THIS WORK
IS GRATEFULLY DEDICATED.

TO THE
AMERICAN

PREFACE.

The Sulphitation Process, as applied in the manufacture of Plantation White Sugar, in cane sugar producing countries, is a subject of such wide-spread interest, and the developments in its application so remarkable, that the author trusts a book on this all-important subject may be found both timely and useful.

Although the greater part of the data presented in this book is the result of investigations by the author, made whilst acting in responsible positions in the different leading Plantation White Sugar producing countries, he has also gratefully referred to results obtained by his colleagues in various parts of the world, chiefly Harloff & Schmidt, Pellet, Horsin-Déon, Dr. Zerban, and others.

He also desires to acknowledge his indebtedness to The Sugar Machinery Manufacturing Co., Ltd., London, for photographs and descriptions of apparatus willingly given.

F. MAXWELL.

SYDENHAM, LONDON,

May, 1914.

EDITOR'S NOTE.

Dr. Maxwell's manuscript was completed early in 1914, and was under revision with a view to publication in September, 1914, when war broke out. Being in Germany at the time, he was, unfortunately, interned as a civilian prisoner of war; and as his release at this date still seems remote, it has been decided not to delay publication further.

August, 1916.

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SULPHITATION IN WHITE SUGAR MANUFACTURE.

INTRODUCTION.

SULPHUR AND ITS COMPOUNDS IN THE MANUFACTURE OF SUGAR.

HISTORY OF THE APPLICATION.

The use of the compounds of sulphur as purifying agents in the manufacture of sugar may be considered to date as far back as 1792, when Achard, the founder of the beet sugar industry, first applied a diluted solution of sulphuric acid to beet juice with a view to precipitating organic constituents, especially albuminoids, the free acid being subsequently neutralized by means of an addition of chalk before the juice was heated.

This process appeared to work satisfactorily, but its application did not gain ground, the simple method of defecation being generally preferred.

It was, however, the French chemist Proust, in 1810, who was the first to propose the application of sulphurous acid to the process of juice clarification. In the following year Dapriez took out the first patent for its practical application as a substitute for the sulphuric acid of Achard's process.

In 1825 a modification was introduced by Dombasle, and perfected by Dubrunfaut, to whom a patent was granted in 1829 for a process of sulphitation, in which sulphurous acid was brought into contact with beet pulps, and the juice submitted to the action of a larger and more constant proportion of lime, to be subsequently neutralized, either by sulphuric or sulphurous acid. In practice, however, the process did not prove to be a success.

Subsequently, Stolle (1838) obtained a patent upon the ground that sulphurous acid would act as a decolorizing substitute for bone black. Other investigators, including Merge, Boulon (1846) and Melsen (1849), carried out extensive experiments on the application of different sulphites, such as sulphite of lime, sulphite of alumina, etc., to this problem. The results, however, were unsatisfactory and impracticable, and consequently the idea of their application was abandoned.

The keen researches along the above lines did not remain confined to beet sugar fabrication, but soon spread to the sugar cane countries, for in the colony of Mauritius in 1865, Dr. Icery conducted successful experiments, which have been of appreciable benefit to the industry in that island. His method was shortly afterwards introduced into Java.

Opinions as to the value of sulphurous acid as a purifying agent, and the most effective method of its application, were for a long time by no means concordant. The next patent, granted to Seyferth (1869) was issued upon the basis of introducing the acid directly into the vacuum pans during the boiling of syrup. This process came into vogue in Germany and France, but certain technical difficulties caused it to be gradually abandoned.

Numerous subsequent experiments, extending over a number of years, have elucidated to a great extent the problem encountered in applying sulphitation processes. Prominent among the numerous investigators who have been engaged in this field of research are Basset, Fradiss and Schulze. It was not till 1884, however, that the sulphitation process in sugar fabrication was finally established. This was chiefly due to the exhaustive researches of Battut.

In the sugar cane countries, where this process has made rapid strides, and is at the present day playing the most important part in the manufacture of superior white plantation sugar, it is evident that it has been, ever since its establishment, the subject of extensive experiments and considerable improvements. During recent years the knowledge of this process in cane sugar fabrication has been greatly extended, notably as the result of valuable researches by Dr. Zerban, Harloff, Hazewinkel, and others.

CHAPTER I.

SULPHUR.

Its Origin, Preparation and Properties.

Origin.—Sulphur, the material used for the generation of sulphurous acid gas in the sulphitation process, is obtained by refining the crude element occurring widely and abundantly in nature, especially in connection with volcanoes.

Some of the most important deposits of sulphur in the world are met with in Sicily, chiefly in the sulphur-bearing zones of Girgenti. The quarried or mined free sulphur derived from these sources is always contaminated with impurities, such as limestone, gypsum, clay, etc., which necessitates a preliminary refining before use. This process consists briefly in melting the element, either by the heat of its own combustion, or by other means, and running it off from the earthy residue.

In Java, the progressive cane sugar producing island, various attempts have been made to use local sulphur which occurs abundantly on the numerous volcanoes, with however little success, owing to the presence of volcanic impurities. It was only quite recently that a source of very pure sulphur was discovered on a volcano in one of the Moluccan islands, since when a sulphur refinery has been built, and is supplying a number of factories in Java.

The sulphur produced appears to be of very good quality, containing some 99·8 per cent. of pure sulphur. It may be interesting to give here Leon's description¹ of the refining process as applied in Java:—

Refining.—“ The crude sulphur is charged into a cast iron tank. “ This is heated by means of coal, by which process the raw material “ is melted. Organic substances, such as pieces of wood, etc., will “ rise and float on the surface of the molten mass. They are “ removed by means of perforated iron skimmers. Sand and clay “ will obviously be precipitated and deposited at the bottom of the

¹ Java Archief, No. 8, 1913.

tank. This heating process is kept up for some five hours, during "which time volatile impurities of low boiling point will have "escaped."

"Subsequently the fluid mass is discharged into a closed furnace, "or so-called 'cornue,' in which its temperature is further raised "to 400° C by means of coal. The distillation of the sulphur is "conducted by leading the sulphur vapours into a cooling chamber. "The temperature prevailing in the interior of this chamber is "gradually brought to about 130° C, so that the distillate accumu- "lates at the bottom as a liquid, which is tapped off from time to "time to be cast into the customary form of rods."

Nature and Properties.—Sulphur exists in several allotropic modifications, but the most important one in our case is the ordinary or rhombic sulphur, the properties of which are therefore dealt with. Commercial roll sulphur has an average specific weight of 1.92 to 2.0. Its composition is naturally subject to considerable variations. Italian and French sulphurs usually contain 96.3 to 99.1 per cent. of sulphur, 2.4 per cent. to 0.2 per cent. of ash and 0.1 per cent. of arsenic. An official analysis of the Javanese sulphur gives the following figures:—Sulphur 99.8 per cent., moisture 0.04 per cent., ash 0.02 per cent., arsenic absent. Obviously this kind of sulphur is exceptionally pure.

Commercial sulphur forms yellow crystals which melt at 113° C, ignite in air at 250° C, and boil at 445° C under ordinary pressure.

On ignition the sulphur burns with a characteristic blue flame; just above the boiling point the vapour is orange yellow in colour but on continued heating it darkens, becoming deep red at 500° C, while at higher temperatures it again lightens, becoming straw-yellow at 650° C.

Other interesting phenomena are witnessed when sulphur is heated above its melting point. The solid melts to a pale yellow liquid, which on continued heating gradually darkens and becomes more viscous, the maximum viscosity occurring at 180° C, the product being then dark red in colour. On further heating the viscosity diminishes, while the colour remains the same.

CHAPTER II.

SULPHUROUS ACID.

Its Preparation, Chemical Properties, and Action.

For the sulphitation process in the manufacture of sugar, the dioxide of sulphur (SO₂) commonly known as sulphurous acid is used. It may be applied in either of two forms, as a liquid or as a gas, the gaseous form being more generally adopted.

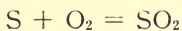
Liquid Sulphurous Acid.—In European beet sugar factories the use of liquid sulphurous acid is frequently met with, owing to the convenience of its manipulation and transport, in addition to the saving in generating apparatus.

The sulphurous acid gas is liquefied under pressure in suitable steel receptacles, in which it comes into the factory. The principal advantages of fluid sulphurous acid are that it produces an exceedingly pure saturation gas of a constant SO₂ content, avoiding the obnoxious occurrence of sublimation in pipes, etc., and that it is readily manipulated.

The fact that up to the present this form of sulphurous acid is more expensive than that which is obtained by the simple combustion of sulphur locally, constitutes the main reason why it has not made its way into the tropical sugar countries, where the cost of transport of heavy receptacles is a prime factor. In Europe the cost in connection with the application of liquid sulphurous acid during the past few years has been reduced to almost equal that of sulphur furnaces, as the liquid acid can be transported in bulk in specially constructed tanks, from which it can be transferred by means of compressed air.

The Sulphurous Acid Gas, which is almost exclusively used in cane sugar factories, is generated by the simple process of combustion of commercial roll sulphur in suitable furnaces.

When sulphur burns in air or oxygen, sulphur dioxide (sulphurous anhydride) is formed according to the equation :—



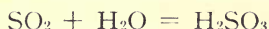
At the same time, small quantities of sulphur trioxide (SO_3) are formed, which render the gas obtained by this combustion, more or less foggy.

Properties of Sulphurous Acid.—Before proceeding further, it may be well to consider those properties of sulphurous acid which may play an important part in the process of its generation and practical application.

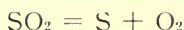
Sulphur dioxide is a colourless gas, possessing a characteristic suffocating odour. It is more than twice as heavy as air, its specific gravity being 2.26. It is readily soluble in water, its solubility at various temperatures being as follows:—

1	volume of water at	0° C	dissolves	79.79	vols. SO_2
1	„	20°	„	39.37	„ „
1	„	40°	„	18.77	„ „

The solution is strongly acid, and is regarded as sulphurous acid, the gas having entered into chemical union with the water:—



When sulphurous acid gas is heated to 1200° C it entirely decomposes into oxygen and sulphur, thus:—



In contact with an excess of oxygen, the sulphurous anhydride will be transformed into sulphuric anhydride:—



These two latter actions are of considerable importance, being detrimental to the successful employment of SO_2 as a purifying agent in sugar manufacture.

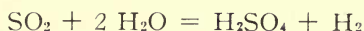
According to experiments conducted by Horsin-Déon, the dissociation takes place even below 1200° C, namely, at 800° - 900° C. When this temperature is reached, a series of dissociation processes occur, *viz.*, first of all, SO_2 into S and O_2 , and this excess of oxygen enters into combination with SO_2 to form SO_3 ; and again SO_3 into SO_2 and O.

When dealing with humid gas, the unavoidable formation of

sulphuric acid is evident. From the above facts, therefore, we deduce the following conclusions applicable in practice:—

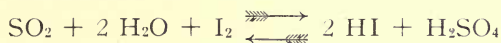
1. High combustion temperatures in sulphur furnaces are to be carefully avoided.
2. As a precautionary measure, sublimators must be connected with the sulphur furnaces, to condense the distilled sulphur.
3. To remove all traces of sulphuric acid from the gas, an additional gas washer is necessary.

Bleaching Action.—Sulphur dioxide possesses powerful bleaching properties in the presence of water. This bleaching action is considered to be due to the liberation of hydrogen consequent upon the formation of sulphuric acid, thus:—



The hydrogen thus set free reduces the colouring matter, with the formation of colourless compounds. In some instances the bleaching is due to the formation of a colourless compound by the direct combination of sulphur dioxide with the colouring matter, as it is found possible to restore the original colour by treatment with dilute sulphuric acid, or weak alkaline solutions.

Action on Iodine.—In the presence of water, sulphur dioxide converts iodine into hydriodic acid, giving a colourless solution, according to the equation:—



This reaction, however, only takes place when a certain degree of dilution is maintained, for in a more concentrated solution sulphuric acid is reduced by hydriodic acid to sulphur dioxide, according to the reverse equation given above.

Bunsen has shown that aqueous sulphurous acid can only be completely oxidized by iodine, as indicated in the foregoing equation, when the proportion of sulphur dioxide does not exceed 0.05 per cent. When this is exceeded, the second reaction comes into operation.

Generation of Sulphurous Acid.

Precautionary Measures to be observed.—The essential points to be borne in mind in connection with the generation of sulphurous acid gas, and the construction and arrangement of sulphurous acid producing plants, are comprised in the following.

The sulphur is almost exclusively burnt in a cast-iron combustion chamber, into which the air necessary for the combustion may be introduced either by compression or suction.

Air Regulation.—The regulation of the quantity of air is of great importance, for we have seen that lack of air involves an incomplete combustion of the sulphur, which in its turn promotes the occurrence of sublimated sulphur in the pipings, and on the other hand, an excess of air renders the saturation gas generated too dilute, which affects the sulphitation process.

Taking the latter point into consideration, therefore, it is important that the sulphur furnaces should always be kept within reasonable dimensions, otherwise an excessive volume of air would be necessary for keeping the sulphur burning; at the same time it is desirable to establish a correct relationship between the size of furnace and the air compressor.

Combustion Temperature.—Excessive combustion temperatures should be avoided; otherwise, as previously stated, dissociation of the sulphurous anhydride is apt to occur, in which case a certain amount of sulphur in the form of vapour is entrained in the pipings, and on cooling becomes re-crystallized, ultimately causing the pipings to become choked.

Sublimators.—In spite of all care and supervision, this phenomenon, called sublimation, is bound to occur to a more or less extent, hence it is imperative to provide such installations with a sublimator, fitted with an effective water-cooling device.

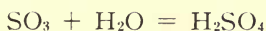
Drying the Air.—Further, it is essential that the air should be dried prior to entering the combustion chamber.

Although it has been repeatedly proved that humid air incontrovertibly promotes the formation of sulphuric acid, and in spite of

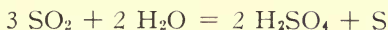
the destructive consequences of this acid being so well-known, yet many factories in tropical cane countries still ignore this important point.

