

## PREFACE

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The information contained in this bulletin was originally submitted to the Government of Bombay in my capacity as a Government of India technical scholar for the years 1920-23. It embodies my experience concerning the sugar industry and methods of sugar manufacture in use in foreign countries, namely, Louisiana, Cuba, Porto Rico, British West Indies, British Guiana, Hawaii and Java, which form the principal canesugar manufacturing countries of the world. I have also briefly discussed the chief difficulties the sugar industry in India has to face, which are so peculiar and intricate that they are not obtained in any other part of the world. On the strength of the information supplied by the Indian Sugar Committee in their report concerning the existing sugar factories in India, I have briefly dealt with the causes of failure of existing factories from a technological point of view.

This bulletin is in no way a treatise on the principles of sugar manufacture, which are usually found discussed in text books on this subject. I have, therefore, tried to avoid theoretical discussion of the principles underlying the process of sugar manufacture, though an occasional reference is unavoidable in order to elucidate a particular point. I have, however, discussed the various methods of sugar manufacture in use in those countries, together with the conditions under which those methods are expected to work successfully, and also the methods that are likely to be suitable to conditions in India. As Government decided to print this information as a bulletin of the Department of Agriculture, I have omitted all references to particular factories, except, where the information supplied by them has already appeared in the press.

Technical scholars from India usually meet insuperable difficulties in foreign countries with regard to practical training in existing factories under actual operating conditions, without which it is not possible to get a practical insight into any industry. Fortunately I had in Dr. Charles E. Coates, the Dean of the Audubon Sugar School, Louisiana, a very sympathetic and helping Professor, without whose help it would have been practically impossible to obtain facilities for practical training in sugar factories, and also for securing practical information from various sugar factories situated in U. S. A. and her insular possessions. In fact, the present bulletin would have been impossible without his help. I owe such a deep debt of gratitude to him that I shall never be able to repay it. I had similarly in Sir Francis Watts, the Imperial Commissioner of Agriculture for the West Indies, Trinidad, a sympathetic helper who made it possible for me to obtain practical training concerning sugar manufacture in the British West Indies. I am also greatly obliged to him.

For the information contained in this bulletin I am much obliged to various sugar manufacturers, engineers and chemists in Louisiana, Cuba, Porto Rico, Jamaica, St. Kitts, Trinidad, British Guiana, Hawaii and Java, to each of whom an individual reference is not possible, but I would like to record their great willingness to give any information concerning sugar manufacture to any one that may visit their factories.

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R. G. PADHYE.

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# SUGAR INDUSTRY IN WESTERN INDIA AND METHODS OF SUGAR MANUFACTURE.

## I. Introduction.

India is considered to be the original home of sugarcane, and was for a long time the principal sugar furnishing country of the world. That position changed long ago. From the position of an exporter of sugar, she has fallen to a position of a large sugar importing country. Before the war, India was importing little more than 700,000 tons of sugar, which fell to about 500,000 tons during the period of war due to increased price of sugar. The maximum, she imported so far in a year, was about 900,000 tons. Most of this comes from Java and Mauritius in the form of white sugar. It is expected that, as the prices go back to pre-war level, the annual imports would not only reach the pre-war figure, but it is likely that she would import much more sugar due to the fact that, her consumption is increasing steadily year by year, while her production has practically remained constant, always verging between 2 to 3 million tons of sugar a year. According to the report of the Indian Sugar Committee the consumption of sugar per head in India, increased by 15 per cent. during the last 10 years, the average consumption per head being 22 lbs. This increase is specially to be noted in the consumption of white sugar. India's present consumption may be taken as 3 million tons of sugar (2 million tons of gul and 1 million tons of sugar), which, at this rate of increased consumption, would reach the figure of 3½ million tons within the next 10 years, of which more than a million tons would be white sugar. It would be a great loss to the country, if this increased consumption is not met by increased production. Already India is paying about 15 crores of rupees for the white sugar, she is importing from Java and Mauritius. Within the next ten years, the valuation of the imports would reach 25 crores of rupees. If India were to increase her production at least to the extent of her domestic needs, which she can surely do, she will add so much to the wealth of the country, besides bringing on prosperity to so many people. It should be understood that the imports of sugar into India rank second in importance in the total imports of India, representing in normal times about 60 per cent. of the total value of the imports of food commodities.

From the figures given above, it is obvious that India is the second largest consumer of sugar next to United States, and is one of the largest importers of sugar. The average area under cane in India is about  $2\frac{1}{2}$  million acres from which she produces only about  $2\frac{1}{2}$  million tons of sugar. In 1918 the total area under sugarcane in the world was 5,800,000 acres, out of which India alone had 2,750,000 acres which is about 47.5% of the area. From this area India produced only 3 million tons of sugar against a total world production of 12 million tons, which is about 25% of the total. So far acreage is concerned, India has the largest area under cane. Cuba, which has outclassed India in point of production, produces annually 4 million tons of sugar from an area less than 2 million acres. It will be worth while to find, why India is not able to produce at least the same amount of sugar, when it is taken into consideration that she has much more area under cane than Cuba has. Is it due to low tonnage that is raised per acre in India or to wasteful processes of making sugar or to both? An answer to this question would suggest remedies which will considerably aid the Indian sugar industry. I have discussed this question later on.

With favourable conditions for growing cane, such as favourable climate, good soil, plenty of labour, a home market and scope for expansion, if it be necessary to increase her production, one wonders why India does not take advantage of these conditions and increase her production to meet the growing needs of the country. Cuba, which was producing only  $\frac{1}{2}$  million tons of sugar before 1898 when she became independent, increased her production to nearly 4 million tons of sugar annually, so that she leads the world to-day in point of production. Similar is the progress in Java. Why is it that India could not keep her premier position in the matter of sugar production, when she has all the favourable conditions? There is no question that, while other countries have made wonderful improvements both in the cultivation of sugarcane and manufacture of sugar, which have brought to pre-eminence countries like Cuba, Hawaii and Java, India is still following the time honoured methods, which are obviously out of date and very wasteful. What is it that keeps the people of India from taking advantage of the favourable conditions to increase her sugar production? Is it due to economic difficulties or due to some other causes peculiar to India? I have carefully studied the factors, that affect the



success of a sugar industry in advanced countries like Cuba, Porto Rico, Hawaii, Louisiana, and Java, and it seems to me, that India presents difficulties so peculiar and intricate that they are unheard of in any other part of the world, and the problem, though not impossible of solution, needs careful consideration. Before I present the peculiar difficulties the sugar industry has to face in India, a discussion of the factors that affect the economic success of a sugar industry will be of utmost advantage.

## II. Factors for a successful Sugar Industry.

The three chief factors, on which depends the success of the sugar industry, are cheaper production of cane, efficiency of manufacture, and market for sugar. The prosperity of the sugar industry in any country depends upon how far these factors have received attention.

1. *Cheaper Production of Cane.*—Of all the questions this is of the greatest importance. It directly affects the cost of production and consequently the economic competition in the sugar industry. A few years ago the competition was not so serious, but with Cuba leading the world in the matter of sugar production, serious competition has started, which has necessitated the reduction of the production cost. It should be remembered, that the cost of cane forms nearly  $\frac{3}{4}$ ths of the total production cost of sugar, as may be seen from below, and no matter how efficiently the manufacturing side is run, so long the cost of cane per ton is higher, there is not much chance to reduce the production cost considerably.

	Hawaii.	Cuba.	Porto Rico.	Louisiana.
	\$	\$	\$	\$
Cost of cane to make a ton of sugar.	37.95	20.56	41.68	60.18
Total production cost.	44.59	28.92	52.29	79.50
Per cent. cost of cane of the total production cost.	80.6	68.61	76.34	75.70

The above cost figures are for the year 1913-14 printed by the Department of Commerce, Washington, D. C. and are considerably lower than the present costs but the relation

of the cost of cane to the total cost of production is practically the same. The figures, however, explain why Cuba is able to compete with other countries. This shows, how important it is to produce the cane as cheaply as possible, if the sugar industry is to stand the competition in the open market.

The cheaper production of cane depends upon the favourable natural conditions for cane growing and the supply of cheap labour. The three favourable conditions are a good soil, a well distributed rainfall, or in its absence, an adequate supply of irrigation water and a favourable climate. In India we have a fairly good soil for growing cane. In Northern India, where more than 60 per cent. of the total crop is raised, the soil is mostly alluvial, which is considered good for growing cane. In the Bombay Deccan, the soils are of volcanic origin and vary in depth from a few inches to as much as 6 feet or more, below which is found a substratum of partially decomposed rock. This is very porous, and if this is within 2 feet of the surface, excellent drainage is secured. As the lands are under cultivation for a long time, cane cannot be raised on the same land without a rotation. To raise a good crop of cane a certain amount of fertilizer is necessary, which means expense, but this is counterbalanced by the increased yields obtained on canals. On the Deccan canals there is, however, a tendency to apply larger amounts of fertilizer than what is needed by the crop, thus considerably increasing the cost of cane. On the Nira Canal where this tendency is noticed, about 600 rupees are spent to raise a crop of 50 tons of cane, out of which, Rs. 250 or about 40 per cent. of the total production cost is spent for manure. If the amounts be reduced by half, which can be done without reducing the yields, the production cost of cane per ton is reduced from Rs. 12 to Rs. 9½.

As regards rainfall, we are not so much favoured as some other countries are, where cane is grown on rainfall alone, but it should be remembered that an uncertain rainfall introduces a factor of uncertainty, which considerably affects the yield. We have a fairly good supply of irrigation water which eliminates this uncertainty. In the Deccan, cane is entirely grown under irrigation, greater proportion being supplied by canals. As some more canals are under construction, the area under sugarcane is bound to increase in the future. The extension of irrigation works affords the most favourable condition for the sugar industry.

*Climate.*—Northern India, where more than 60 per cent. of the cane crop of India is raised, is situated outside the tropical belt and consequently winter is severe. Frosts are not unknown. Though the crop is not actually killed as happens in Louisiana in winter, it checks the cane growth. On account of severe climatic conditions in winter, only a short growing period is available. This is a limitation on the tonnage that can be raised in Northern India. It is thus impossible to raise such a heavy tonnage as is raised under tropical conditions. In the Bombay Deccan on the other hand, conditions are tropical, winter is not so severe and frost is unknown, and though cane does not make much growth during this period, it helps it to ripen.

Coupled with these factors, we have in India a good supply of cheap labour. In the sugar industry a good deal of labour is required both in the field and the factory. For the field work labour is required practically throughout the year. A cheaper supply of labour ensures a cheaper production of cane and in this respect India is much favoured. In all other countries except Java, the question of labour has become serious. Not only is there a shortage of labour, but wages are exceedingly high. Consequently, the production costs are high in all those countries, except in Cuba, and labour saving machines are being used to reduce the cost. In Cuba cane grows like grass and practically no cultivation, fertilizer or irrigation is required. This is possible on account of the fertility of the Cuban soils and more or less favourable rainfall. The cost of production is low, because there is practically no expense except what is required for one or two weedings and harvesting.

Taking the above facts into consideration it seems, that India on the whole is more favoured than any other country except Cuba and Java which have equally favourable conditions and under the circumstances, India ought to be able to produce the cane much cheaper. Whether it does so or not, will be evident from comparative figures obtained in other countries. For this purpose I am quoting the figures from the 'Cane sugar industry' printed by the Department of Commerce, Washington D. C. It should be remembered that in countries like Louisiana and Cuba, where most of the cane is purchased on the basis of the price of sugar, the actual cost of production is very difficult to be obtained.

Cost of cane at the mill per short ton of cane in 1913-14 was in Hawaii \$ 4.66, in Cuba \$ 2.37, in Porto Rico \$ 4.62, and in Louisiana \$ 4.27 which in Indian currency is approximately Rs. 14, 7, 14, 13, respectively. In India before the war the cost of cane at the factory in Northern India was probably Rs. 7. These prices have now increased by about 50 per cent. so that the present prices in Hawaii, Porto Rico and Louisiana are Rs. 21, 21 and 19.5 respectively. It is evident that the cost of cane at the mills in Hawaii, Porto Rico and Louisiana is considerably higher, but this is due to the prevalence of high wages in those countries. It is for this reason that the United States gives them a considerable protection from countries like Cuba, which is able to produce sugar much cheaper. The sugar from those countries enters the United States free of duty, while all foreign sugars are heavily taxed to the extent of \$ 2 (Rs. 6) per 100 lbs. of sugar, Cuba getting a little preference of about 24 cents per 100 lbs. over other foreign countries. Two dollars a 100 lbs. is practically equal to \$ 5 per ton of cane, assuming 12 per cent. recovery on cane, which the Hawaiian and Portorican factories usually obtain. This means, that so long the cost of cane at the mill in Hawaii and Porto Rico, is not higher than that in any other country by \$ 5, i.e., Rs. 15, they can compete easily with countries like Cuba. This is certainly a great protection. For this reason the conditions of those countries are not comparable with those of India. Therefore, a comparison with Cuba and Java, which are the possible competitors to India, will be better. The average sugar produced by India, Java and Cuba during 1906-21 is about 65 per cent. of the total, each producing  $25\frac{1}{2}$ ,  $14\frac{1}{2}$ , 25 per cent. respectively. In both those islands the natural conditions are similar. In Java labour is plentiful and cheap. In Cuba, however, labour is scarce and dear, but as the cultivation of cane is so simple, that it does not need much labour, and a number of ratoons,—may be 15-20—are taken, the cost of production on the whole is much lower.

As regards the cost of cultivation in India, it is impossible to obtain figures which will represent the actual cost of cane growing by farmers in India as such figures are unobtainable. For this reason I am quoting the cost of cultivation at the Government farms at Shahajahanpur (U. P.) and Manjri (B. P.) printed in the report of the Indian Sugar Committee.

	Cuba.	Br. Guiana.	Java.		India.	
			I	II		I
Cost of growing per acre...	Rs. 16-9	06-8	302-1	285-0	270-0	347-5
Cost of harvesting and transporting.	" 92-0	60-4	84-8	26-0	30-0	98-0
Yield per acre	" 108-9	266-7	336-4	311-0	300-0	380-5
Short tons of cane per acre.	18-0	22-2	46-8	44-4	34-5	44-0
Cost of cane per ton at the mill.	Rs. 60-5	12-0	7-2	7-0	8-7	8-6

In the above statement, for Cuba I have quoted the actual figures of one estate, which grows its own cane to the extent of 33,000 acres, which include plant as well as ratoon cane. These figures are not subject to change according to the price of raw sugar, and for this reason are comparable. With the exception of British Guiana, the cost of growing cane in India is higher than it is in Cuba or Java. The above figures show, why Cuba is able to dominate the sugar market. With regard to the cost of growing cane in India, the figures quoted are obtained at the sugar experiment stations in India. In the Bombay Deccan, I believe the cost of growing cane by the cultivators is fifty per cent. higher so that the cultivator is producing the cane at not less than Rs. 12 a ton, which is practically the same as in British Guiana. It shows that even though wages in India are as low as in Java, the cost of producing cane is considerably higher than is the case in Java.

One fact which is brought out by the above figures, is the low tonnage obtained in Cuba and in spite of that fact, she is at present able to dominate the sugar market in open competition. What is, therefore, more important, is not so much the tonnage per acre, but it is the cost at which a ton of cane is being produced and delivered at the mill. For a successful sugar industry this is more important. So much has been written about the extraordinarily low yields obtained in India, that it is looked upon as one of the causes, which affect the success of the sugar industry. To my mind even if the outturn per acre in India is increased, it will not immediately result in enabling the manufacturers to

obtain cane cheaper, because, as will be explained later, in India the manufacturers will have to purchase cane on the basis of the price of gur, if they are to obtain cane from the farmers. The result of increasing the yield will be to secure a greater profit to the farmer, which is no doubt desirable. Indirectly, it will have an effect on the gur market. If a little increase in the production of gur per acre is secured all over India, it will increase the production of gur, which will consequently lower its price. From this point of view the increase of yield is desirable, because it will ultimately make it possible for the manufacturers to secure cane at cheaper rates, which will be a great help to the sugar industry. What is more important, therefore, is the cost at which the factory can obtain cane at the mill. There is no doubt that the cane farmers on the Deccan canals are at present spending so much money that the cost of raising cane is considerably higher, but one should not expect them to practice economy, so long the present high prices for gur enable them to make a profit. It is only when the margin of profit becomes narrow, that the farmers will pay more attention to the reduction of the expenditure as an economic necessity.

I have purposely refrained from quoting figures for the cost of cane in the British West Indies, because in most of those islands cane is purchased from the farmers on the basis of the price for raw sugar. As the prices for raw sugar are fluctuating, the cost of cane is also changing accordingly. From enquiries made in the West Indies, I find the cost of cane per ton at the mill on the average is not less than \$ 4, i.e., Rs. 12, which is practically the same as is in British Guiana. It is obvious, that with such prices for cane, the West Indies cannot compete with Cuba in the open market and for this reason they are at present given a preference by England, which is the natural market for the West Indian sugar, to the extent of 1/6th of the full customs rate charged for foreign sugar. At present the customs and excise tariff for foreign sugar in Great Britain is £ 1-2-4.5 and 1-0-4.1 per cwt., respectively, the colonial sugars getting a preference of 1/6 of this amount. It explains, why in the face of the competition with Cuba, the West Indian colonies are clamouring for protection. In fact at the present time without protection there will be no sugar industry in the West Indies.

The figures quoted above include all the expenses except the profit. In India as cane will have to be purchased, a

higher price than the net cost will have to be paid. But this is immaterial, so long the price for cane has to be paid according to the price of gur. So long the prices for gur remain high, there is no chance to obtain cane at cheaper rates. It is, therefore, necessary to increase gur production in order to reduce the cost of cane at the mill. Thus, though India has all the favourable natural conditions and plenty of cheap labour, factories will not be able to obtain cane at cheaper rates, so long the prices for gur remain high.