The formation of sulphuric anhydride in the sulphur furnace may occur, for example, when dissociation takes place, or in the presence of an excess of air.

In the presence of humidity, the sulphuric anhydride combines with the water, forming sulphuric acid, according to the equation:—



Priestley and Berthollet have given us another equation, according to which H_2SO_4 may be formed at high temperatures, *viz.*:—



Apart from the notorious inverting properties of sulphuric acid in sugar solutions, we have the destruction of piping, boilers, etc., due to corrosion, which goes hand in hand with the formation of this acid.

In order to reduce the formation of sulphuric acid to a minimum, the air for combustion should pass through several layers of quick-lime prior to entering the sulphur furnace, by which process the moisture is absorbed. Even then, as explained above, the occurrence of traces of sulphuric anhydride due to dissociation cannot be entirely avoided.

Its presence may be obviated by passing the fumes produced in the sulphur furnace through a washer, where the sulphuric anhydride readily enters into combination with the water to form sulphuric acid solution which will remain in the washer.

The final process to which the gas is to be subjected before coming into contact with the juice to be treated consists in purifying it, by allowing it to pass through layers of coke or other kindred material, with subsequent cooling through an efficient water-cooling device.

CHAPTER III.

GENERATING PLANTS FOR SULPHUROUS ACID GAS.

Sulphitation Vessels for Juice and Syrup.

There are a great number of types of installations for the generation of sulphurous acid gas. The simplest, but at the same time most primitive installation imaginable, is such as is still to be met with in a number of factories in Mauritius.

The plant usually consists of a couple of miniature chimney-like iron furnaces, the top-ends of which are connected with the sulphitation vessels by means of piping. The air required for the combustion of the sulphur is drawn into the combustion chamber by means of an injecting arrangement (Giffard), which carries the sulphur fumes forward directly into the sulphitation vessels by means of steam.

Owing to the absence of gas purifying and cooling devices, it is evident that this manner of operation involves a generation of impure saturation gas, in addition to the occurrence of sulphuric acid and sublimation products. In a few cases gas washers and sublimators are employed.

Another apparatus met with in a few factories on that island, which appears to be appreciated owing to its simplicity, cheapness, and alleged efficiency, is shown in Fig. 1, a description¹ of which is as follows :—

The installation is composed of—

A sulphitation tank **A**.

A cast iron furnace **B**, provided with a slide arranged in such a manner as to reduce the amount of air entering the chamber to a minimum.

A refrigerating sublimator **C**.

A washer **D**, which consists of a rectangular vessel of solid antimonized lead, divided vertically into two compartments by means

¹Baissac, Société des Chimistes de Maurice, August, 1912.

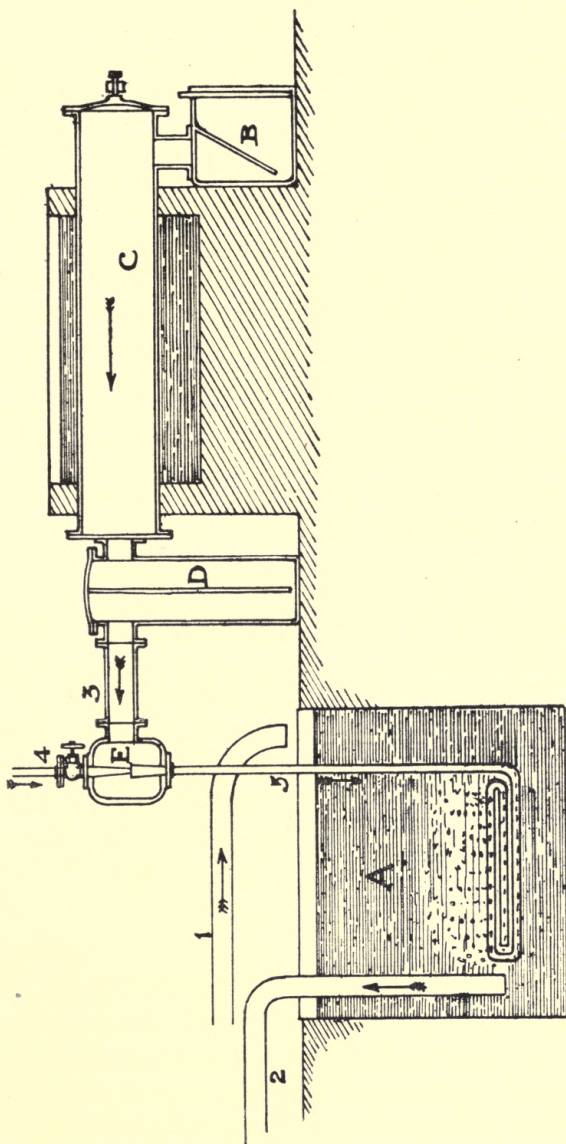


FIG. 1.
A FORM OF SULPHITATION APPARATUS USED IN MAURITIUS.

of a leaden partition, leaving a communicating space between the compartments of one inch from the bottom. This arrangement enables the washing of the sulphurous gas to be carried out. The gas is drawn by an injector **E** through the water, thus ridding it of its impurities. Juice inlet is **1**, juice outlet **2**, the washed gas enters injector chamber by **3**, and steam by **4**.

The gas washer contains about 20 litres of water, which is changed at intervals of eight hours. The quantity of sulphuric acid contained in the water, according to analyses taken on different occasions, varied from 16 to 28.6 grms. per litre, giving an average of 20.3 grms. of SO_3 , or 400 grms. per washer during eight hours' work. At the end of the milling season, a greyish powder is found to adhere to the partition, principally composed of sulphates and sulphites of lead, silicon, traces of iron, etc.

The main advantages attributed to the gas washer are that it retains the SO_3 formed during the combustion process, and also the impurities of the sulphur which have not been deposited in the sublimator.

Quarez Sulphitation Installation.

We now come to an installation which enjoys a wider range of application, and may be met with in beet sugar as well as in cane sugar factories, namely the Quarez Sulphitation Plant. It belongs to the class of continuous sulphitation apparatus, and owing to its simplicity as well as efficiency, it is much appreciated.

The installation consists of an ingenious combination of an air dryer, sulphur furnace, sublimator, juice pump and sulphitation tank, which entire arrangement takes up but a small space.

The sulphur is burnt in a rectangular combustion chamber **L**. The tray on which the sulphur is charged is moveable for the purpose of introducing the latter, and also for cleaning; the door may be opened without the sulphur fumes escaping into the atmosphere. The air is drawn from underneath through an air drying device **S**, composed of a chamber containing several layers of quicklime, and thence into the combustion chamber.

The sulphur fumes pass through a cooling device **M**, situated on the top of the furnace, and thence through the sublimator **N**, consisting of a long vertical pipe, provided with a water-cooling jacket.

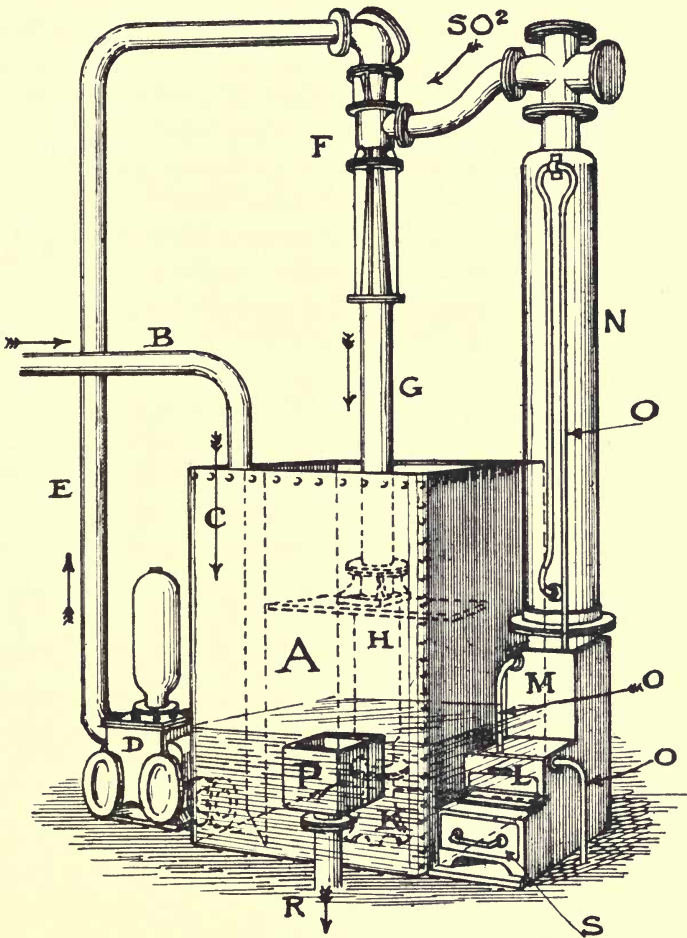


FIG. 2.

QUAREZ SULPHITATION INSTALLATION.

The sulphitation tank **A** is divided into two compartments, the juice to be sulphitated being introduced into the smaller division **C**, to which also the suction of a pump **D** is attached. The pump draws

the non- or slightly sulphitated juice up and forces it into the injector **F**, whence it circulates downwards through the column **G**, drawing the sulphurous acid gas with it into the larger division of the tank. The juice is thus continuously kept in circulation, until the required degree of acidity is obtained. The actual sulphitation process therefore occurs in the vertical column, where the gas and juice are intimately mixed.

The gas which has not been absorbed will bubble through the juice in the tank. The sulphitation tank is provided with a test box **P**, and a run-off pipe **R**.

The sulphitation process is controlled by regulating the quantity of juice to be treated and the speed of the pump.

The points in connection with the Quarez installation put forward by its advocates are:—

1. The sulphurous acid gas is introduced into the juice by means of suction and not forced through by compression.

2. The quantity of juice in contact with the acid is small, namely, three to four hectolitres.

3. The entrance and discharge of the juice being continuous, the sulphitation process may be interrupted and recommenced instantaneously without any inconvenient consequences.

4. The Quarez apparatus is readily installed, occupying very little room and allowing of various combinations of the different parts.

5. Its manipulation is of the simplest nature.

6. The apparatus has no valve in contact with the sulphurous acid; the injector is constructed of special metal, proof against deterioration due to the acid gas.

7. The quantity of sulphur consumed is very small, and no gas is allowed to escape into the factory.

Although the general advantages claimed for the Quarez apparatus justify its extensive application in sugar countries, it is evident that local conditions are bound to play an important part in the usefulness of this type of sulphitation installation.

In countries like Mauritius, Natal and Louisiana, where generally the sulphitation process occurs before tempering, this apparatus is

not infrequently applied with satisfactory results. In this case it is evident that the accuracy with which the sulphitating operation is conducted need not be a great factor, for the degree of acidity of the mill juice may be conveniently brought back to neutrality by the subsequent process of liming.

On the other hand, where the "liming before sulphitation" process is adopted in cane sugar factories, the installation in question is much less suitable. Owing to the continuous method of sulphitation, it becomes a more delicate problem to control the saturation of limed juices, to give a constant neutrality of the sulphitated juice. This is especially so in the case where several cane varieties, producing juices of considerably fluctuating composition, are daily passed through the mills. Therefore in Java, for instance, the Quarez plant is rarely met with.

In beet sugar countries the case is different. On the European continent, particularly in France, the Quarez is frequently employed. Here, however, we are dealing with beet juices, the constitutional properties of which are quite different from those of cane juices. Moreover, in beet sugar factories sulphurous acid is generally applied as an additional agent to carbonic acid.

Apparatus as used in Java, etc.—Among the most successful and best sulphurous acid gas-producing plants is the combination shown in Fig 3.¹

This system is almost universally met with in plantation white sugar factories in Java, and has always maintained a superiority over others.

Its composition and operation are as follows:—

The sulphurous acid gas is generated in an oval-shaped, cast-iron furnace **E**, provided with a water-cooling jacket, in order to diminish the combustion temperature.

The required charge of sulphur is placed on an internal sliding tray, which is thrust into the furnace after the sulphur is ignited. Further additions of sulphur are afterwards made by way of the feed hopper cast on the top part of the furnace, and provided with a butterfly valve.

¹As supplied by The Sugar Machinery Manufacturing Co., Ltd., London.

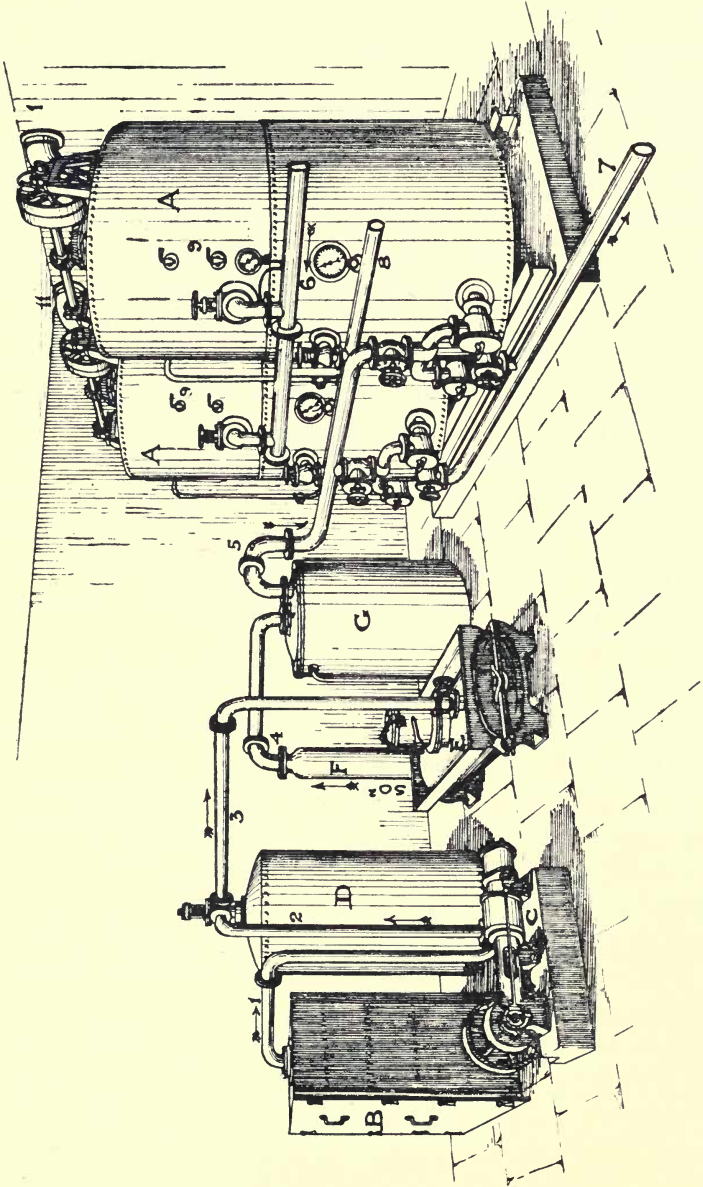


Fig. 3.
APPARATUS FOR SULPHITATION AS USED IN JAVA, ETC.