2. *Efficiency of Manufacture.*—Efficiency of the factories varies in different countries. So far the highest efficiency is secured in Hawaii. The sucrose extraction by mills is 98 and over in Hawaii, about 95 in Porto Rico, 92-93 in Cuba and Java. The recovery of sucrose in sugar for every 100 lbs. of sucrose in cane is 89-90 in Hawaii, 87-88 in Porto Rico and about 85 in Cuba and Java. In Hawaii, the raw material is very expensive and consequently higher recovery has necessarily to be secured. In Cuba on the other hand, the cost of cane per ton at the mill is very low and there efficiency is sacrificed for capacity. In India, as the raw material is likely to be costly, so long it is bought on the basis of gur, a higher efficiency will have to be secured to run the factories on a profitable basis. With modern equipment and the employment of necessary technical men, it is not difficult to secure a greater efficiency.

3. *The Market for Sugar.*—In this respect we are in the most favoured position. We have already a domestic market, which is steadily growing every year, and time will not be far distant when our consumption of white sugar will be million tons a year. This increase will not stop, whether India increases her production or not. Java is our competitor in the matter of sugar supply, but Java has solely to depend for the disposal of her produce on the markets in Asia. Her domestic consumption is not much, though she has a large population. Cuba which produces about 4 million tons of sugar in a year, is solely dependent on the foreign market. On account of the preference given by the United States, a great part of the sugar goes to that country. Conditions have already reached a stage when United States had to increase the duty on the Cuban sugar in order to protect the domestic sugar industry. That means, a stage has been reached when any excess of sugar, that may be manufactured hereafter in Cuba will have no market in the States.

The other market for the Cuban sugar is Great Britain, which gives preference to her colonial sugars. Thus though Cuba has all the natural advantages to expand her sugar industry so as to supply sugar at cheaper price to a great part of the world, she is at the mercy of the foreign countries. This is one of the reasons, why Cuba has to curtail the extension of the sugar industry, though she has enormous possibilities for expansion. In these days, when every country is putting high tariff to protect the domestic or the Colonial industry, the position of a country, which depends for the disposal of its products on the foreign market, has become very precarious. But in India, we have no such problem to face, we have a growing domestic market, and it will probably be a long time before India will reach a position when she will have to look to outside market for the disposal of the surplus sugar.

From the discussion of the three chief factors, which affect the success of a sugar industry, it would seem that we have practically all the conditions necessary for a successful sugar industry and one would naturally ask, why then India is not increasing her production at least to meet the domestic needs, if not to supplement the needs of the Empire in addition. There are some difficulties peculiar to India, the solution of which requires great consideration.

### III. Chief Difficulties in India.

Before I discuss the practical difficulties the sugar industry in India has to face, a knowledge of the actual conditions, under which the Indian gur industry is working, is necessary.

At present sugarcane is cultivated all over India by small farmers. Each farmer grows his own cane, harvests it and turns it into gur. On the Deccan canals, the average area of cane grown by each farmer may be 5 acres or more. In this tract on account of the favourable climate, good soil and irrigation water, good yields are obtained. Here also the crop is harvested and turned into gur by the individual farmer. Gur making is comparatively a much simpler and cheaper process, and though it involves a far greater loss than is obtained in a modern sugar factory, it leaves a decent profit for the farmer. If, therefore, factories were to start in the existing cane area, they will have to depend solely on



the cane farmers for the cane supply, and this is the first difficulty which a sugar factory in India has to face.

1. *Supply of Cane.*—The extreme difficulty, in obtaining a steady and adequate supply of cane, is the chief cause, to which the failure of the existing sugar factories in India may be attributed. Almost all land, on which cane is grown is owned by farmers or small proprietors whose love for land is well known. In India, land forms the sole means of maintenance of the family, and a farmer is generally very reluctant to part with his land. If circumstances force him, he will go to the extent of mortgaging it. It is only under extreme necessity, that he may part with it. Besides, the extreme sub-divisions of land probably unheard of in any other part of the world, and varied interest in the same, present such difficulties, that it is practically impossible to purchase land for the factory. Nor is it possible to obtain land on lease for growing cane by the factory. So far, I find, Java is the only country, where sugar manufacturers obtain land on lease for a period, not exceeding  $21\frac{1}{2}$  years from land holders of their free will. Though the land is leased for long periods, the factory cannot occupy it for more than 18 months at a time, after which, it must be returned to the land holder, who grows rice and other crops for the next 18 months, after which, the factory gets possession for a similar period. This goes on till the lease expires, which is renewed again. It may be asked, why in Java farmers do not cultivate cane themselves, as they do other crops and sell it to the factory, when it is such a paying crop. I was told, attempts were made by a few farmers to raise cane and sell it to the factory, but their yields were so low—practically half the yield obtained by the factory that it did not pay them to grow cane. Besides, the sugar manufacturers offer so much rent for the land, that the Javaneese find it more profitable to lease the land temporarily, rather than grow cane or rice or any other crop. Some of the managers told me, that if the Javaneese were to cultivate cane successfully, they would be glad, because they could raise the crop at a considerably low cost. There is, however, one marked difference between the conditions in Java and India, and that is, the Javaneese have no alternative to dispose of their crop. If they grow cane, they have to sell it to the factory. Besides there is no competitive crop, which will give them an equally good return as sugarcane. Such is not the case in India, where gur making is a paying industry, which requires very

little skill and much less capital. It would, therefore, seem, that sugar manufacturers will have to solely depend on the small farmers for their cane supply, if factories were to be started in the existing cane areas. It may be possible to obtain crown waste lands in scattered holdings but they require lot of preliminary work to make them suitable for growing cane, and it is, therefore, a question for the future.

As said previously, farmers are at present harvesting their crop and making gur at a profit. If, therefore, sugar manufacturers wish to obtain cane from them, the only way is to offer them a price, which will bring them at least the same returns, as they would obtain, if gur was made. This means, prices will have to be based on the market price of gur, and the recovery farmers obtain from cane with their present methods of manufacture. The profit of the sugar manufacturers lies, therefore, in the increased recovery, that they would be securing on account of the modern equipment and high technical skill, and also the higher price for sugar. Whether it will pay to buy cane from the farmers on this basis is another matter, which is discussed later on.

The real difficulty, in obtaining cane from the farmers, is the uncertainty of obtaining a steady supply. As the holdings are much smaller, a factory will have to make agreements with so many cane growers. The difficulty is still further augmented by the fact, that every cane grower would like to cut his crop, when the prices for gur soar high. Similarly, when prices go down, cane growers may not like to harvest the crop at all. This adjustment of when to harvest and who is to harvest is a very difficult matter and requires careful handling. It has to be solved by previous consultation and a spirit of co-operation between the factory manager and the cane growers. In the West Indies I observed this trouble. There they solved it by paying for the cane according to the average price of sugar during the whole campaign. This is done in the case of those who make previous agreement to that effect. In the West Indies when the agreements are made, the planters are required to accept one condition, which is, that they have to supply cane during the grinding season, and it is the manager of the factory, who decides the following points: (1) what particular farmer should cut his crop, (2) how much cane he should supply every day, (3) when he should deliver the cane. These points increase in complications, as the number of cane growers increase.

On account of these complications, there is some chance for dissatisfaction, which is likely to prove ruinous to the factory in India. This is the real trouble, and unless there is a spirit of co-operation between the manufacturers and the cane growers, it is very difficult to secure a steady supply of cane to the mill.

There is one special point, which the manufacturers in India have to face. In India a farmer is in a far more favourable position than his brother in other parts of the world. He can ruin the factory, if he wishes by refusing to sell the cane to the factory. This he can very well do without causing loss to himself. He has an alternative to dispose of his crop, which is not the case with farmers in other parts of the world. He can harvest his crop, make gur according to indigenous methods and still make a profit. He may not make as much profit, as he would make by selling his cane, but that is immaterial to him, when he is dissatisfied. The price of cane to be paid should, therefore, be the value of a certain per cent. of gur on cane, the percentage depending upon the Brix of the normal juice and the extraction of juice obtained by local mills. This basis will be fair to both the parties. The purchase of cane on the flat rate will not make any discrimination between those, who supply ripe cane and those who supply immature cane. Besides, it will be very difficult to settle a flat rate, which will satisfy both the manufacturers and the cane growers. I believe, the recovery of gur by cane growers in India with their present methods of manufacture, leaves a sufficient margin for the sugar manufacturers to make a profit, provided sugar is made by modern methods. As the farmer in India has an alternative to dispose of his crop, there should not only be sufficient inducement for him to sell his crop to the factory, but it is necessary to create in him an interest for the factory by allowing him to participate in the profits of the factory, because he has got the key in his hand to ruin the factory. This will give him a much higher return than he would obtain by making gur, and at the same time the factory will be able to ensure a steady supply of cane to the mill. It is possible to create interest in him for the factory by arranging to pay a certain bonus to cane-suppliers and also allotting a part of the shares of the company. I saw this system of co-operation between the manufacturers and the planters in St. Kitts and Antigua, which resulted in benefits to both of them, and for our present conditions, this seems to be the only system, which will assure a steady

supply of cane as well as profit to both the manufacturer and the planter. Both in St. Kitts and Antigua, many estate owners did not join the factory at first, because they were doubtful about the success of the novel scheme, but later experience convinced them so much, that they were after the factory to enter into participation. A description of this system is given later on.

It should be clearly recognized that there are certain differences between the conditions in St. Kitts and India, which are given below:—

1. In St. Kitts individual planters grow comparatively much more cane than is the case in India. While on the Deccan canals majority of farmers may have 5 acres or more under cane, in St. Kitts majority of them grow 50 acres or more. This naturally reduces the number of agreements and also the complications arising therefrom.

2. The land on which cane is grown is owned by the planters and not leased as is so common on the Deccan canals.

3. In St. Kitts sugarcane is grown on the same land without a rotation. Consequently the area is more concentrated.

4. There is no alternative for the disposal of the cane crop. It has to be sold to the factory.

5. There is no competitive crop, which will fetch an equally good return as the cane. Consequently there is a tendency to grow as much cane as is possible.

In Antigua this system is in use for a longer time. There the factory was started in the year 1905, and by 1920 all the capital has been redeemed, and the planters have been issued shares equal in number to the original shares of the company. It will be interesting to see how the planters, who made the contract originally with the company, have fared in the business. The following figures have been taken from the West Indian Bulletin, Vol. XVIII, No. 3:—

Total cane supplied in fifteen years ...	tons.	350,126.
Price paid according to the contract ...	£	2,26,610 equal to 0-12-11 per ton.
Bonus paid during 15 years ...	£	1,26,930-11-7 equal to 0-11-0 per ton.

Total price obtained per ton of cane is £0-23-11, which is about 85 per cent. higher than the price contracted for (the contract was to pay for the canes the value of  $4\frac{1}{2}$  lbs. of 96° sugar for every 100 lbs. of cane supplied). At the present rate of exchange this is nearly equal to Rs. 18 a ton. It should be remembered that this represents the average for the last 15 years, during which, prices for sugar fluctuated from £8 to £25 a ton. In addition, the planters have received shares representing one half of the valuation of the factory which is practically equal to £0-5-7 per ton. Thus the total price received for the cane is £0-29-6, which is practically equal to Rs. 22 a ton. The original share holders, who were also largely debenture holders, received £1,26,930-11-7 as their share of the profits of the factory in addition to 5 per cent. interest on their debentures. It is obvious, how this system of co-operation has worked to the benefit of both the parties. The planters in fact obtained 128 per cent. more price than they would have obtained with the price contracted for, while the factory secured a steady and assured supply of cane. This is the only solution to secure a steady supply of cane under existing conditions in India.

2. *Competition with Gur Industry.*—This is another difficulty, the like of which is not seen anywhere else outside India. A few years ago, in the West Indies, the planters used to make muscovado sugar by a process, similar to gur making in India, but this difference, that molasses was removed by drainage before the sugar was bagged. This was a very wasteful process requiring about 15 tons of cane to make a ton of sugar instead of 9 tons which is required if sugar is made by modern methods. In course of time this wasteful process could not pay and at the present time it has been practically abandoned giving place to modern factories. In India gur making is still a profitable industry and this is the key of the whole situation. It should be recognized, that the competition of gur making with sugar manufacture is unequal. First of all, it is a much simpler and cheaper process requiring ordinary technique and less capital. The process consists in simply concentrating the cane juice in open pans. Usually no extra fuel is necessary beyond what is supplied by the cane. Thus, it entails much less expenditure. Secondly, prices of gur are not much affected by the fluctuations in the sugar market. As sugar is a product in demand all over the world, it is subject to the influence of the world market. Such is not the case with gur.

It is consumed as such only in India, and consequently the gur market is controlled by the demand and supply in India. The very fact that gur market is still able to maintain a comparatively high price, shows that gur production in India is not yet sufficient to lower the price. The only way to bring down the price of gur is to increase the production.

This brings me to the question of relative efficiency and profitableness of the gur and sugar industry. It is very difficult to obtain average figures for the whole of India, but as I am conversant with the gur industry in the Bombay Deccan, where prices for gur are usually high due to the excellent quality of gur made, and where also higher efficiency is secured, I shall make a comparison of gur industry as is carried on here and a possible sugar industry. I shall be making a comparison of the actual recovery obtained in making gur. For this purpose the following data has been assumed, which, however, is not far from actual facts:—

Sucrose in cane=14 per cent. (this is not high).

Extraction of juice on cane obtained by bullock mills=64 per cent.

Composition of juice. Brix 19, sucrose 16.5, purity 85.

Per cent. gur on juice 19 (Manjri farm has shown that this corresponds with the Brix of the juice).

Composition of gur. Pol. 72, sucrose 75.

On this basis the amount of gur on cane comes to  $\frac{64 \times 19}{100} = 12.2$  per cent. Taking 40 tons as the average yield of cane per acre, it comes to 4.9 tons of gur per acre.

For a comparison with the yield of sugar, an account based on sucrose is necessary, because gur contains only 75 per cent. sucrose, the rest of the 25 per cent. being impurities and moisture while sugar contains more than 99.5 per cent. sucrose.

Data for recovery of sucrose by modern methods with a crusher and 4 mills:—

Sucrose in juice per cent. sucrose in cane=93

„ „ sugar per cent. „ „ juice=88

„ lost in molasses per cent. „ „ = 9

With the above data the following statement is prepared:—

	Recovery in gur making			Recovery in sugar making (product white sugar).		
	Cane.	100 S. in cane.	100 S. in juice.	Cane.	100 S. in cane.	100 S. in juice.
Sucrose per cent. ...	14.0	...	...	14.0	...	...
„ in juice per cent. ...	10.8	73.7	100.00	13.02	93.0	100.0
„ in product per cent....	9.1	65.8	88.8	11.5	81.9	88.0
„ in mollasses per cent...	...	...	...	1.2	8.4	9.0
„ lost in manufacture per cent.	1.2	8.4	11.2	0.8	2.7	3.0

S.—Sucrose.

The above statement shows that in gur industry about 65 per cent. of the sucrose in cane is recovered in gur as against a recovery of 81.9 per cent. in sugar making. As no separate mollasses is formed in gur making, the total loss of sucrose on the sucrose in cane is 8.4 per cent. as against 2.7 per cent. obtained in sugar making. All these figures are expressed in percentages, which will not appeal to the ordinary public. It will, therefore, be worthwhile to calculate the loss of sucrose involved in gur making on the Deccan canals alone in money value, without which it is not possible to realize the magnitude of the loss.

According to the report of the Indian Sugar Committee, the area under cane on the Deccan canals is 29,742 acres. For ease of calculation it may be taken as 30,000 acres. Taking a yield of 30 tons of cane to an acre as the average on the Deccan canals which is really low, the following figures are obtained:—

Tons of cane raised every year	... 900,000
„ „ sucrose in cane	... 126,000
„ „ recovered in gur	... 82,278
„ „ sucrose lost in gur making	... 43,722
„ „ sucrose recovered in sugar making.	103,194
<i>Deduct</i> tons of sucrose recovered in gur making.	82,278

Tons sucrose lost annually in gur making ... 20,916

With sugar at Rs. 280 a ton, this is equal to Rs. 5,856,480 worth of sucrose lost annually. Deducting the cost of making sugar by modern methods, which will be about Rs. 80 a ton, the net loss obtained with present methods is equal to Rs. 4,183,200\* (5,856,480—1,673,280). In this I have not taken into consideration the valuation of the molasses that is obtained in sugar making. Still the loss of 4 million rupees suffered annually on the Deccan canals is tremendous. The above figures are more or less speculative, but they show the extent of the loss suffered annually on the Deccan canals alone.

The above figures indicate that sugar making by modern methods may pay in the Bombay Deccan. There are, however, certain considerations to be made. As said previously, if cane is to be obtained from the farmers it must be bought at a price based on the price of gur. But it should be recognized, that the gur market is not affected by fluctuations in the sugar market, and so long the price of gur remains lower than the price of sugar, it will pay to make sugar by purchasing cane on this basis. But at times it happens that the price of gur goes practically as high as sugar, in which case sugar making cannot pay. It is, therefore, important to know what should be the difference between prices for gur and sugar so that sugar making would pay, how much price the factory can pay for the cane, and what are the limits beyond which it will not be profitable to make sugar. This is the crux of the situation. For this purpose I have calculated some figures which are also speculative, though the data assumed in arriving at the figures is not far from actual facts. The figures are calculated per short ton of cane for the sake of convenience.

The amount of gur obtained by farmers with present methods with 18, 19, and 20 Brix juices will be 230.4, 243.2, and 256 lbs., respectively, or  $11\frac{1}{2}$ , 12 and  $12\frac{3}{4}$  per cent. on cane approximately. At Rs. 20 † a palla (of 250 lbs.) which is the usual rate prevalent in the Bombay Deccan, this is equal to  $18\frac{1}{2}$ ,  $19\frac{1}{2}$ , and  $20\frac{1}{2}$  rupees in value. From this should be deducted the expense for gur manufacture. For this purpose, I have assumed Rs. 2 as the cost of making gur for each boiling of 1,100 lbs. which will be yielding 198, 209 and 220 lbs. of gur with juices of 18, 19 and 20 Brix,

\* See Appendix A.