The air necessary for the combustion is drawn by the air compressor **C** through an air dryer **B**, consisting of a mild steel chamber, fitted with a number of perforated pull-out trays or drawers, each carrying a layer of unslaked lime, which serves to absorb the moisture of the air.

The compressor pumps the dried air into a receiver **D**, whence it enters the furnace. In this manner the formation of sulphuric acid owing to the presence of humid air is avoided, and any desired air pressure maintained.

The air passing across the sulphur tray carries the fumes into the outlet pipe, which owing to its length and enlarged form and water-cooling jacket **F**, acts as a sublimator, and thence into the gas purifier and cooler **G** before reaching the sulphitation vessels **AA**.

This combined apparatus **G** consists of a cylindrical cast iron vessel, containing several layers of coke or other suitable filtering substance (pumice stone, etc.). This vessel is supported in a tank, the open space between the two vessels being kept full of water, constantly flowing in at the bottom and out at the top. The gas passes down an internal pipe into the bottom of the inner vessel, and rises through the layers of coke to the top, whence it passes on to the sulphitation tanks, the water jacket cooling the hot gas during its passage through the gas purifier.

It is evident that the saturation gas generated by such an installation is of a very pure nature, owing to the many precautionary measures taken, including drying the air, retaining unburnt sulphur particles, cooling and purifying the gas.

Though at first sight the installation described above may appear rather complicated, its manipulation is very simple, and requires only one man of ordinary skill to effect its satisfactory working.

Sulphitation Vessels.

The sulphitation of the juice is performed in several ways.

Sulphur Box.—One of these methods, frequently employed in Mauritius, Natal, etc., is the use of what is known as a "Sulphur Box." (Fig. 4).

This consists of a vertical rectangular wooden chamber **C**, of suitable dimensions, varying greatly according to the special requirements in different localities. The height of this tower ranges from 8 ft. to 12 ft. At intervals within the tower, horizontal or slanting perforated partitions or similar devices for the purpose of distributing the juice are fitted.

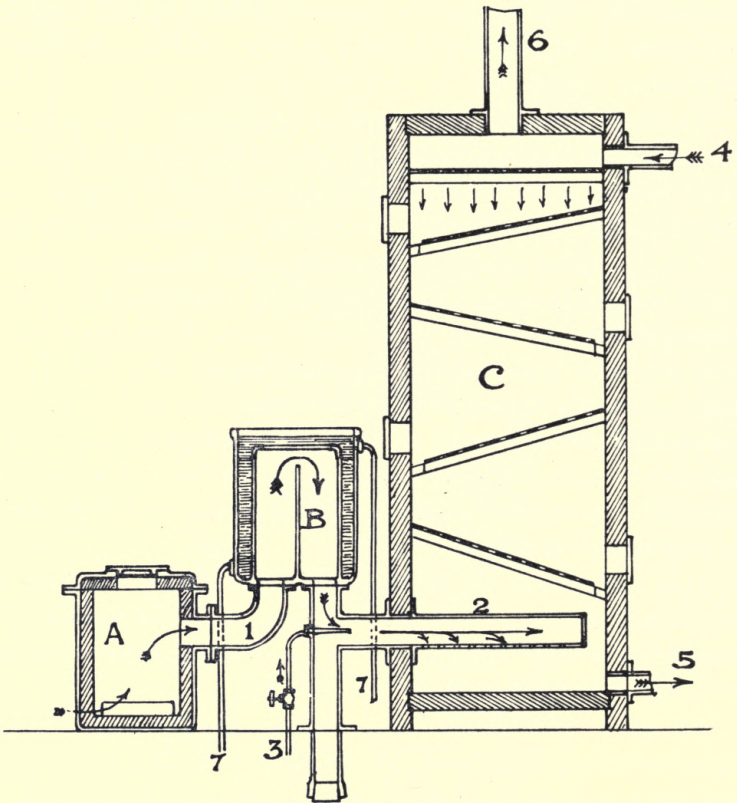
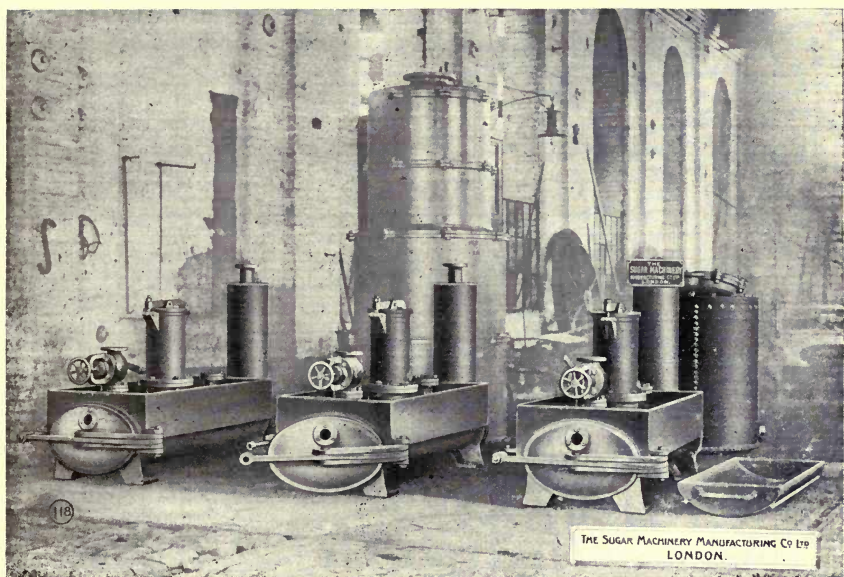


FIG. 4.
THE "SULPHUR BOX."

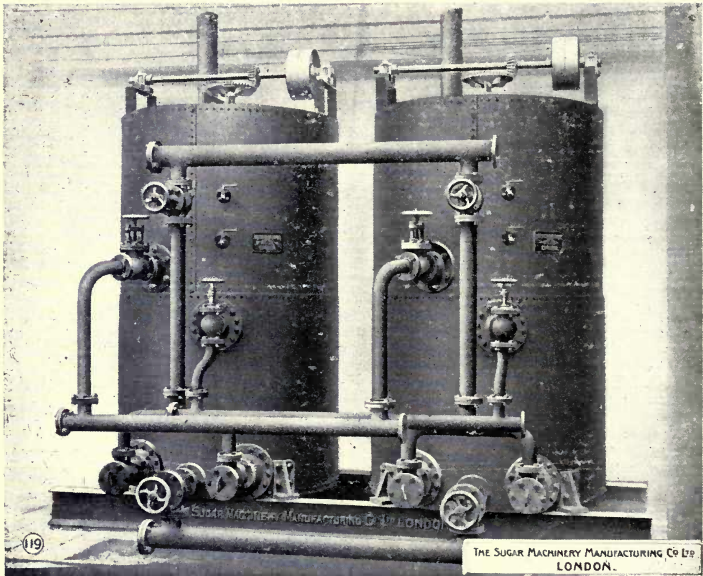
The juice enters at the top of the tower **4** and gravitates as a fine shower, being broken up as much as possible by the partitions, whilst the sulphurous acid gas enters the box at the bottom **2**, either under suction or pressure promoted by a steam jet **3** suitably arranged. After thoroughly intermixing with the gas in its downward

Plate I



MODERN SULPHUR FURNACES.

Plate II



SULPHITATION VESSELS WITH STIRRING GEAR.

passage, the juice leaves the box at the bottom **5**. **A** is the sulphur furnace, and **B** the cooler, or sublimator.

Sulphitation Tanks.—Another method consists of the application of an ordinary tank, provided with an agitating device and gas distributing pipes. The juice is allowed to run continuously through the tank, in which it comes into contact with the saturation gas.

It is obvious that, though both the above methods of operation are simple and quick, they do not allow of an accurate control of the sulphitation process. In factories where the sulphitation precedes the liming of the juice, however, these appliances have proved to be satisfactory.

A very suitable and effective sulphitation vessel, most usually met with in the leading cane sugar countries, is shown on *Plate II*,¹ and described below.

It consists of a cylindrical mild steel vessel about 5 ft. 6 in. in diameter and 9 ft. high, with a closed top having a round opening and sliding cover for cleaning and similar purposes, and a chimney for carrying the waste gas outside the factory.

The sulphitation vessel is fitted with copper heating coils and an agitating arrangement.

The saturation gas enters at the bottom of the vessel through either perforated iron tubes or a so-called "spider web," its supply being regulated by means of a valve worked from the staging. The juice entrance occurs in the above illustration through a separate valve; in other designs it is arranged that juice and gas enter the vessel through a common pipe, with a view to promoting the intermixing process. Further accessories, such as manhole, test cocks, gauge glass, sight glass, thermometer, etc., are usually supplied.

The sulphitation of syrup and molasses is readily carried out in similar tanks.

¹ Kindly supplied by The Sugar Machinery Manufacturing Co., Ltd. London.

CHAPTER IV.

THE CONTROL OF THE SULPHUROUS ACID GAS GENERATING STATION.

Quantity of Lime.—The amount of quicklime required for drying the air cannot be pre-determined, owing to the varying degrees of humidity in the atmosphere, as well as to the gradual formation of a skin of slaked lime, resulting in a decrease of drying power. For this reason, it is always advisable to place a larger quantity of lime in the air dryer than is theoretically necessary. The regular changing of the lime at certain intervals is also essential.

The Manipulation of the Sulphur Furnace is performed as follows:—Different methods may be applied to start the furnace. The requisite amount of sulphur being placed on the tray, it may be ignited by throwing upon its surface burning sulphur wicks, which are readily made by dipping ends of old ropes into melted sulphur. This method, however, often produces merely local combustions, so that when the door is closed and the compressor started, it frequently happens that the flame is soon extinguished or that the SO_2 production is poor.

Another mode of operation sometimes applied consists in first melting the sulphur rolls in the tray by burning wood under it. The advantage is that a well-distributed layer of melted sulphur is obtained, allowing of an easy ignition.

By spraying some alcohol on the sulphur, an evenly distributed ignition may also be attained.

Regulation of the Air Supply.—The next point which deserves attention is the regulation of the air supply for combustion. It is obvious that an excessive quantity of air rushing through the furnace may either be the cause of extinguishing the flames, or producing a gas of poor strength; on the other hand, an insufficient supply of air causes incomplete combustion and sublimation. By rational regulation of the speed of the air compressor, and the air valve on the furnace, a smooth working of the furnace is ensured.

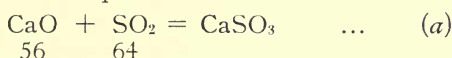
With regard to the cooling devices, it is of great importance that the temperature of the gas should be kept as low as possible during its journey to the sulphitation tank. The cooling-water supply should be regulated according to the temperature noted after passing through the various jackets.

The piping connecting the sulphur furnace with the sulphitation tanks should be cast iron to resist acid, and of sufficient diameter to prevent any possible obstruction. It must be arranged with a view to convenience of cleaning, therefore an excessive number of bends should be avoided.

Consumption of Sulphur.—An approximate estimate of the amount of sulphur consumed by the sulphitation process may be arrived at by the following method of calculation:—

(1) *Juice Sulphitation after Tempering.*—In the event of the tempering occurring before sulphitating the juice, let it be assumed that 1 kg. of lime is used per 1000 litres of juice (equivalent to about 7 litres of lime-milk of 15° Beaumé), of which only 550 grms. enter into combination with the SO₂, the rest (equal to 3 litres of lime-milk of 15° Beaumé) being used for the neutralization of the original acidity of the juice.

According to the equation :



64 parts of SO₂ are required to neutralize 56 parts of CaO, and further according to :



for the production of 64 parts of SO₂, 32 parts of sulphur are necessary. From these equations it is seen that 56 parts of CaO require 32 parts of S, that is, 7 parts of CaO require 4 parts of S. Thus for the precipitation of the above-mentioned 0.55 kg. CaO per 1000 litres of juice, $\frac{0.55 \times 4}{7} = 0.314$ kg. of sulphur are

necessary. Assuming that 100 parts of cane produce 90 parts of juice, we conclude that an excess of 0.55 kg. of lime per 1000 litres of juice involves a consumption of not more than 0.03 per cent. of

sulphur on the weight of cane. This calculation is naturally based on the assumption that rational operation of the sulphitation process takes place, entailing the use of no more SO_2 than is necessary for neutralization purposes.

(2) *Juice Sulphitation before Tempering.*—In factories where sulphitation precedes the tempering of the juice, the consumption of sulphur obviously depends on the degree of acidity to which the juice is brought. Assuming this to be 0.7 grms. SO_2 per litre, and considering that according to the equation (b) 1 part of S produces 2 parts of SO_2 , it follows that 0.35 grms. S will produce 0.7 grms. SO_2 per litre of juice. Taking the above figures of 100 parts of cane giving 90 parts of juice, we again obtain a consumption of 0.03 per cent. of sulphur on the weight of cane.

(3) *Syrup Sulphitation.*—The approximate quantity of sulphur required for the sulphitation of syrup and molasses may be arrived at in a similar way to that under (2).

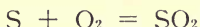
It is evident that these figures are only approximate, as there are many factors of a complicating nature, which, if taken into consideration, would make a calculation impossible. These above methods are however, sufficiently accurate for practical purposes.