† See Appendix B. For other values, see statements on pages 218 and 219.



respectively. The expense of manufacture for 230.4, 243.2 and 256 lbs. of gur would be about Rs. 2.3 for each. This is summarised as below:—

*Extraction of juice on cane 64 per cent.; price of gur  
Rs. 20 per Palla.*

Brix of the juice	...	18	19	20
Lbs. of gur obtained per ton	...	230.4	243.2	256
Per cent. gur on cane	...	11.5	12	12.75
Value of gur in Rs.	...	18.5	19.5	20.5
Expense of manufacture Rs.	...	2.3	2.3	2.3
Cost of cane per ton in Rs.	..	16.2	17.2	18.2
Per cent. gur on cane to be paid for	...	10.1	10.75	11.4

The figures given in the last line would be the amount that will have to be paid to the cane growers on this basis. In the above calculations I have not made any deduction for the expense required for cutting cane, which is, however, balanced by the expenses for hire of mill, pans, marketing, &c.

I will now calculate the returns that can be obtained if sugar is made. For this purpose I assume the same data as I did before in statement on page 17. A ton of cane would contain 280 lbs. of sucrose, out of which 229 lbs. can be recovered by modern methods (based on 81.9 per cent. recovery on 100 lbs. sucrose in cane) in the form of sugar and 23.5 lbs. in the form of molasses. It should be remembered, that with a juice of 20° Brix, the recovery would be still higher. The value of 229 lbs. of sugar at 8 lbs. a rupee (*i.e.*, Rs. 280 a ton, would be Rs. 28.6.\* The amount of molasses containing 23.5 lbs. of sucrose would be 71 lbs.  $\frac{(23.5 \times 100)}{93}$  the value of which would be roughly rupee 1.

The total value, therefore, comes to Rs. 29.6. The cost of manufacture will be Rs. 8.5 (based on Rs. 80 a ton). The net return, after deducting the charges of manufacture, comes to about Rs. 21.1, which leaves a margin of Rs. 4.9, 3.9 and 2.9 per ton of cane, respectively. It is obvious, with gur prices going higher and sugar remaining at the same level, the margin of profit would get less. Elsewhere in other cane sugar countries, when the planters get

\* See Appendix D. Also see statement on page 220.

a high price for cane on account of the high price for sugar, the manufacturers also get the benefit of the high price, but in India where cane has to be purchased on the price of gur, which is not affected by the fluctuations of the sugar market, this would surely work to the detriment of the sugar factory, if gur prices soar high, without a corresponding increase in the price of sugar.

One fact I would like to consider. At the gur price of Rs. 30 a Palla, the cost of cane to be paid to the planters comes to Rs. 26 to 29 a short ton, a price considerably higher than what is paid in countries like Java, Cuba or the West Indies. It clearly shows, that though we have all the favourable natural conditions and plenty of labour for growing cane, the price of cane is much higher than anywhere else, which is solely due to the prevailing high prices for gur. This is the chief difficulty that lies at the root of the Indian sugar industry.

As previously said, in any country where the raw material is expensive, a higher efficiency in manufacture is necessary. In India under present conditions, the price of cane is high due to the high price of gur. It is, therefore, desirable to secure higher efficiency than what is secured above. Instead of 93 per cent. sucrose extraction, an extraction of 96 per cent. will increase the yield of sugar to 237 lbs., an increase of 8 lbs. With our high purity juices, the retention of sucrose in sugar on sucrose in juice can also be increased from 88 to 90, which will give an increase of 5 lbs., thus bringing the total yield of 242 lbs. of sugar to a short ton of cane. This is possible with our soft and rich cane, but it shows how necessary it is to secure a far greater efficiency than is usually obtained with existing factories in India. This is the chief reason, why I consider a mill tandem of a crusher and 4 mills is quite essential to secure greater efficiency for conditions in the Bombay Deccan, which I have discussed later on.

This brings me to another question. If there is any thing which will directly help the Indian sugar industry, it is this fact—the desirability of bringing about a reduction in the price of gur by means of increased production. There is no reason why an article like gur, which is much impurer than sugar and which requires much less expense, should command such a high price. With increased production the price of gur would come down, which will benefit both

the consumers and the sugar manufacturers. The consumers would get gur at a considerably lower price than they are getting now and the sugar manufacturers would get the cane much cheaper, which will stimulate the establishment of sugar factories. The increased production will not act to the detriment of the cane planters, because, even though a low price for gur may make cane growing unprofitable under existing conditions, there is a scope to reduce the expenditure at least on the Deccan canals. It seems, that the cane growers on the Deccan canals would not care to reduce the expenditure, unless an economic necessity compels them to do so. In fact, at present there is not much competition amongst the cane growers, which will stimulate economy in the cost of production.

The increase in gur production can be secured in many ways—by improving our present wasteful methods of gur making, by increasing the cane yields per acre and by increasing the acreage under cane. In the calculations given above I have shown how much loss is incurred in our present methods. The only possibility of effecting a higher recovery will be to use power driven mills, but this requires capital, some initiative and trained men, and I doubt very much how far individual farmers, leaving aside a few capable ones, would be able to put up power driven mills. In fact the area under cane grown by individual farmers is so little, that it will not be economic to use power driven mills in their case. It is, however, possible to have power driven mills, if the co-operative societies take up this question in hand. Already a few societies have undertaken this. In places, where cane area is isolated, as is found on smaller canals or where cane is grown on wells, a sugar factory industry is not possible, and under such circumstances a gur factory industry is desirable. The use of power driven mills would increase the yield by 9 to 16 per cent. on the present yields depending of course on the extraction they are obtaining at present. On account of the difficulties mentioned above, the possibilities of increasing the production in this direction are limited. There does not seem to be any chance in reducing the losses of sugar caused by inversion and formation of caramel, so long the open kettle system, which by the way is much cheaper, is in use.

*Increasing the Yield of Cane.*—According to the report of the Indian Sugar Committee, the average outturn of cane in Upper India is only 10 tons. This is considerably lower

than what is obtained in any other part of the world, and if an increase in the yield is secured, it will not only benefit the Indian farmer but will increase the production of gur. The cane breeding station at Coimbatore, has evolved some varieties, which are expected to give increased yields in Upper India, and with their introduction, the outturn per acre will be considerably increased.

*Increase in Acreage.*—In India the increase in cane area depends mostly on the water supply. It is the chief reason, why acreage in India under cane is fluctuating. As the water supply improved, there is no doubt that there will be an extension of cane area. In this respect the Deccan has admirable prospects for extension. According to the report of the Indian Sugar Committee, the maximum area of cane cultivated on the Deccan canals during the 10 years previous to 1920 was 27,500 acres, which it is expected would rise to 66,200 acres in the near future, when the extensions of the Nira and Pravara canals are completed. It is likely that this area may rise to 90,000 acres, when the Gokak canal extension, which is already sanctioned, is completed. With other projects of extension of the existing canals in contemplation, the Indian Sugar Committee expects that the area may rise as high as 1,50,000 acres. This is a very hopeful situation for the sugar industry. It will ultimately lead to the reduction of prices of gur, which will stimulate the establishment of modern factories. In my opinion the Deccan canals would form an admirably suitable place for sugar factories, because there the yields of cane are much higher than those obtained anywhere else in India, a tonnage of 40 tons to an acre being easily obtained. Secondly, the type of cane grown here is very suitable for making white sugar, the purity of the juice being 86-88, at times reaching 90. On account of the higher yields the area from which the factory can command cane, will be more concentrated so that the distance of transportation will not be long. At the same time, it should be understood, that it is in this tract that the best quality of gur is prepared, and that high prices for gur prevail. As I have previously said before, a high price of gur is a great difficulty in the way of the sugar factories, and the only way to ensure success for the factories is to cheapen gur market by increased production. This is certain with the completion of the canal extensions in the near future. That is why I consider the prospects of sugar industry in the Bombay Deccan to be hopeful.

3. *The Indebtedness of the Indian Farmers.*—This is a minor difficulty, which comes in the way of securing cane to the factory. On the Deccan canals a great majority of the farmers are indebted to money lenders, and the crop in fact is mortgaged. The money lenders or Sawkars as they are called, in addition to giving loans to the farmers, act as brokers or middlemen in selling gur. They finance the cane growers on condition, that they purchase manure from them as well send all the gur they make to them for sale. Thus, in addition to securing interest on the money lent, they obtain brokerage both on the manure supplied and gur disposed. The cane growers are, therefore, not free to dispose of their crop in any way they like. In case, they decide to sell the cane to the factory, they will have to obtain permission of the Sawkars, who of course would demand their commission even if no gur is sent to them for disposal. Under such circumstances, the factory will have to come to a certain understanding with the Sawkars, which will be rather difficult, as it is they, who will have to lose a great part of the commission, if not all. Failing to arrive at any understanding, the factory will have to undertake financing the cane growers. This is a thing, for which a separate department will have to be maintained by the factory. Owing to small holdings there will be a number of cane growers, who are to be financed, and in my opinion, the factory will not be in a position to correctly understand the assets of the cane growers, which is necessary before the loans are given. The illiteracy and poverty of the Indian farmer present great difficulties in this direction.