CHAPTER V.

ANALYSIS OF THE SULPHUROUS ACID GAS.

In spite of the obvious advisability of occasionally analysing the combustion gases as to their SO_2 content, this operation is frequently neglected. The knowledge of the purity of the gas obtained enables one to control accordingly the air supply and regulate the sulphitation process.

Theoretical Purity.—For the determination of the theoretical maximum purity of sulphurous acid gas, recourse is had to the familiar equation :



which teaches that one volume of oxygen on entering into combination with sulphur gives one volume of SO_2 . Taking the percentage of oxygen in the air to be 21 (the figure is actually a trifle smaller, owing to the presence of carbonic acid and moisture), and assuming that all existing oxygen is used for combustion, the SO_2 content of the combustion gas will then be 21 per cent., which is therefore the theoretical maximum.

This figure is, of course, never realized in practice, an excessive quantity of air being necessary to keep the sulphur burning; 12 to 15 per cent. of SO_2 in the gas is usually considered satisfactory, while 8 per cent. is by no means uncommon.

Methods of Analysis.—The analysis of the gas may be performed in different ways ; for instance, employing an iodized starch solution, through which the gas is allowed to pass until complete decolorization has occurred. This method is an excellent one for laboratory purposes, but less applicable on a practical scale.

A convenient method, which is usually employed in sugar factory practice, is described in the following paragraphs.

The determination of sulphurous anhydride in the saturation gas is based upon the same chemical process as used in connection with the analysis of carbonic acid, namely by absorption of the gas with a solution of caustic potash. The diminution of the volume of gas caused by this operation indicates the quantity of SO_2 present.

Figure 5 shows the apparatus employed for this purpose, of which the following gives a brief description.

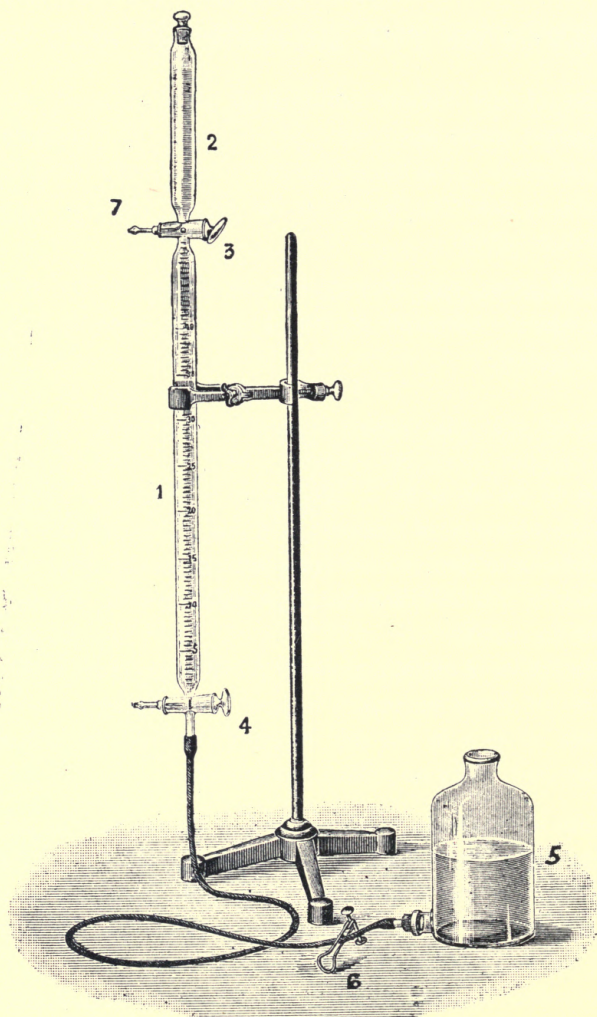


FIG. 5.

APPARATUS FOR ANALYSING SULPHUROUS ACID GAS.

Owing to the easy solubility of sulphurous acid gas in water, the apparatus as well as the method of application differs somewhat from that used for analysing carbonic acid.

It consists of a burette **1** after Stammer, provided with a scale. The top of the burette ends in a funnel-shaped vessel **2** with a stopper. **3** and **4** are three-way cocks, the latter of which is connected with a bottle **5** by means of a rubber tube provided with a pinch-cock **6**. This bottle is filled with water and serves to replace the absorbed quantity of SO_2 by water, as well as to regulate the level for the purpose of reading.

Before proceeding to analyse the samples, the burette should be thoroughly cleansed with alcohol or ether, and subsequently dried.

Then the cock **4** is opened, so that communication is made between the atmosphere and the water in the bottle through the rubber tube, and the burette is raised until the water falls below the cock **4** when the latter is closed.

Both cocks **3** and **4** are then opened, allowing communication between the interior of the burette and the atmosphere: tube **7** on cock **3** is connected by means of a rubber tube with the piping conducting the sulphurous acid gas to the sulphitation vessels, and the gas allowed to rush through the burette, escaping through the stem of cock **4** until all air within the burette is expelled. Cocks **3** and **4** are now closed, and the connection with the gas piping detached.

After having filled the upper tube **2** with a solution of caustic potash of about 1.25 density, the solution is allowed to flow into the burette, absorbing the sulphurous acid gas. The process of absorption may be promoted by removing the burette from its stand and shaking it for some time in a horizontal position. The burette is subsequently replaced in its stand, and cock **4** opened, allowing water from the bottle to run into the burette and replace the volume of absorbed gas.

After a lapse of some ten minutes or so, the bottle is raised until the surfaces of the liquid in the burette and in the bottle are at the same level. The decrease of volume denotes the proportion of sulphurous acid in the saturation gas.

CHAPTER VI.

ACTION OF SULPHUROUS ACID ON JUICES.

The methods of application of the sulphitation process with regard to cane juice in plantation white sugar factories are twofold, namely :—

1. After tempering the juice.
2. Before ,, ,,

The former is the standard method as applied in Java, while the latter is generally in vogue in Mauritius, and is also frequently met with in Natal and Louisiana.

Action of the Gas on Juice.—Before proceeding to discuss the *pros* and *cons* of the different methods, however, it is necessary to enter into a general study of the various properties and actions of the sulphurous acid gas in connection with the cane juice.

It is an acknowledged fact that sulphurous acid gas is a purifier, a decolorizer, a neutralizer, a reducer of viscosity, and a good antiseptic.

Purifying Action.—When sulphurous acid gas is applied to raw cane juice (mill juice), the following phenomena may be observed :—A sample of the cane juice of the typical greyish to dark green colour is treated with sulphurous acid gas in a glass cylinder to about 0.7 grms. SO_2 per litre. As soon as the sulphitation operation ceases and the liquid is again at rest, very small particles are formed in the juice, which however are soon transformed into voluminous and flocculent masses of varying density. The difference of density causes a convection, and so the heavier parts move downwards and the lighter ones upwards. After a lapse of time, varying according to circumstances, the settling process is completed. The sediment which usually occupies about one quarter of the total volume, is of a lemon-yellow to greenish-grey colour, while the juice is less opaque and of a much lighter shade.

The precipitate is mainly composed of organic matter.

It is interesting to note here the difference between the sulphitation of the cane juice by means of steam injection, and the sulphitation by compressed air, as recently investigated by the author.

It has been observed that by applying steam injection for the purpose of forcing SO_2 gas into the juice, more precipitate of a more flocculent nature is obtained than when using compressed air. The settling process occurs also more quickly in the former case. Using compressed air the juice was sulphitated to 1.2 grms. SO_2 per litre; using steam injection, although the juice only attained an acidity of 0.7 grms. SO_2 per litre, the precipitate was considerably greater than in the former case. Evidently the steam, though a comparatively trifling amount is required for injection purposes, has a favourable effect on the formation of precipitate in the sulphitated juice.

Purifying Effect.—From the above it is evident that sulphurous acid gas acts as a purifier upon raw cane juice. However, by the subsequent addition of lime, without previous removal of the precipitate, the purifying effect of the gas is practically nullified.

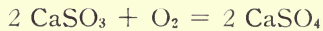
Bleaching Action.—The decolorizing action of sulphurous acid is well known, and its application in the manufacture of sugar is universally appreciated. As previously mentioned, sulphurous acid brought into contact with juice does not only produce a precipitate, but in addition distinctly bleaches the liquid.

This change of colour may also be obtained by using other acids besides sulphurous acid. It has, however, been established that juices treated with other mineral acids, such as sulphuric or phosphoric acids, actually exhibit a slight improvement in colour, but not to the same extent as that obtained by sulphurous acid. Hence, apart from its action as a mineral acid, sulphurous acid has a decolorizing effect due to its reducing property.

The decolorization due to the latter property, as has been described in Chapter II, is based on the liberation of hydrogen, which reduces the organic colouring substances, with the formation of colourless compounds. This decolorization is but temporary, for on exposure to the atmosphere the reduced colouring matter becomes gradually

oxidized by the oxygen of the air, causing the juice ultimately to assume its original colour.

By acidifying juices by means of SO_2 , it may be further observed that, as long as the acidity of the juice is preserved, the decolorization is maintained. This permanent decolorization in case of acid solutions is chiefly attributed to the bleaching action of the sulphurous acid salts formed. During the different phases of evaporation processes these sulphites check, to a greater or less extent, any subsequent development of colouring and air oxidizing processes. They are easily oxidized to sulphates, in which form they are invariably found subsequently in the syrups and molasses; for example:—



It is also owing to the said property that sulphites do not impart a darker colour to glucose solutions on heating.

On subsequent neutralization of the acid juices, however, the decolorization entirely disappears so that the juice assumes its original colour.

Neutralizing action.—As an agent for neutralizing the alkalinity of limed juices, the application of sulphurous acid is generally adopted. Besides being cheap, the lime-salts of this acid are practically insoluble in neutral or alkaline solutions.

Reducing viscosity.—Although the opinions of authorities with regard to the alleged property of sulphurous acid of reducing the viscosity of juices are not unanimous, in practice it is generally accepted that such an action occurs. So far, however, numerous experiments have failed to disclose such an influence.

Preservative action.—Another property ascribed to sulphurous acid is a preservative action on juices. It is generally accepted that juices and syrups are less liable to fermentation after sulphitation.

CHAPTER VII.

PRINCIPLES OF THE APPLICATION OF SULPHITATION TO JUICE.

Having briefly dealt with the various actions of sulphurous acid on cane juice, we can now proceed to study the principles of juice purifying processes by means of sulphitation.

As already stated, there exist two methods of applying the sulphurous acid gas, namely after and before tempering the juice.

(I) Sulphitation after Tempering the Juice.

According to this method the cane juice coming from the mills is previously treated with a certain quantity of lime, a process known as "tempering" the juice. This purifying agent being of no less importance than sulphurous acid in the process in question, a study of its chemical action on cane juice is obviously indispensable.

Tempering.—The first action of lime on cane juice is to neutralize the free organic acids, forming calcium organic salts. The combined organic and inorganic acids may likewise be decomposed.

The phosphoric acid occurring in the juice will unite to form acid calcium phosphates which are precipitated as flocculent tribasic phosphate.

Further, lime acts upon albuminoid, gummy and pectin matters, which are partly precipitated. The lime combines with the albumen which was previously suspended in the juice in a gelatinous condition. This compound is coagulated during the subsequent treatment by the combined action of lime and heat.

With regard to the action of lime upon gummy substances, the opinions of various authorities are divided. Dr. Maxwell¹ found some time ago that a large quantity of gum was separated by liming in the cold. A series of experiments conducted by the present

¹Report of the Hawaiian Exp. Station, 1896.

author in Mauritius, supplemented by analyses carried out at the local "Station Agronomique," gave identical results, namely, that a distinct separation of gum was observed on allowing an adequate amount of lime to act during a certain time on cold cane juice.

Pectin ingredients unite with lime to form insoluble as well as soluble compounds, which latter are also precipitated to some extent during defecation.

Colouring substances, such as anthocyan and chlorophyll, are precipitated by sufficient tempering.

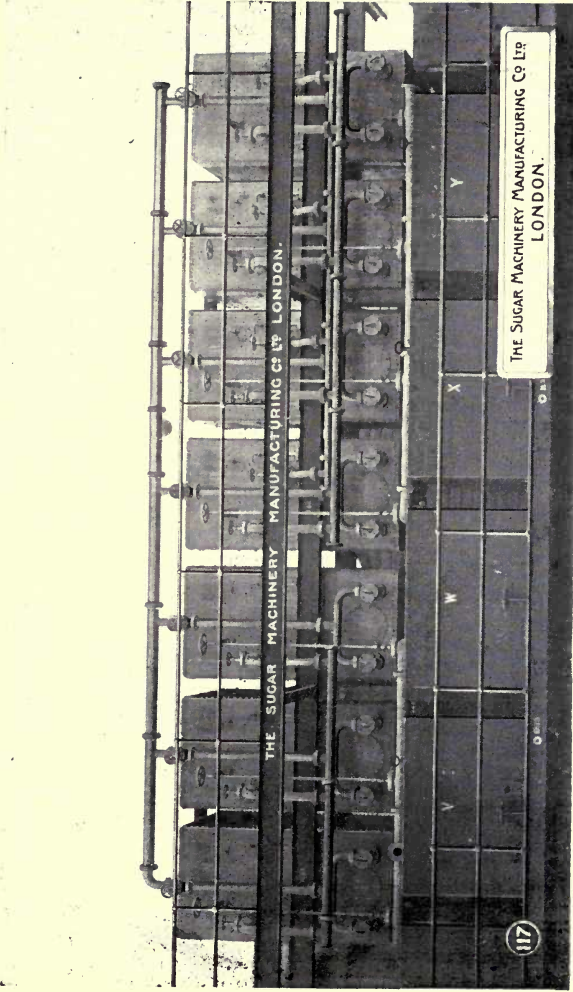
The sugar further combines with the excess of lime, dissolving and forming saccharates, as long as the juice is not heated.

Besides gummy matter, the most obnoxious substances playing an important part in the manufacture of white cane sugar are the "reducing sugars," or, as they are often termed, "glucose."