Fortunately, the establishment of co-operative societies on the Deccan canals afford a solution to this difficulty. Factories will find it to their benefit as well as to that of the cane growers, if they finance them through the co-operative societies. This will not only remove the difficulty of dealing with a number of small cultivators, but there is every chance that the money would be utilized in financing the right persons, and that the money loaned is not mis-spent. The co-operative society established in a village is in a far better position than any other organization to know the individual cultivators, and on account of the responsibility involved in conducting a co-operative society it is in a better position to see that the advances are properly utilized. The organization of co-operative societies on the Deccan canals will thus be a great help to the sugar industry.

4. *Competition with other Crops.*—This point has special importance in India. With the exception of India, Java and Louisiana, in most of the cane sugar countries notably Cuba, Porto Rico, West Indies and Hawaii, sugarcane is the only crop grown on cane lands. No rotation is followed. In Cuba, it is a usual practice to take 12-15 ratoons, in Porto Rico and the West Indies 2 and in Hawaii 3 ratoons. After the ratoons are taken, land is ploughed and replanted with cane. In all these countries there is no competitive crop which pays as much as sugar cane. During war time in St. Kitts, the cultivation of sea island cotton attended with a great success, and it was expected the cultivation would increase. But during recent years the market for this cotton has fallen very low, and at present sugarcane is the only crop which is sustaining the West Indies. In Hawaii, recently the cultivation of pine apple has started a competition but it seems that, there both the industries can work side by side, provided sufficient labour is obtainable. Usually lands which are not so favourably located for growing sugarcane are found to be suitable for growing pine apple and at present the question is of labour adjustment. In Cuba and the West Indies, the crop is entirely grown on rainfall alone.

In Louisiana and Java a regular rotation is followed as is the case in India. In Louisiana, corn and cowpeas are taken in rotation with cane. In Java it is not permitted to grow cane more than once in 3 years on the same land. This is probably done with the object of growing enough rice for the country. With all that, some rice has to be imported every year to supplement the needs of the population. But it should be remembered, that in Java there is no competitive crop for sugarcane. The same is the case in Louisiana, where benefit is secured of prevailing high prices for sugar in U. S. A.

In India conditions are very different. First of all, it has been found impossible to grow more than 2 crops of cane on the same land without a rotation. This naturally makes the cultivation of cane more scattered than it would have been if cane and cane alone could have been grown. The rotation followed is a three years' one during which a crop of cane is followed by 2 or 3 rotation crops. On the Deccan canals at the present time, there is no crop which pays as much as sugarcane. Besides, cultivators find one advantage in taking sugarcane, and that is, it gives employment to the

cultivator for the whole year. Still, there is no doubt, that on the canal tracts there are some other crops which pay equally well, but the cultivation of such crops is restricted, because they have a limited market necessitating a limited cultivation. Besides the fluctuation in the market is so wide in their case, that at times such crops do not pay. With the completion of irrigation works in the Bombay Decan, the area under cane would increase so much so, that the price of gur would go down, in which case the margin of profit may become so low if cane is grown under existing conditions, that the cultivators may turn their attention to the competitive crops. For a successful sugar industry, cane growing must pay. At the same time, cane must be produced at as low a cost as possible. Under such circumstances, cane growers will have to exercise economy in the cost of cultivation. However, it is not likely that the price of gur would fall to such a limit, as will make the cultivation of cane unprofitable, because with fall in prices of gur, more and more cane would be utilized for making sugar which has the world's market. When such a condition arises, it will be necessary to reduce the expenditure and increase the yield for which there is a scope at least on the Deccan canals.

To summarize, the peculiar difficulties the sugar industry has to face in India, are (1) the difficulty of securing a steady supply of cane due to small holdings and an alternative to disposal of the cane crop by individual farmers, (2) the unequal competition with gur industry and specially the high prices for gur, (3) the indebtedness of the Indian farmer and (4) the competition of cane with other crops.

#### IV. Causes of Failure of existing Factories in India.

1. In discussing the peculiar difficulties obtained in India, I have observed, that the chief cause, to which the failure of the existing factories can be attributed, is the cane supply. Not only factories do not get sufficient cane so that they can work to their full capacity, but even what they get is so irregular, that it seriously interferes with the proper working of the factory. According to the report of the Indian Sugar Committee, about 50 per cent. of the factories handle half of the cane which their mills can grind, while 30 per cent. obtain  $\frac{2}{3}$  to  $\frac{3}{4}$  of the cane while the remaining 20 per cent. obtain about  $\frac{4}{5}$  of the cane. The difficulty of obtaining a steady cane supply is the main reason, why

factories in India cannot be operated to their full capacity. This seriously affects the overhead expense and the efficiency of the factories.

2. The second cause seems to be the very low efficiency obtained by the existing factories in India. I have already pointed out that in India, where the raw material is expensive, it is essential to secure a high recovery to compensate for the high price paid for cane. This is true of any industry. Unfortunately, the information on this subject is not as complete, as one would wish to have, but from the figures available, one could judge of the low recovery they are obtaining at present. In this connection I am quoting the figures from the report of the Indian Sugar Committee. While Java obtains a yield of 9.75 per cent. sugar on cane with an average sucrose content of 12.11 per cent., in India from a similar quality cane only 6.85 per cent. sugar is obtained, which is nearly 30 per cent. less. On the basis of tons of cane to make a ton of sugar, it means 14.5 tons of cane are required in India to make a ton of sugar, as against 10.2 tons required in Java for the same quality cane. This involves a considerable loss, and under the circumstances it is no wonder, why factories cannot make a profit when it is taken into consideration the high price required to be paid for cane. Nowhere else I saw so many tons required to make a ton of sugar except in Louisiana. But the case of Louisiana may be excepted as the cane there contains a very low sucrose not exceeding 10 per cent. I give below for comparison figures from some typical mills grinding the same quality cane from other countries. Most of those mills have only a crusher and 3 or 4 mills, tandems with shredders having been excluded:—

	Java.	Hawaii.				Porto Rico.	St. Kitts.
		I	II	III	VI		
Sucrose in cane per cent.	12.26	12.21	11.70	12.24	12.02	12.43	12.60
Tons of cane to a ton of sugar.	9.30	8.6	9.16	8.79	9.08	8.5	8.8
Fibre in cane per cent.	15.16	12.8	12.5	12.26	13.83	12.7	14.8



In no case the cane required to make a ton of sugar, has exceeded 9 tons. In India on the other hand, 14.5 tons of cane are required to make a ton of sugar. This may be due to 2 causes—the low extraction obtained by sugar mills and the low retention of sucrose in sugars. The average extraction obtained by sugar mills in India was 60 per cent. of the normal juice, which is equal to a sucrose extraction of 71.43 per cent. of sucrose in the cane. The sucrose extraction is the best figure for comparison. So I am quoting figures obtained in the mills referred to above:—

	India.	Java.	Hawaii.				Porto Rico.	St. Kitts.
			I.	II.	III.	IV.		
Sucrose in cane per cent.	12.00	12.26	12.21	11.70	12.24	12.02	12.43	12.60
Sucrose in juice } % Sucrose in cane }	71.43	94.6	98.84	98.00	97.3	97.3	94.5	93.8

The above statement clearly shows, that the mills in the Indian factories are extracting 25 per cent. less sucrose, than what is obtained in other countries. In Hawaii where the cost of cane is very high, the average sucrose extraction is nearer 98.

With regard to the recovery of sugar on sucrose in juice the factories in India obtained 80 per cent. commercial sugar from every 100 sucrose in juice. This is compared with what is obtained in the mills referred to above.

	India.	Java.	Hawaii.				Porto Rico.	St. Kitts.
			I.	II.	III.	IV.		
S in sugar per cent. S in Juice.	80.0	93.0	92.7	91.4	92.7	90.8	92.3	92.0
S in sugar per cent. S in cane.	57.14	88.1	91.6	90.5	90.2	68.4	87.3	86.3

S = Sucrose.

Leaving aside the case of Hawaii, where high recovery is secured on account of high extraction by mills, the Indian factories recovered 13 per cent. less sucrose in sugar on sucrose in juice, which is an indication that either a great loss is being incurred in inversion or the molasses is not exhausted to the required purity. The total loss of sucrose in sugar per cent. sucrose in cane in the Indian factories, thus, comes to about 34.5 per cent. over what is obtained by factories in other countries. Is it any wonder then, that sugar factories in India are not working successfully, specially when the raw material has to be bought at a comparatively higher price?

In a sugar factory, the two products which are produced are sugar and molasses. The efficiency of the factory can be judged from the quantity of each produced per ton of cane. The molasses produced by the Indian factories according to the report of the Indian Sugar Committee varies from 4.5 per cent. on cane against 2.5-3 per cent. produced in Java. I quote below figures obtained by the same factories mentioned above:—

	Java.	Hawaii.				Porto Rico.	St. Kitts.
		I.	II.	III.	IV.		
Molasses per cent. cane.	2.9	2.6	2.4	2.4	2.8	2.9	2.9

It clearly shows that the factories in India are turning out about 40-50 per cent. more molasses than is done by factories in other countries. The production of more molasses per ton of cane is an indication, that there is a greater loss due to either inversion or fermentation. It is, however, difficult to exactly state the reasons for this, but it seems that a greater loss is obtained chiefly due to above two causes.