Lime, like other alkaline agents, acts on the reducing sugars in the cold, forming glucosates which are analogous to saccharates. These compounds are unstable, and hence easily decomposed. At lower temperatures (below 55° C.) the chief product due to the action of lime on glucose is lactic acid, which is a comparatively stable acid and not subject to spontaneous decomposition. At higher temperatures, however, dark-coloured lime-salts of organic acids, especially glucinic and saccharic acids, are formed. These lime-salts easily decompose, forming acid substances which may cause inversion and which moreover do not crystallize, hence they retard evaporation and crystallization. Their viscosity is generally known to cause considerable trouble and losses in the boiling and curing departments.

The main actions of lime upon the various constituents of the cane juice, therefore, may be summarized as follows :

Lime neutralizes the free acids; combines with albuminoid, gummy and pectin substances, which are subsequently partly removed; precipitates various bark pigments and chromogens. On the other hand, it also forms saccharates and glucosates, depending on the temperature, the concentration both of lime and sugars, and the duration of contact.

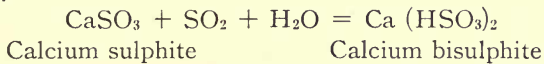


BATTERY OF SULPHITATION TANKS.

It is thus evident that lime is an excellent purifying agent, and it is therefore no wonder that its application as such to sugar juices has been more than justified from the earliest times.

Sulphitation.—After tempering by lime in the cold, the sulphurous acid saturation is commenced. By this treatment the greater part of the lime compounds enter into union with the sulphurous acid to form insoluble sulphites, which, after undergoing a heating process, are finally precipitated and removed with other substances in the defecators or subsiding tanks. It is evident that sulphurous acid is used in this case simply as a neutralizing agent. The clear juice from these tanks should be of a very light olive yellow colour, quite transparent, devoid of the impurities in suspension which cause the liquid to assume a turbid or less transparent appearance.

The sulphitation is continued until neutrality is reached as shown by the phenolphthalein test, described under "Indicators" at the end of this chapter. If the extent of saturation were still further carried out, over-sulphitation would occur. This would mean the conversion of the insoluble sulphites, such as those of calcium and potassium, into soluble bisulphites, according to the equation :—



The juice would consequently be rendered acid. During heating in the juice-heaters, and especially during evaporation, these soluble bisulphites are split up into sulphurous acid, water and insoluble sulphite. The latter is deposited around the heating tubes of the evaporating vessels, thus forming an incrustation which reduces considerably the transmission of heat. The liberated sulphurous acid passes into the condensed water of the evaporators, causing corrosion of the tubes.

It is therefore obvious that great care should be taken to see that the sulphitation process is not carried too far.

(II) Sulphitation before Tempering.

This method, as stated previously, is generally adopted in Mauritius, and is also met with in Natal and Louisiana. It is performed in the following manner :—The cane juice from the mills is

directly treated with sulphurous acid gas until an acidity of from 0.8 to 1 per cent. of SO_2 is reached, and after this the juice is neutralized by means of lime.

While in Mauritius, the author fortunately had the opportunity of investigating the advantages and disadvantages of both methods, in the laboratory as well as in general practice, that is, in a factory which formerly worked according to the sulphitation-before-liming process, but which on the author's advice subsequently abandoned it in order to introduce the reverse method. The results¹ of these investigations, later extended to Natal practice, where both methods are in vogue, are studied in the following sections.

As we have seen, treatment of crude mill juice with sulphurous acid gas results in the production of a precipitate and a decolorization of the liquid. On subsequent neutralization of the acid juice, however, the greater part of the precipitate which is mainly composed of organic matter, is re-dissolved, and simultaneously the juice assumes its original dark colour.

We therefore conclude that the beneficial influence of the sulphurous acid on the cane juice, both from a purifying as well as bleaching point of view, disappears with the subsequent liming process, the only useful action of the SO_2 in this case being that it renders the mill juice acid for subsequent neutralization.

It would be different if the voluminous precipitate due to the sulphurous acid could be removed before the application of lime. The nature of the precipitate does not allow of a practicable filtration so that the removal involves considerable practical difficulties, but undoubtedly it has a beneficial effect upon the ultimate quality of the purified juice.

In Mauritius, one factory adopted this principle of removing the precipitate due to sulphurous acid prior to the liming, and obtained excellent results. This operation was effected in what is locally called a "bac portal," a shallow tank divided into narrow longitudinal compartments, at alternate ends of which the partitions are cut away to a depth of about 1 in., thus allowing the juice to travel

¹ The main practical results have been elaborately dealt with in an article by the author in "Bulletin de la Société des Chimistes de Maurice," Nov., 1911, No. 7.

a distance of about 200 feet, all the time depositing the suspended precipitate.

Returning to the sulphitation-before-liming process, the acidified juice is subsequently limed to neutrality. Now, how does the lime act under these conditions? The juice being strongly acid, it stands to reason that the lime will preferably enter into union with the acid, forming insoluble sulphites, consequently the purifying property of the lime is not allowed to act sufficiently before being rendered partly ineffective by the formation of lime salts.

Comparison.—Although, in the laboratory, scarcely any external differences can be observed in juices treated according to the two processes, liming-sulphitation, and sulphitation-liming, this is not so in the case of factory practice. In the above-mentioned mill, where both methods could be applied alternately, it has been distinctly observed that the defecated clean juice derived from the sulphitation-before-liming process is inferior in all respects. Though the same light-olive colour may be obtained, the juice is much less transparent. Further, by regulating the quantities of sulphurous acid gas and lime, this peculiar condition of the juice could not be improved.

The peculiar opaqueness of the juice (if it may be so termed) is most probably due to gummy and pectin impurities in suspension, which have escaped the action of the lime. To enter into fuller details regarding this subject would be exceeding the scope of the present work; it will suffice to mention that experiments conducted in both laboratory and factory all go to prove that under normal circumstances the liming-sulphitation is superior to the reverse method.

Only under abnormal conditions is the application of the sulphitation-before-liming process justifiable, or even advisable. For instance, in Natal, in certain seasons, the glucose content of the "Uba" cane may rise to a proportion unheard of in other sugar cane countries, so that the operation of sulphitating the juice prior to tempering is obviously more advantageous for the following reasons.

High Glucose Proportion.—In cane juices containing a high percentage of reducing sugars, it is evident that the notorious action of lime on glucose, with the regrettable consequences pointed out previously, is readily promoted. This fact has been repeatedly confirmed by practice in Natal.

After abnormal seasons, including prolonged droughts when juices with excessively high glucose contents occur, and the tempering-before-sulphitation process is adopted, it has been frequently observed that considerable inconvenience and manufacturing losses are experienced, especially in the boiling and curing departments, the resulting strikes being usually of an inferior quality, and requiring an exceptionally long boiling time, whilst at the curing station the capacity of the centrifugals is reduced, a decrease in both output and quality of the cured sugars being observed.

Naturally under such abnormal conditions, a greater or less quantity of viscous constituents of analogous obnoxious characteristics are likely to occur in the juice concurrently with the glucose, so that one is apt to attribute the above mentioned abnormalities to these ingredients. This is obviously partly true, but nevertheless, cases frequently occur when the cane juice is comparatively devoid of such viscous ingredients, but rich in reducing sugars, the treatment of which is accompanied by the above phenomena.

By applying sulphitation before tempering, it appears that the reducing sugars are more likely to escape the detrimental action of the lime, owing to the latter entering into immediate combination with the sulphurous acid contained in the juice.

Dextran Fermentation.—Another case where the sulphitation-liming operation may be advantageously applied is the following:—

The occurrence of micro-organisms called *Leuconostoc mesenteroides* is undoubtedly familiar to those concerned with milling operations. Although in nearly all colonial sugar mills the cane juice may be to a less or greater extent infected by these micro-organisms, the extent to which Natal mills are frequently subject to them is considerable, especially after prolonged droughts.

These *Leuconostoc mesenterioides* rapidly form from sugar a gelatinous substance, principally consisting of "dextran," which process is accompanied by a strong formation of acetic and lactic acids. A small deposit of this dextran is apt to grow very rapidly in a current of alkaline juice. A notable peculiarity is that they are among the few organisms which require an alkaline reaction as one of the principal conditions for their propagation.

So we see that it would be inadvisable to treat juices under these conditions with lime without an effective preventive, such as previous heating. By sulphitating the juice prior to liming, it is likely that the propagation of the *Leuconostoc* germs is checked, and consequently the occurrence of dextran fermentation avoided.

Viscous Juices.—On the other hand, it is well known that one of the peculiar characteristics of the "Uba" cane, which is the stable variety in Natal, is the production of extremely viscous juices, containing besides cane wax large quantities of gummy and pectin ingredients. Although under normal seasonal conditions the cane juices are comparatively pure, having a low percentage of glucose and being free of *Leuconostoc* germs, the excessive viscosity of the juice still remains.

The influence of these viscous substances upon the sugar solutions in later stages of the manufacture is of a no less damaging nature than those dealt with above, and it stands to reason that the early and effective elimination of such ingredients is a matter of importance. The application of lime before sulphurous acid gas promotes a more vigorous precipitation of these viscous constituents, and would therefore be more advisable on this account.

From this we see that in Natal, where the cane juices are of such a variable nature, either of the methods of sulphitation can be advantageously applied according to the predominant condition.

Summary.—The results described in the above study, which are fully confirmed by mill practice, show that there actually is a difference in the resulting product obtained from the two methods of sulphitation; they may not be observed in the laboratory, but this is probably owing to the small quantities of chemicals used.

The Control of the Sulphitation of the Juice.

The control of the purification process of the crude juice, or in other words, the correct reaction of the juice after treatment with both agents, lime and sulphurous acid, is of the utmost importance, both in regard to effect on the subsequent stages of the manufacture, and the preservation of the installation and pipings.

Indicators.—Although the application of *litmus paper* as an indicator is undoubtedly the easiest and simplest method of testing the juice reaction, it must be borne in mind that apart from its unreliability in an atmosphere contaminated with acid gases, litmus reacts alkaline to acid sulphites, hence it is apt to make it difficult to determine accurately when the point of neutrality of the juice has been reached.

Phenolphthalein.—The only indicator of practical utility in sugar factories is phenolphthalein. This indicator may be applied in the form of air-dried paper or solution, the latter, owing to its superiority, being almost exclusively used. The phenolphthalein solution may be prepared according to different prescriptions, and consequently its composition varies in the different factories.

One method of preparing this indicator solution is to dissolve pure commercial phenolphthalein in a 90 per cent. alcohol solution, in the proportion of 1 to 30.

Another prescription,¹ which has the advantage of giving a more sensitive indicator, is as follows :

A 2 per cent. solution of phenolphthalein in a solution of alcohol (70 per cent.) is made, to which a few drops of dilute solution of potassium hydroxide are added. The bottle is then well shaken, to ensure thorough mixing. On the disappearance of the red colour, more drops of potassium hydroxide are added, until it is observed that the colour does not easily disappear, and that a faint coloration of the liquid may be noticed by holding it before a sheet of white paper. The solution is then ready to be used and should be preserved in closed bottles securely stoppered.

¹ Archief, 1908, p. 412.

Testing for Neutrality.—The operation of testing the juice may be described as follows :—¹

“The detection of the very last, very slightly pink reaction is not always equally simple, and requires some routine. The best way of conducting this test is to place the juice and the indicator together on a white porcelain plate, taking care that this does not take place in an atmosphere charged with sulphurous acid, and always in the same proportion, the decoloration of the solution in these extremely sensitive tests being to a certain extent dependent upon the quantity of the indicator solution employed . . .”

“It is, therefore, desirable always to bring together the same number of drops of the juice and the same number of drops of the indicator solution; for instance, three drops of juice and one drop of phenolphthalein . . . Other methods favoured in factories consist in placing a small quantity of the juice at the bottom of a porcelain dish when a few drops of neutral phenolphthalein solution are added; or in placing a single drop of juice by means of a glass rod on paper freshly moistened with the solution.”

¹ “Plantation White Sugar Manufacture,” Harloff & Schmidt, p. 86.

CHAPTER VIII.

SULPHITATION OF THE SYRUP AND OF MOLASSES.

The clear olive-yellow juice, on undergoing the concentration process in the evaporating installation, is converted into a turbid dark-coloured syrup. This change of colour invariably occurs during the concentration, so that even the best treated and clearest juices are bound to assume a darker colour on leaving the evaporation plant.

In order to manufacture plantation white sugar, it is imperative that the colour of the solution in which the crystallization of the sugar takes place should be as light as possible, for obvious reasons.

Thus besides the usual mechanical treatment of the syrup, consisting of the removal of impurities (which owing to the degree of concentration have not sufficient water to keep them in solution, and which have to be removed either by filtering or settling processes), it is manifest that the syrup requires to be decolorized prior to entering the vacuum pans.

Decolorizing Agents.—For this purpose various chemicals are used, including sulphurous acid, sodium acid phosphate, sodium hydrosulphite, etc.

Generally the application of sulphurous acid is preferred, owing to its cheapness and its powerful bleaching property. It is also usual to employ, in addition to the sulphurous acid, one of the other mentioned chemicals.

The sulphurous acid causes decolorization in two ways, as we have already noted. Firstly decolorization occurs from the reducing and consequent bleaching action of the sulphurous acid, and secondly it arises from the acid reaction imparted to the syrup, a decolorization engendered not only by SO_2 but by any acid more powerful than the organic acids present in the juice.

Sulphitation Operation.—The sulphitation of the concentrated juice or syrup may be conducted according to the “intermittent” or the “continuous” method.

Apparatus for Intermittent Sulphitation.—For the first mode of operation similar vessels to those dealt with in the chapter regarding thin-juice sulphitation may be suitably applied. The main advantage of these vessels is that they allow of an effective control of the sulphitation process. A simpler and more convenient method is undoubtedly the continuous sulphitation process. It may be carried out in an ordinary cylindrical vessel provided with a mixing arrangement or better in the following apparatus.¹

Continuous Sulphitation Apparatus.—“The continuous sulphuring process of concentrated juice is effected by means of two saturation tanks. In the first tank the filtered concentrated juice is roughly sulphured to just below the required point for the maximum bleaching, while but little sulphurous acid is admitted to the second tank in order clearly and easily to observe the final reactions.

“The supply of sulphurous acid to the first tank may remain unaltered, while the supply stop-cock of the second is turned on or off according to requirement. In both tanks of course the juice should be admitted from below, and run off at about the same level. From the second tank it simply runs to the syrup supply tanks.”

The sulphitation process generally occurs after the mechanical treatment of the syrup, *viz.*, elimination and either settling or filtration, as for obvious reasons it is inadvisable to allow the syrup to stand with a strong sulphurous acid reaction longer than is necessary, or to raise its temperature above 65° C.

The Control of the Sulphitation of Syrup.

The extent of sulphitation to which the concentrated juice is subjected varies considerably in different factories and countries.

In some factories the colour of the acidified syrup is taken as a basis to indicate the extent of the sulphitation. In this case a sample of decolorized syrup acts as guide to the man in charge of the station.

Other factories, again, adopt litmus paper as an indicator, and conduct the sulphitating operation until a faint acid reaction is attained.

¹ “Plantation White Sugar Manufacture.” Harloff & Schmidt, p. 109.

A practice much favoured in the manufacture of white sugar is to treat the syrup with sulphurous acid gas to an acidity of 1 to 1.4 grms. of SO_2 (and sulphites) per litre.

Determination of Extent of Sulphitation.—For the purpose of controlling the sulphitation of syrup, the ordinary iodometric determination of sulphurous acid and its compounds is generally adopted.

The iodometric titration is based upon the oxidation of sulphurous acid and its salts by free iodine to sulphuric acid and sulphates. As indicator for this titration, a solution of starch is used, which on combining with free iodine to give starch iodide, assumes a blue colour. Thus by dropping the iodine solution into the acidified syrup, to which a little starch solution has previously been added, the blue coloration which is formed will disappear, at first quickly, but towards the end more slowly, until all the sulphurous acid and sulphites are converted, when further free iodine will form starch iodide, which causes the blue colour to be of a more permanent character.

Standard Iodine Solution.—With a view to simplicity in reading the degree of acidity, the iodine solution may be prepared as follows :—

Assume the acidity to which the syrup is to be sulphitated to be 1 gm. of SO_2 per litre. In using 10 c.c. of syrup for the titration it follows that these 10 c.c. correspond to 10 mgrms. of SO_2 .

Further, according to the proportion :

127 iodine are equivalent to 32 SO_2

or (approximately) 4 iodine ,, 1 SO_2

we find that in preparing a solution of 4 mgrms. of iodine to the c.c., one c.c. of the iodine solution used for the titration indicates 1 mgrm. of SO_2 . Hence to test the sulphitation of 10 c.c. of syrup to an acidity of 1 gm. of SO_2 per litre (or 10 mgrm. of SO_2 for the 10 c.c. of syrup), 10 c.c. of the iodine solution are required, and similarly, for an acidity of 1.4 grms. of SO_2 per litre, 14 c.c. of the solution. We thus see that the number of cubic centimetres of the iodine solution used is ten times the number of grms. of SO_2 per litre of syrup. It is obvious that this arrangement considerably facilitates the reading of the titration.

The solution itself is prepared by dissolving 4 grms. of iodine in a solution of about 7 grms. of potassium iodide dissolved in water, and making the liquid up to 1000 c.c.

Iodine Titration Apparatus.—Taking into consideration the fact that this process of titration in tropical cane sugar factories is usually

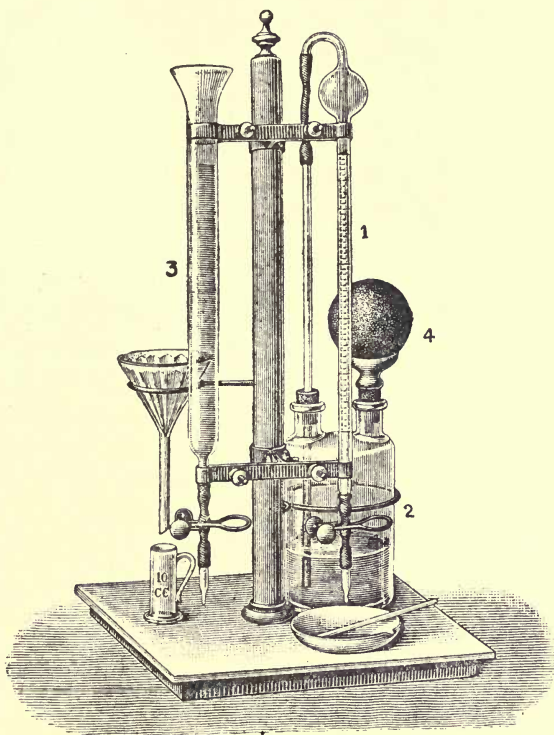


FIG. 6.

IODINE TITRATION APPARATUS.

entrusted to an Asiatic man-in-charge, and further that it is of importance that the operation should be conducted rapidly, it is evident that a practical and simple apparatus for this purpose should be adopted.

A description of such an apparatus (Fig. 6) is as follows:—

The principal parts of the arrangement consist of a burette **1**, a Wulff's bottle **2** containing the iodine solution, and a wider burette **3** filled with the starch solution. The connection between the first burette and the bottle is made by a syphon arrangement. A rubber cork carries a bent piece of glass tubing, the longer end of which reaches the bottom of the bottle, while the other end is melted into the wall of the burette, in such a manner that its mouth is on the same level as the zero mark.

By pressing the rubber ball **4** the iodine solution is forced through the glass tube into the burette, which is filled to a point a little above the zero mark. On releasing the rubber ball, the excess of the solution syphons back into the reservoir, leaving the burette filled exactly to the zero mark. The burette, which is generally graduated to one-tenth of a c.c., has a capacity to suit the circumstances. The regulation of the discharge of the titration liquid is effected either by a glass cock fixed on the burette or by a pinch cock acting on a rubber tube connecting the lower end of the burette with a pointed glass mouthpiece.

Method of Titration.—The process of titration may be carried out in an ordinary test tube, which is provided with a mark indicating a capacity of 10 c.c. The tube is filled to the mark with the syrup to be tested, to which a small quantity of the starch solution is added. Subsequently, the iodine solution in the burette is allowed to flow in small quantities into the test tube. This operation is repeatedly interrupted in order to thoroughly agitate the liquid in the tube. At first the blue coloration which is formed disappears immediately, but becomes gradually more permanent. The operation is repeated until the disappearance of the blue colour is effected only with difficulty on shaking the mixture, care being taken to add the iodine solution little by little as this point is approached and then only a drop at a time until the blue colour is finally fixed. The number of cubic centimetres of the solution required for the titration is read off the burette, indicating the degree of acidity according to the scheme previously outlined.

Simple Titration.—Another method of titration, which is to be recommended owing to its simplicity, is the following:—

As a reservoir of the iodine solution, a simple bottle provided with a syphon, Fig. 7, is used. The titration is conducted in a

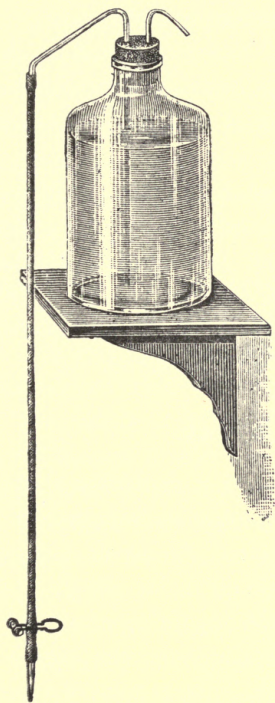


FIG. 7.

SIMPLE TITRATION APPARATUS.

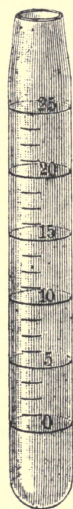


FIG. 8.

VIVIEN TUBE.

Vivien tube, (Fig. 8). After filling the tube to the zero-mark (10 c.c.) with syrup, the same method of titration is carried out. The reading in this case is obtained from the graduated tube.

Although the iodometric method is naturally not quite exact, owing to the syrup containing other substances which will also be oxidized by the iodine, it is sufficiently accurate and satisfactory for mill practice.

Sulphitation of Molasses.

Whether the sulphitation of the first molasses is justifiable or not is a matter of opinion. Some factories apply this process, others again find it more profitable to have recourse to other bleaching agents, such as sodium phosphate or sodium hydrosulphite.

The question of the sulphitation of molasses should be decided in each particular case. This may be done by laboratory experiments, namely by sulphitating a sample of molasses and examining the result.

In case this decolorization process is adopted, it is imperative that the molasses should be diluted prior to the operation, to approximately the concentration of the syrup. Mechanical treatment of the molasses, as in the case of the syrup, should precede the sulphitation process. The control of the operation is conducted in exactly the same way as with the syrup.

Inversion in Syrup.

Sulphurous Acid and Inversion.—It is a well-known fact that at a high temperature the action of sulphurous acid gas on pure sugar solutions is of an inverting character. However, it is equally established that in the case of cane (or beet) juices, which contain a certain quantity of organic salts, this inverting influence of the SO_2 is exerted to a much smaller extent. Thus the organic salts present in the syrup have a beneficial influence in checking the process of inversion. This property is attributed to the fact that these organic salts combine with the sulphurous acid and sulphuric acid occurring in the syrup, forming sulphites and sulphates, and liberating organic acids. Hence, the free mineral acids previously existing in the syrup are replaced by weak organic acids, the inverting power of which is considerably less.

Not only is the inversion process dependent upon the temperature, but also on the conditions under which the heating operation is performed. For instance, there is an appreciable difference between the results obtained from heating the sulphitated syrup at say 70°C , "in air" and "in vacuo."

In the first case the acidity of the syrup scarcely diminishes, and the sulphurous acid (obviously occurring in the form of H_2SO_3) is apt to be oxidized by the oxygen of the air forming sulphuric acid. In the second case, however, this process is not likely to occur, for these reasons :

1. The acid reaction of the syrup in the vacuum pan diminishes rapidly with the volatilization of the free sulphurous acid and the organic acids.

2. The quantity of oxygen occurring in the pan is insufficient for the above-mentioned process of oxidation.

We thus conclude that, provided the treatment of the syrup in the sulphitation station is rationally conducted, no fear of extensive inversion need be entertained, though the syrup is strongly acid.

Conditions to be observed.—For the rational treatment of the syrup, the following points should be borne in mind.

1. The sulphitation operation should be carried out after the mechanical treatment (filtering or settling) of the syrup.

2. The syrup to be sulphured should not be at a temperature above $65^\circ C$, and if previous filtration is applied the syrup should be cooled down to this temperature.

3. The time between the end of the sulphitation process and the drawing of the acid syrup into the vacuum pans should be as short as possible.

4. All pipings through which acid syrup is to run should be made preferably of copper, and all reception tanks for acidified syrup should be provided with a coating of acid-proof paint.

The last point, of course, has nothing to do with inversion, but is a preventive measure against the contamination of the syrup with iron compounds, which impart a greyish colour to the sugar crystals.

Corrosion in Syrup Apparatus.

The detrimental effect of corrosion, which invariably occurs to a greater or less extent when strongly acid syrups are dealt with in the vacuum pans, is familiar to those concerned with the manufacture of white sugar.

During the boiling process, volatile organic acids and free sulphurous acid are carried along with the vapours, so that eventually the piping conducting these vapours is bound to suffer from the corrosive action of these acids.

In order to reduce the effect of corrosion to a minimum, it is advisable to coat the inside of the vapour-conducting piping and domes of the pans with a layer of ferric oxide.

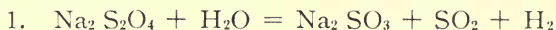
Sodium Hydrosulphite, or "Blankit."

Its Use in Syrup Bleaching.—Since this subject belongs to the category of salts of sulphur acids, the treatment of this compound is within the scope of this work.

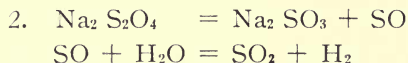
Blankit is the pure sodium salt of hydrosulphurous acid ($\text{Na}_2\text{S}_2\text{O}_4$) and comes into the market as a white powder, readily soluble in water; if protected from moisture, it will keep for an unlimited time in any climate.

The chemical action of sodium hydrosulphite on sugar juices is explained in two ways.¹

According to the first equation, sulphurous acid gas and hydrogen are formed thus:



and according to the second, under the influence of temperature, the hypothetical SO is formed, which is immediately oxidized to SO_2 , thus:



The decolorization of the syrup by sodium hydrosulphite is instantaneous, and in spite of the small quantity of the agent used, the effect is striking.

Sodium hydrosulphite does not require an acid medium, but bleaches as well in neutral or alkaline solutions. The decolorization brought about by Blankit, however, is unstable, the original colour of the decolorized juices returning on exposure to the air.

¹ Deutsche Zuckerindustrie, 1908, p. 735.

For this reason the agent should be applied at as late a stage of the manufacture as possible, *viz.*, in the vacuum pan, shortly before graining.

A further advantage attributed to Blankit is that it diminishes the viscosity of the syrup or molasses.

Application.—Sodium hydrosulphite may be applied either as a powder or in solution. The latter is obviously to be preferred, as it tends to a thorough mixing. It must be remembered, however, that solutions of sodium hydrosulphite cannot be kept for long, as they lose in decolorizing power through oxidation by the air, and must therefore always be made up fresh immediately before use.

In practice the application of Blankit is made in various ways. One method is to add the Blankit to the concentrated juice not long before it is boiled. Another, which is a most rational one, is to draw a solution of Blankit into the vacuum pan before graining, and at certain intervals during the growth of the sugar crystals.

Syrup or Molasses—Order of Application of the different Agents.

Whether the Blankit should be applied to syrup or molasses, or both, is an open question, and greatly depends upon individual opinion. While in Mauritius the author conducted a series of experiments touching this point.

Notable characteristics of Mauritian sugar are its brilliancy and whiteness. These qualities are indispensable if the sugar is to compete with the Natal sugar on the Cape market. Now, as the brilliancy of the sugar is a prime factor, the investigation of this point was one of the chief aims of the experiments.