3. The third cause is the amount of extra fuel used by factories in India. According to the report of the Indian Sugar Committee, factories in India consume fuel to the extent of 4.2 to 6.2 per cent. on cane, the average being 4.31 per cent. on cane ground. On sugar produced, it comes to 63 per cent. This is enormous and entails a heavy expenditure. This seems to be a great handicap to the Indian

sugar factories, when it is taken into consideration that cane in Upper India contains more than 15 per cent. fibre. In Hawaii and Java where cane contains only 13 per cent. fibre, no extra fuel is required beyond what is supplied by cane.

With such a low recovery, production of large quantity of molasses, a commodity which does not fetch a high price and extra expenditure for fuel, it is no wonder why sugar factories in India are not operating successfully.

The chief cause of the low efficiency of the Indian factories is the absence of chemical control, without which it is impossible to locate the losses. Under a chemical control is included the account of every pound of sucrose that enters the factory in the form of cane, and chemical control tells how much of it is lost in bagasse, filter-press, in evaporation, crystallization, and so on. The high efficiency, obtained in Hawaii and Java, may be attributed solely to the maintenance of a strict chemical control, and no money is better spent in sugar factories than what is required in maintaining a chemical control.

While discussing the chief causes of failure of existing sugar factories in India, I have not referred to the question of rum. There is a general belief in India, that the excise policy of the Government is not favourable to the making of rum, which is a necessary and profitable commodity on which the success of the sugar industry depends. This belief is erroneous and has no foundation. I have treated this point fully in the chapter on the utilization of the by-products.

I have already referred to two other minor points, which are considered to affect the sugar industry. They are the sucrose content of the cane and the low yields obtained per acre in India. Taking into consideration the climatic limitations in Upper India, the sucrose content of 12 per cent. is not low. In Louisiana, where climatic conditions are much more unfavourable, the sucrose content is not over 10 per cent. Besides, present experience has shown, that so far no surprising increase has been obtained in the sucrose content of the cane in other countries. The climatic conditions set a definite limitation on the growing period in Northern India, which affects the sucrose content. On the other hand, in other countries notably in Hawaii and Java, a notable increase in the tonnage per acre has been secured by scientific cultivation. The obtaining of 123 tons of cane

equal to 15.5 tons of sugar per acre in Hawaii (in 2 years) marks a tremendous success of the application of science to cane agriculture, and though, I do not think that the increase of yield of cane per acre in India will directly aid the sugar industry, unless it is attended with a reduction in the prices of gur to reasonable limits, still, from the point of increasing the profit of the Indian farmer, an attempt in this direction is desirable. Other countries have shown what can be done in this respect by the application of scientific methods to cane agriculture.

#### V. Manufacture of Sugar by Modern Methods and Cost of Manufacture.

In the discussion in the foregoing pages, I have referred to the enormous loss of sucrose in our present methods of manufacture either of gur or sugar and no method, which cannot secure as great an efficiency as is obtained in modern mills, will establish the sugar industry on a sound footing. In India various attempts have been made so far to manufacture sugar by various systems. Mr. Sahasrabuddhe, a former Government of India technical scholar, has exhaustively dealt with the four systems in use—the Khandsari, Hadi, gur refining, and small vacuum pan factory, both with regard to their yields and cost of manufacture in his note on the Indian sugar industry. None of the attempts proved successful, because none of them approached a modern factory in securing a higher recovery of sugar. It seems, the guiding principle of all those attempts was to provide a method of making sugar, which would require a low initial outlay, and though every succeeding attempt resulted in obtaining greater recovery, none of them could recover more than 65 per cent. of the sugar recovered in a modern factory. This means, that where a modern factory would require about 10 tons of cane to a ton of sugar, these methods required at least 15 tons of cane and more. This was a great handicap to these attempts, because no matter what saving they could have caused in the cost of manufacture, which is after all  $\frac{1}{4}$  of the total production cost of sugar, they increased the cost of cane that would be required to make a ton of sugar by 50 per cent. or more. The result was, the production cost of sugar was considerably higher. On the face, these attempts were bound to fail. Besides the different systems, though they involved a small capital expenditure,

in no way reduced the cost of manufacture as has been shown by Mr. Sahasrabuddhe. On the contrary, on account of the small capacity of the plants, the cost of manufacture with different systems was found to be higher still. At that time, it seems the originators of those attempts paid more attention to the initial outlay rather than to the amount of cane that was required to make a ton of sugar, which was the chief cause of high production costs. This could never have been reduced, unless the tons of cane to make a ton of sugar were brought low by a higher efficiency, which was impossible with smaller plants.

The working of the Government experimental factory at Nawabganj near Bareilly in the United Provinces has clearly demonstrated the hopelessness of establishing the sugar industry by small factories. The capacity of the plant was one ton of cane per hour, and white sugar was manufactured by the sulphitation process. Evaporation was done under atmospheric pressure. The yield obtained was only 45.53 parts of sucrose as crystalline sugar per 100 parts of sucrose in the cane, a considerable loss being caused by evaporation under atmospheric pressure. I have already shown that, even bigger factories in India, which obtain 57 per cent. recovery of sugar on sucrose in cane, are not working successfully. The recovery is too low to make sugar making pay. All these attempts clearly show, that the solution of the problem lies in having bigger factories with modern equipment, which must be operated at least at an efficiency secured by modern mills in other countries. I have discussed the economic size of a modern factory later on, for conditions in the Bombay Deccan.

*Grade of Sugar.*—In almost all the cane sugar countries with the exception of Java, Louisiana, and Mauritius, the product manufactured by modern sugar factories is a 96° test raw sugar, which is not suitable for direct consumption. Countries, which mostly depend on foreign markets, find it more profitable to make a raw sugar of 96° Pol., rather than make white sugar, due to the difference in duty on raw and white sugars levied by the importing countries. In Louisiana, majority of the factories make white sugar, which goes into direct consumption. Of course this sugar obtains a slightly lower price than the standard granulated on account of a slight "off" colour. It should be remembered, that when raw sugar is made, the market is very restricted,

being only limited to the sugar refiners. White sugar has a wider market being suitable for direct consumption, which eliminates the profit of the sugar refiners. In Java about 50 per cent. of the total production is of white sugar, most of which is exported to India.

Countries, which depend for their sugar supply on the outside market, have put up different duties on the raw and white sugar in such a way, that for an exporting country it is profitable to make raw sugar only. This has resulted in the building up of a sugar refining industry in countries like England and the United States. There are at present a number of refineries in England and the United States, which refine raws and make granulated and all fancy grade sugars by the bone char process. The advantage of a refining industry is, that, a part of the profit which would have gone to the exporting country, if there would have been no difference in the duty for raw and white sugar, is retained by the importing country. Secondly, establishment of sugar refineries gives an employment to many men as well as gives an opportunity for the sugar machinery manufacturers to develop a market. India is also dependent on other countries for the supply of white sugar, and, I do not understand, why similar differentiating duties were not levied on raw and white sugars with the object of encouraging the refining industry in India. It might be said, that, in India a refining industry would not have been successful, because raw sugar is mostly refined by a bone char process, against the use of which, the Hindus have religious objection. Consequently people would not have bought this sugar. All this talk about the religious objection started for the first time in the year 1904, when the Swadeshi movement was organized in India. Even before that, India was importing sugar, and if there would have been differentiating duties on sugar, the refining industry would have been long established before the Swadeshi movement started. Secondly, even if such a difficulty would have arisen, which, by the bye, is only restricted to the Hindu population, it would have surely stimulated the refiners in looking for other methods for refining sugar. Instead of the bone char process, a chemical treatment would have been evolved, which was already known. At present, a vegetable carbon process is being experimented upon in Louisiana and the results, obtained so far, are so encouraging that within a few years Louisiana would be conducting refining operations on a large scale.

When such a process gets standardized, it will have a good future in India, because it does not involve treatment with any animal char. It may be quite possible to prepare a carbon at a cheaper price from raw materials available in India. If differentiating duties were levied later, when the suitability of vegetable carbon process is established, it will encourage the factory owners in India to put up refining plants. The advantages of a refining industry are already referred to. Besides, it would make it possible to train a number of technical men in the art of sugar refining, who would render considerable help in improving the working of the sugar factories.

At present, however, in India there is a market for direct consumption sugars. Raw sugar is not suitable for direct consumption, and it has, therefore, to be refined, before it is offered to the public. This increases the cost to a certain extent, though it gives the best grade of sugar. Factories in India, therefore, have to manufacture plantation white sugar directly from cane. The processes in use for making white sugar, directly from cane, are the sulphitation and the sulpho-carbonatation, also called acid thin juice process, out of which on grounds of economy and simplicity, the sulphitation process is suitable for conditions in India. I have discussed this question in more detail later on.