For this purpose syrups were separately treated with the three decolorizing agents, *i.e.*, sulphurous acid, sodium phosphate and sodium hydrosulphite, prior to entering the vacuum pans. The sugars cured from the different strikes were examined as to whiteness and brilliancy. The sugar originating from the syrup treated with sodium hydrosulphite was by far the whitest, but at the same time

the least brilliant. Its appearance was comparable with that of snow, exceedingly white but dull. The syrup treated with sodium acid phosphate produced the most brilliant sugar, of a satisfactory white colour. In both cases the syrup was first sulphitated.

In the case of first molasses, on the other hand, the crystals are so small that there is no question of brilliancy, so that the whiteness of the sugar crystals became the prime factor. The very same experiments were carried out with the first molasses, the superiority of sodium hydrosulphite in this case being indisputable.

Thus we conclude that for the production of "superior plantation white sugar" it is advisable to treat the syrups with sulphurous acid and subsequently with sodium phosphate and the first molasses with sodium hydrosulphite.

CHAPTER IX.

THE SULPHITATION PROCESS IN PRACTICE.

Having studied the principle of the sulphitation process as applied to cane juice, syrup and molasses, we can now proceed to survey the process as applied in practice, and, in the next chapter, review "white sugar processes" in general.

General Scheme of Operation.—The usual *modus operandi* adopted by numerous white sugar mills follows with slight variations the course given below.

Purification of the Mill Juice.—The mill juice runs from the mill through copper strainers into two reception tanks, used alternately, in which some of the insoluble impurities are deposited by gravity. These tanks are provided with overflows, which allow the juice, now freed from its larger and heavier impurities, such as sand and mud originally adhering to the cane, to discharge into a third reception tank. It is then pumped into measuring vessels, whence it gravitates into liming tanks. Frequently the measuring tanks are also used for liming purposes.

Tempering.—The tempering or liming of the juice is performed by adding a definite quantity of lime-milk to the juice, the amount used varying considerably according to circumstances. It ranges from about 6 to 12 litres (in exceptional cases even higher) of lime-milk of 15° Beaumé to 1000 litres of juice. The usual practice is to use 8 litres, equivalent to 8×198 grms. of CaO. As it is essential to obtain a thorough mixture of the lime-milk with the juice, the mixing process is best carried out in U-shaped stirring tanks fitted with a double spiral, gear-driven. The juice is then run into a reception tank from which it is pumped into sulphitation vessels.

Sulphitation.—Under continuous agitation, the juice is sulphitated until neutrality with phenolphthalein is reached. Previous heating of the limed juice to about 45°C (in no case beyond 50°C) will prove beneficial.

Heating.—The sulphitated juice on leaving the sulphitation tanks is pumped through a multi-circulation quick-speed heater, in which the temperature of the juice is raised under pressure to about 105°C. A usual practice is to discharge the juice into a correction heater (Aspinall pan) provided with a steam heating device. The juice is here “corrected” from the somewhat varying temperature prevailing in the first heaters.

Cleaning.—It then runs by an overflow into a series of juice settling tanks or subsiders, where it is allowed to settle. The settling process is followed minutely by taking samples at intervals and observing the progress of the clarification of the juice.

The clear juice is tapped off from cocks, or float cocks, at suitable levels, and runs into a clear-juice tank, whence it is pumped into the evaporation plant. It is advisable to filter the juice prior to its entering the reception tank through a revolving sieve of very fine bronze gauze.

The sediment or dirty juice is allowed to discharge into blow-up tanks provided with a perforated copper coil, where it is diluted and boiled by means of live steam.

After a thorough boiling, the diluted dirty juice is pumped into a second set of settling tanks, having about one-fifth the capacity of the first tanks, and subjected to a second thorough subsidation.

The clear juice from these second subsiders is discharged into the same clear juice reception tank, but the sediment goes into a second series of blow-up tanks where it is diluted and boiled, and afterwards filtered in either filter-presses or Taylor filters. The clear juice from these filters runs into the clear juice tank.

Evaporation.—“ If measures have been taken for settling the syrup, it should be borne in mind that the concentrated juice must not be allowed to become too thick . . . A proper settling is proportionate to the difference which exists between the density of the concentrated juice and that of the subsiding impurities. If this difference is considerable, in other words, if the juice is less concentrated, settling will proceed much more readily, and *vice versa*.”

“ In general the impurities subside very readily and rapidly at 26° Bé, but above 27·5° Bé the process is less successful.”¹

Treatment of the Syrup.—The syrup is drawn from the last vessel of the evaporating installation and discharged into eliminating tanks and heated to boiling point. The scum formed on the surface is carefully skimmed off, and the syrup allowed to gravitate through special filters into cooling tanks, or discharged into a series of syrup subsiders. The sediment in the latter case is preferably returned to the mill, or one of the first reception tanks, slowly and regularly, so that it may be distributed as much as possible over large volumes of the raw juice.

At a temperature below 65°C, the syrup is subsequently sulphitated to an acidity of 1·0 gm. of SO₂ per litre of concentrated juice and pumped up into the vacuum pan supply tanks. An addition of sodium hydrosulphite may be made in the tanks or in the pans at option.

Treatment of the First Molasses.

The molasses obtained on curing the first massecuites, of a purity of 65 to 68 and a Brix of about 80°, contains all the impurities of the massequite in a more concentrated state, in addition to traces of iron compounds originating from the tanks by their constant contact with the acid syrups and molasses. A separate clarification of the molasses is therefore to be recommended, so that all the suspended mechanical impurities may be removed before a new crystallization takes place. These impurities may otherwise impart a dark tint to

¹ “ Plantation White Sugar Manufacture.” Harloff & Schmidt, p. 112.

the crystals of the second massecuite, and so prevent the obtaining of a superior product. An efficient clarification of the molasses is effected by the following method.

Clarifying the Molasses.—The molasses obtained on curing the first massecuites is pumped into eliminators provided with perforated steam coils. After being diluted to about 65° Brix (35.5 Bè), the molasses is thoroughly boiled. The skimming off of the scum formed on the surface is most important and should be continually repeated.

The further treatment of the molasses, as in the case of the syrup, may be conducted in two ways, by (1) filtering, or (2) settling,

1. *Filtering*—The molasses is allowed to flow through special filters into tanks to cool down to a temperature below 65° C., at which temperature it is sulphitated to an acidity of 1.2 to 1.5 grms. of SO₂ per litre.

2. *Settling*—The molasses is discharged into subsiding tanks, where a quantity of sodium phosphate is added. The determination of the quantity required is carried out in the laboratory, where samples of the same molasses are treated with different quantities of the phosphate.

After having undergone either of these treatments the molasses is drawn into the vacuum pans. The application of sodium hydro-sulphite in the vacuum pan will undoubtedly prove beneficial. The quantity of Blankit obviously varies according to circumstances, but approximately 17 to 20 grms. of this substance to the ton of massecuite may be applied.

Treatment of Second Molasses.—The molasses obtained on curing the second massecuites is diluted and thoroughly boiled in blow-up tanks, fitted with perforated copper coils. Generally a further clarification of this molasses is not required.

Boiling.

The treatment of this subject in detail would naturally be outside the scope of this work, hence only a summary is given in the following section:—

In Java, two methods of manufacturing white sugar are in vogue. The first produces only superior first sugar and superior

molasses sugar, while the second method consists in turning out only superior white sugar and exhausted molasses.

By keeping the first product separate from the after-product, it is evident that the quality of sugar is bound to be superior. Therefore, in white sugar producing countries like Mauritius and Natal, where the colour of the sugars is of utmost importance, the method of obtaining the whole product in one "jet" cannot be advantageously adopted.

The Two-sugar Method.—"In obtaining sugar in two jets, all the thick-juice is entirely boiled to a primary massequite in such a manner that the "run-offs" from it shall have a purity of about 65°. These run-off syrups are then worked up by slow boiling and lengthy cooling to a molasses of about 33° quotient of purity."

"When the initial purity is high, the sugar is separated in three stages, *viz.* (1) first sugar with a run-off of 70°; (2) superior molasses sugar, with a run-off of 55°; and (3) molasses sugar. This last sugar is spun white simultaneously with the superior molasses sugar, and mixed with it."

Single Sugar Process.—"In the method of making white sugar and molasses, the purity of the thick-juice is continually lowered by mixing-in the first run-off. Generally, it is best to work with a mixture having a purity of 78°-80°, when the resulting massequite after machining gives a run-off of about 58°-60° purity. As above, the run-off is worked in one jet to molasses, obtaining so-called 'molasses sugar,' which however is not machined white as before, but is pugged and drawn into the first sugar pans. The pugged grain is diluted in the pans with some mixed thick-juice, and thus forms a 'pied-de-cuite' [or starting grain] for the first sugar massequite."

"Such a first massequite sugar consists of molasses sugar as the primary grain, and is boiled with a mixture of syrup and thick-juice having a purity of about 78°-80°. The remaining run-off once again gives molasses sugar, etc."¹

¹ "Plantation White Sugar Manufacture." Harloff & Schmidt, pp. 128 and 129.

For the manufacture of superior white sugar it is rational to adopt fractional centrifugalling, by which process the "green molasses" (impure molasses from the first set of centrifugals) is separated from the "clear molasses" (which is an almost pure sugar solution coming from the second set of centrifugals). The clear molasses is pumped either directly into the concentrated juice tanks or into special tanks, whence it is drawn into the pans separately. The green molasses is treated as explained previously.

Blueing the Sugars.

In order to neutralize the last traces of yellow tint on the crystals, it is a usual practice to blue the superior sugars with a solution of either ultramarine or indanthrene in the centrifugals. When employing this method, it is essential that the solution shall not contain large particles of the blueing substance in suspension.

CHAPTER X.

PROCESSES ADOPTED BY THE LEADING WHITE SUGAR COUNTRIES.

After studying a general scheme of white sugar manufacture, we can now proceed to deal with the main processes as applied in the three leading white sugar countries, *viz.*, Java, Mauritius and Natal.

I. Java.

The scheme described in the previous chapter may be taken as the standard method of white sugar manufacture according to the sulphitation process in Java.

The Bach Treatment of Syrup.—Recently, however, a new process of treating the concentrated juice has been introduced by Bach, and has given satisfactory results. The mode of operation may be described as follows:—

The syrup is drawn from the last vessel of the evaporation plant, and pumped through a syrup-cooler. The cooled syrup is discharged into a series of first sulphitation vessels, where it is first treated with lime until a distinct alkaline reaction is reached, and the limed syrup subsequently sulphitated to neutrality. It then runs into eliminating pans, where it is heated to boiling point, the scum formed on the surface of the liquid being carefully skimmed off, and eventually the concentrated juice gravitates into a reception tank, whence it is pumped through filter-presses.

The filtered syrup is pumped from a reception tank through a cooler into a second set of sulphitation vessels. After being satisfactorily bleached by the second application of the sulphurous acid gas, the syrup is discharged into a reception tank and ultimately pumped into the vacuum pan supply tanks, whence it is drawn into the pans.

II. Mauritius.

The general method of manufacturing white sugar in Mauritius is along the following lines :

Sulphitation.—The mill juice is pumped continuously through a sulphitation tank of the “continuous sulphitation” type, the sulphurous acid gas meanwhile being forced through the juice by means of steam injection (Giffard). The acidity to which the raw juice is generally sulphitated ranges from 0·8 to 1 per cent. SO_2 .

Liming and Measuring.—The sulphitated juice is then run into liming tanks, in which it is measured and limed. The extent of liming varies in different factories : usually the acid juice is limed until only a slight acid reaction with litmus paper is obtained. Neutral juices are met with only in a few factories, the reason being the difficulty of obtaining an exact neutrality by means of lime. A few other factories, again, prefer to work with slightly acid juices. In some instances the sulphitated juice is rendered alkaline by a surplus of lime and subsequently treated with phosphoric acid until a slight acid reaction is reached.

Heating the Juice.—The juice is pumped through a series of heaters, being usually heated to 70° – 75° C. In a number of factories the juice, after being heated, is allowed to run through a “bac portal” (described in Chapter VII), in which it deposits part of its impurities. This apparatus is gradually becoming, however, less popular, and a great number of factories have discarded it.

Defecation.—From the “bac portal” the juice either runs or is pumped into defecators, provided with heating coils or double bottoms. It is heated to boiling point, in other words until the layer of scum formed on the surface begins to burst (cracking point), when the juice is allowed to settle.

Filtering.—The clear juice gravitates through a series of Danek filters, or in some cases through a sieve of fine gauze into a reception tank.

The sediment of the defecators is discharged into blow-up tanks, where it is thoroughly boiled, and afterwards pumped through filter-presses, from which the filtered juice runs into the same reception tank.

Evaporation and Treatment with Phosphate.—This clear juice is pumped into the evaporation plant and is concentrated to about 26°–28° Beaumé. The syrup is discharged into settling tanks of ample capacity, where it is treated with phosphoric acid (in the form of calcium superphosphate containing 43–45 per cent. of phosphoric acid). The amount of phosphate applied varies, ranging from 1 to 1.5 grms. (in some cases even 2 grms.) of superphosphate per litre of syrup.

Subsiding.—As this agent not only decolorizes the syrup, but also produces an appreciable precipitate, it is evident that sufficient time should be allowed for settling; according to the settling capacity at the factory's disposal, the period ranges from 10 to 24 hours. The degree of concentration and the temperature of the syrup are of course factors to be taken into consideration in deciding the period of the settling process.

Sometimes the syrup from the evaporating installation is further heated to boiling point and "eliminated" prior to undergoing the settling process. After the settling is completed, the sediment in the syrup subsiders is usually discharged into the juice defecators.

Boiling.—The clear concentrated juice is then drawn into the vacuum pans. Often sodium hydrosulphite is applied to the syrup either just before entering the pans or during the boiling.

As pointed out previously, the quality of the sugar in Mauritius is mainly estimated on the colour of the product. Under these circumstances it is not surprising that the process of "drawing in of molasses in head boilings" to recover as much superior white sugar as possible, is not favoured there.

The method generally adopted on that island is to produce "first sugars" from syrup and "second sugars" from first molasses (both of a superior white colour) without utilizing the "drawing in" process. Further low grade sugars of an inferior colour are also produced.

Molasses.—The molasses is treated in a manner previously described. It is thoroughly boiled in blow-up tanks and the lighter impurities carefully skimmed off. A certain quantity of phosphoric acid is added, and the molasses allowed to settle for a considerable time, the length of which depends upon circumstances.

Sodium hydrosulphite is also frequently applied in the pans, when boiling first molasses.

The crystallization and curing processes in the larger factories are usually carried out according to the methods now universally adopted.

III. Natal.

The manufacture of white sugar in this country is almost on the same lines as that in Mauritius. The following main differences, however, may be noted :—

Wax Separation.—Owing to the fact that the Natal juices (from “Uba” cane) generally contain excessive quantities of wax and other viscous substances, the limed and sulphitated juice is pumped into a series of defecators, better called “wax separators.”

The majority of factories use the ordinary type of French defecators for this purpose, and follow the usual defecation process.

A more rational mode of operation now employed in several factories consists of allowing the juice to run through “continuous wax separators” composed of three or four defecators connected to one another. The juice runs slowly through the consecutive defecators, while the waxy matter rises to the surface to form a thick layer of scum, which is removed at frequent intervals. The temperature of the juice is kept below 82° C, as the wax melts at about that temperature, and the regulation of the temperature requires careful attention.

The clear juice running out from the last vessel is pumped through quick-speed heaters and its temperature raised to boiling point, when it gravitates into subsiding tanks and subsequently undergoes the same process as applied in Mauritius.

SUMMARY.

In conclusion, it may be useful to give a summary of the observations and conclusions arrived at in our study of the sulphitation process and the manufacture of "superior white sugar" according to that process. For convenience and facility of reference this can be done in the form of a series of questions and answers.

Tempering.

1. In what form is the lime added to the juice ?
 2. Which form is preferable, and for what reasons ?
 3. What quantity of lime-milk is used ?
 4. How is the quantity of lime-milk determined ?
1. As powdered quicklime, or a lime-milk.
 2. Lime-milk, as it conduces to thorough mixing. Unslaked lime is slaked incompletely in cold juice and is apt to form hard nodules covered with a sticky layer of impurities, which subsequently affect the quality of the juice.
 3. Usually 8 litres of lime-milk of 15° Beaumé per 1000 litres of juice. This figure varies considerably, and may range from 6 to 12 litres.
 4. (a) In the laboratory by determining how many c.cs. of lime-milk are necessary to obtain a complete precipitation in one litre of juice.
(b) The following method is preferable: Add a certain quantity of lime-milk to the mill juice and treat the latter

Summary.

in the factory according to the usual practice. A sample of the defecated juice is examined in the laboratory with a few drops of a solution of calcium saccharate. The formation of a precipitate indicates insufficient application of lime to the juice. The amount of lime-milk added to the mill juice is gradually increased until no further precipitate is obtained in the laboratory test. The absence of a precipitate in the first experiment shows that either the exact quantity or an excess of lime-milk has been applied: the regulation of the tempering should be performed accordingly.

5. Where and how is the juice to be treated with lime?
5. Preferably in special liming tanks under constant agitation. Another practice is to temper the juice in the measuring tank, whence it is discharged into limed juice stirring tanks.
6. What form of agitating tank is most suitable?
6. Horizontal U-shaped tanks, provided with a double spiral, mechanically driven. Vertical tanks have been proved to allow the settling of lime at the bottom.
7. At what temperature should the tempering process be carried out?
7. The temperature should preferably be kept low, say about 30°-35° C.

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| 8. Is it beneficial to heat the limed juice prior to sulphitation? | 8. The heating of the limed juice immediately before sulphitation has given satisfactory results. The rise of temperature increases the energy of the liming action from the chemical point of view, so that gummy and pectin matters will be more readily precipitated. This is best done in the sulphitation vessels, which should be provided with heating coils. The resulting temperature should not exceed 50° C. |
| 9. What is the action of lime on the juice? | 9. It neutralizes the free acids occurring in the juice, acts on albuminoid, gummy and pectin substances, which are subsequently partly removed, precipitates various bark pigments and chromogens and forms saccharates and glucosates. |

Preparation of Lime-milk.

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| 10. What are the qualities of the lime to be used? | 10. The lime should be of the purest and best kind available, containing as little impurity as possible. The maximum of magnesia in the lime allowable is 2 per cent. If over-burned, the lime becomes rocky and slakes with difficulty, so that it loses its efficiency. The lime should not contain any unburned particles, as these cause trouble. |
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11. Of what nature should the lime-milk be ?
11. The lime-milk should be homogeneous and void of hard particles of lime, which are apt to escape the action of the sulphurous acid and afterwards gradually dissolve, imparting an alkaline reaction to the juice.

It is therefore essential that the lime should be thoroughly powdered and slaked.

Sulphitation of the Juice.

12. What form of sulphitation vessel is to be preferred ?
12. Vertical cylindrical vessels, provided with heating coils, agitating device, gas distributing piping and further accessories, such as gauge glasses, test cocks, thermometers, etc.
13. How is the distribution of the saturation gas performed ?
13. Either by means of perforated pipes or by so-called "spider webs." The efficiency of the SO_2 gas is obviously dependent upon the thoroughness of its distribution and also upon the height of the juice to be treated. Hence these points should be taken into consideration when designing a sulphitation vessel.
14. How can the mixing process of the juice and the gas be assisted ?
14. By continuous agitation of the juice during the sulphitating operation and also by allowing the juice and gas to enter into the tank through a common pipe.

15. How is the sulphitation process controlled ?
15. By the use of indicators, usually litmus or phenolphthalein, in the form of sensitized paper or solution. The phenolphthalein solution is preferable.
A supplementary control of the sulphitation process may be advantageously carried out "by sight," that is, by following the course of sulphitation and taking samples at intervals, also observing the process of settling.
16. How is the phenolphthalein solution prepared ?
16. By dissolving phenolphthalein in a 90 per cent. alcohol solution, in the proportion of 1 to 30.
17. How is the indicator solution applied ?
17. By adding to a few drops of juice in a white porcelain dish one or two drops of the phenolphthalein solution, or by placing a single drop of the juice by means of a glass rod on paper freshly moistened with the solution.
18. To what extent is the sulphitation process carried out ?
18. Until the indicator solution assumes only a faint pink coloration, instead of a deep crimson.
19. What occurs if the sulphitation is further extended ?
19. "Over-sulphitation," which renders the juice acid and causes the formation of soluble bisulphites, which are subsequently decomposed in the evaporators into insoluble sulphites and free sulphurous acid.

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| 20. To what is incrustation and corrosion attributed? | 20. Chiefly to the above-mentioned decomposition. The sulphites form incrustations on the tubes of the calandrias, while the liberated sulphurous acid is converted into sulphuric acid which exerts its corrosive properties. Free sulphurous acid is also produced by volatilization. |
| 21. How does inversion occur? | 21. When acid juices are subjected to high temperatures inversion takes place. |
| 22. For what purpose is the sulphurous acid gas used? | 22. In the case of limed juices, SO ₂ is chiefly used as neutralizer. |

Generation of Sulphurous Acid.

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| 23. In what form is the sulphurous acid used? | 23. In cane sugar factories almost exclusively in the gaseous form. |
| 24. How is it obtained? | 24. By the simple combustion of sulphur in air ;
$S + O_2 = SO_2$ |
| 25. What is the most suitable installation for the production of SO ₂ ? | 25. The combination shown in Fig. 3, Chapter III, composed of air-drier, air-compressor, air-recipient, sulphur furnace, gas purifier and cooler. |
| 26. What are its advantages over other plants? | 26. Mainly the generation of very pure saturation gas, and an easy control of the operation. |
| 27. What is the usual proportion of SO ₂ in the combustion gas? | 27. This figure varies considerably, but 15 per cent. is satisfactory. |

28. What are the main points to be borne in mind in the generation of SO_2 ?
- 28.(a) Dry air for combustion.
(b) Air supply to be regular.
(c) Combustion temperature in the furnace to be kept as low as possible.
(d) Uniform combustion of the sulphur layer in the furnace.
(e) Sublimation in the pipings to be checked as much as possible.
(f) The temperature of the saturation gas to be kept low.
(g) The gas to be purified before entering the sulphitation vessels.
29. How are the precautionary measures to be carried out?
- 29.(a) By drawing the air through an air dryer, composed of several layers of quicklime.
(b) By using an air-recipient and regulating valves.
(c) By cooling the furnace by means of continuously running water.
(d) By melting the sulphur rolls in the furnace by previous heating of the tray, as explained in Chapter IV.
(e) By cooling, and the provision of sublimators.
(f) By constant cooling of the gas by means of water-jackets.
(g) By filtering the gas through coke or pumice stone, and washing to absorb free SO_3 .

Treatment of the Syrup and Molasses.

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| 30. How is the syrup treated prior to sulphitation ? | 30. The syrup is heated to boiling point, eliminated, and either filtered or settled. If filtering is employed, subsequent cooling of the syrup is necessary. |
| 31. How is the sulphitation carried out ? | 31. The syrup is pumped up into sulphitation vessels and treated with sulphurous acid gas until an acidity of 1 to 1.2 grms. of SO_2 per litre is obtained. |
| 32. How is the sulphitation of the syrup controlled ? | 32. By means of an iodine solution, with a starch solution as indicator. |
| 33. How is a standard iodine solution prepared ? | 33. By dissolving 4 grms. of iodine and about 7 grms. of potassium iodide in 1 litre of water. |
| 34. How is the titration carried out with the iodine solution ? | 34. 10 c.c. of syrup are diluted with water, a little of the starch solution added, and subsequently titrated with the iodine solution. Each c.c. of the standard iodine solution indicates 1.0 grm. SO_2 . |
| 35. What is the action of SO_2 on syrup ? | 35. The action of SO_2 on syrup is fourfold, namely :
(a) It reduces the organic colouring substances occurring in the syrup to colourless compounds. The bleaching effect due to this phenomenon is, however, only of a temporary nature, as by oxidation the original dark colour of the syrup gradually returns. |

- (b) It imparts an acid reaction to the syrup, by which a decolorization is caused. This decolorization is preserved so long as the syrup remains acid.
- (c) It exercises a purifying influence, as it decomposes part of the non-sugars, which may be removed eventually.
- (d) It further acts as a preservative of the syrup.
36. How does the question of inversion enter here ?
37. At what temperature is the sulphitation process to take place ?
38. How is the molasses treated ?
36. Although the syrup has a distinctly acid reaction, a rational treatment of the syrup after sulphitation precludes inversion to any extent.
37. It is advisable not to allow the temperature of acid syrups to exceed 65° C in the atmosphere. A rise in the temperature in the vacuum pans is of no consequence, as already pointed out.
38. The first molasses is diluted to about the density of the syrup, and subsequently treated in the same way as the syrup. The application of additional bleaching agents, such as phosphates or sodium hydro-sulphites may prove to be advantageous.

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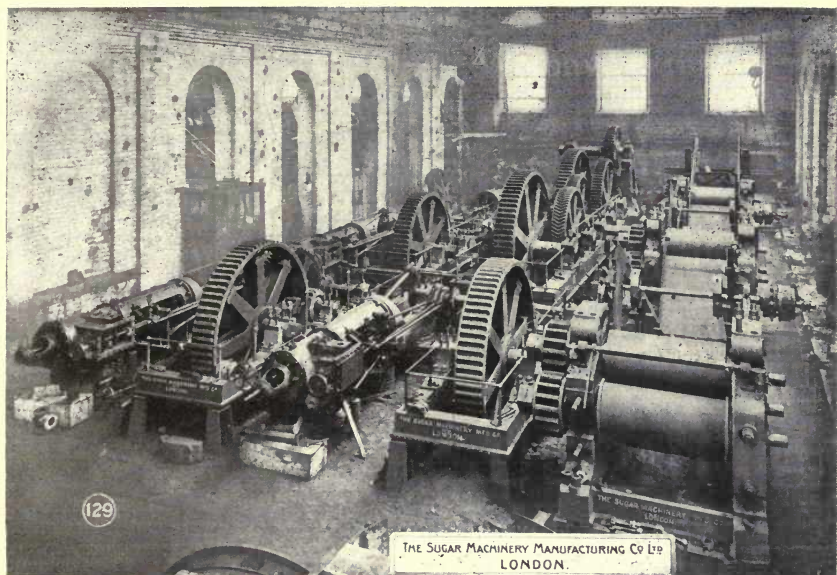
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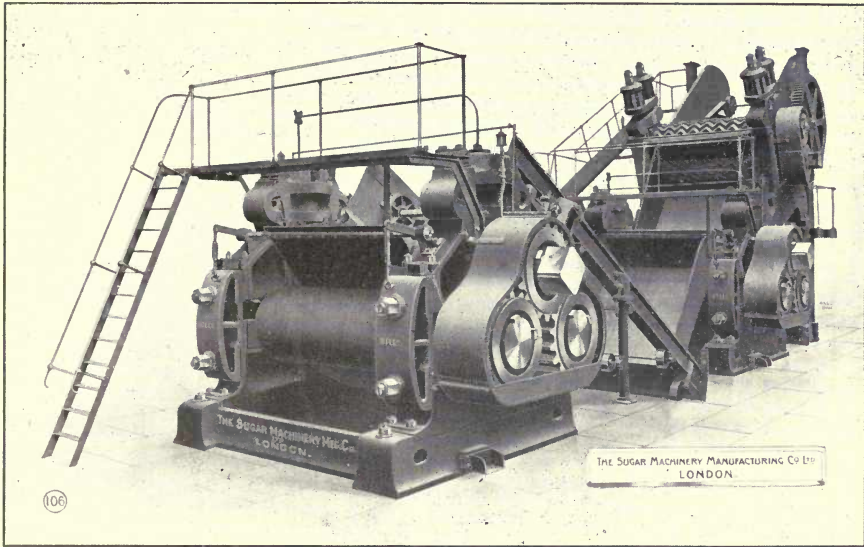
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