*Cost of Manufacture.*—It is very difficult to obtain average figures which will represent a number of factories. In the year 1913-14, the Department of Commerce, Washington, D. C. published certain figures with regard to costs in Cuba, Porto Rico, Louisiana and Hawaii. They are as below:—

	Hawaii.	Cuba.	Porto Rico.	Louisiana.
Cost of cane to a ton of sugar	8-14	8-68	9-01	18-96
Cost of cane to make a ton of sugar	\$ 37-95	20-56	41-68	60-18
Cost to manufacture a ton of sugar	\$ 6-81	8-99	12-08	19-32

With the exception of Louisiana, the other countries make raw sugar of 96° test, which requires less expense. The figure for Louisiana was \$ 19-32 in 1913-14 but since

then, a considerable increase has taken place in the manufacturing cost due to increased cost of living and high price of sugar due to the effects of the world war. Specially, in 1919-20 when the prices for sugar reached the highest mark, the cost of manufacture was the highest. This was followed by a tremendous drop in the price of sugar from 25 cents to 2 cents a lb. The manufacturers therefore, had to adjust themselves to changed conditions by curtailing expenses. Even now, the cost of manufacture has not stabilized due to the fact that labour, on the whole, is not prepared to go back to pre-war wages. I have, therefore, secured cost of making white sugar in one factory in Louisiana, and Java, both making white sugar by the sulphitation process in the years, when wages were low, though in no case the wages have gone to pre-war level. It should be recognized that conditions in India are different from what they are in those countries specially in Louisiana, but the figures would help to form a correct estimate of the expense for making white sugar in India.

*Cost of making white sugar in a factory in Louisiana by the sulphitation process for the year 1921.*

		Cost per ton of cane in	
		\$	Rs.
1.	Transportation of cane ...	0.50	1.50
2.	Cost of manufacture—		
	(1) Wages in the factory yard... \$ 0.07		
	* (2) " " " ... 0.39		
	(3) Boarding for the employee... 0.04		
	(4) Administration ... 0.25		
	(5) Material such as fuel, &c... 0.50		
	Total per ton of cane... 1.25	1.25	3.70
†3.	Interest and depreciation ...	0.80	2.40
Total cost of manufacture including transportation of cane.		2.55	7.60 per sh
Equal to			8.5 " to

\* This includes the salaried staff such as Chief Engineer, Superintendent, C Chemist, &c.

† I have calculated on the basis of 20 per cent. depreciation and 6 per cent. interest on capital.



Based on the above figures, the cost of manufacture including cost of transportation of cane per ton of sugar in India comes to Rs. 73·8, taking the recovery of sugar on cane to be 11·5 per cent. as has been calculated in statement on page 17. This recovery is not high, if we take into consideration the quality of the cane on the Deccan canals. I do not think the cost would exceed Rs. 80 in any case because, in India, labour is comparatively much cheaper than it is in Louisiana. On the Deccan canals, it may be taken as 8-10 annas as compared to Rs. 3-5 per day in Louisiana. Secondly, in Louisiana fuel is required in large quantities for making white sugar due to the fact that cane contains a low fibre (not above 10 per cent.) Thirdly, the interest and depreciation will be comparatively higher in Louisiana, as the factories are operated only for 2 months in a year. Fourthly, most of the men employed in the factory are given free board. Against these, one has to consider that, in India the salaried staff will have to be employed on the basis of the year. In Louisiana, they are employed for the crop, after which they are discharged. This is not possible in India, because the factories will not be able to get the men again due to the fact that, there are very few trained men in India. On the whole, the cost of manufacture cannot exceed Rs. 80 a ton of sugar on the Deccan canals.

The cost of manufacture in Java is given below :—

*Cost of manufacture of white sugar in Java by the sulphitation process.*

	1921-22.	1922-23.
	Per picul of sugar in guilders.	
Cane transport ...	1·04	0·69
Fabrication ...	0·46	0·33
Supervision ...	1·41	1·14
Fuel ...	0·19	0·04
Packing ...	0·62	0·33
Transport of sugar to port.	0·53	0·52
Upkeep ...	0·81	0·48
Interest ...	0·11	0·15
Sundries ...	0·60	0·42
Taxes ...	0·86	0·81

	Per picul of sugar in guilders.	
Total cost exclusive of cost of cane.	6.63	4.91
Bonus ...	0.67	0.71
New building and machinery.	0.72	0.64
	<hr/>	<hr/>
Total cost f. o. b. exclusive of cost of cane.	8.02	6.26
Equal to per ton of sugar	130.2	102.7
in Rs. based on one guilder equal to a rupee.		

In order to arrive at the figures of manufacture only, the following items must be omitted from above:—

	Per picul of sugar in guilders.	
Transport of sugar ...	0.53	0.52
Taxes ...	0.86	0.81
Bonus ...	0.67	0.71
	<hr/>	<hr/>
Total ...	2.06 = 33.8	2.04 = 33.4
	per ton of sugar.	
	Rs.	Rs.
Net cost of manufacture inclusive of cost of transportation of cane per ton of sugar.	96.4	69.3
Cost of manufacture per ton of cane.	8.37	6.24

The difference in the cost figure for the two years, is due to the reduction of wages. Even the cost of cane was reduced by about 40 per cent. According to these figures, the cost of manufacture, comes to Rs. 69.3 per long ton. The difference in conditions between Java and India are: first of all in Java, the wages are lower than what they are on the Deccan canals. Secondly, in Java a considerable European staff is employed for supervision both in the field and the factory, which increases the expense. Leaving aside technical men such as the Engineer, Superintendent and the Chemist, Europeans are employed for doing minor

works of supervision in the factory which can be easily done by trained men in India. On the whole, the cost of manufacture should not exceed the figure of Rs. 70. To be safe, I have assumed Rs. 80 as the cost of manufacture per ton of sugar in my previous calculations.

## VI. Cane Supply.

Amongst the factors that contribute to the success of the sugar factories, the matter of cane supply is the most important. The question of cane supply mainly influences the economic working of the factory. The two chief points in the matter of cane supply, are, a cheaper production of cane and the certainty of a steady supply of cane to the mill. The former is obviously of importance, because it forms nearly 75 per cent. of the total production cost of sugar.

The steady supply of cane to the mill chiefly affects the efficiency as well the economy of the factory. With a steady supply of cane, the mills are operated continuously, which supply bagasse as fuel to the boilers, so that no extra fuel is necessary but, when mills have to be stopped every now and then on account of a shortage of cane, it at once cuts the fuel supply and extra fuel such as wood, coal or oil, whatever is available, has to be used to run the other departments of the factory, as they cannot be stopped, unless the juice is rendered into a condition fit for keeping. The irregular supply of cane, thus, directly affects the fuel problem, and consequently the economics of the factory. It is this fact, which is largely responsible for the large amounts of extra fuel used by the existing factories in India. The irregular supply of cane, also, affects the recovery of sugar in the house. Another factor, which affects the economics of the factory, is the capacity, to which it is worked. A modern sugar factory entails a heavy capital expenditure. It works only 3 or 4 months in a year, while it is remaining idle during the rest of the year. The supervising staff, such as, the Chemist, Superintendent, Engineer, &c., are paid on the basis of the year. All this involves a heavy overhead expense, which is borne by the tonnage ground during the season. If, on account of irregular supply of cane, a factory cannot be run to its full capacity, and only half the tonnage is ground, the overhead expense becomes at once double, which seriously affects the manufacturing cost. In Cuba,

where cane supply is most assured and steady, and where the tonnage ground in a year depends upon the tonnage raised, the manufacturing cost is considerably lower, even though high salaries are paid to the supervising staff. The matter of cane supply is thus vital to the cane sugar industry.

In the various cane sugar countries that I visited, I saw four systems under which a steady supply of cane is secured to the mill. They are:—

1. (1) Administration or estate system.
2. (2) Colona system.
3. (3) Mixed system.
4. (4) Co-operative system.

*The administration or estate system.*—In this system, all the cane is exclusively grown by the administration on land either owned or leased by the factory. This system is very common in Porto Rico, British Guiana, Hawaii and Java. In Cuba, I saw only two big estates of 30,000 to 60,000 acres under cane exclusively operated by the administration. The rest of the factories in Cuba obtain their cane under the Colona system. With the exception of Java, the land is owned by the company. In Java, ownership of land by the factories is prohibited by law, and in every case, it is obtained by lease from the land holders by the company. The longest lease allowed is not over 21½ years, and the factory cannot occupy a piece of land over 18 months, after which it must be returned to the land holder. One thing common to this system is that the factory grows cane and cane only. On none of the estates in Hawaii, British Guiana, and Porto Rico, any rotation crop is taken. This simplifies the administration of the plantation considerably. Only in Java, a rotation is compulsorily followed, but in this case, the rotation crops are exclusively grown by the farmers, the factory growing cane only. The Java system has, therefore, a double advantage: it secures the benefit of a rotation crop, which maintains the fertility of the land, while, at the same time, it is free from the trouble of looking to rotation crops in which the factory is not interested.

The size of the estate depends primarily upon the size of the factory, that is considered economically necessary. It also depends upon local conditions, which involve the facility

of purchasing the land and water supply. In British Guiana, the majority of the estates have 1,000 to 2,000 acres each under cane, the largest area on any one estate being 6,000 acres on the plantation Diamond. In Hawaii, the average sized estate has 5,000 acres under cane, while, in Java, it is about 2,000 acres under cane. The estate employs hired labour, most of the work being done by contract. This eliminates supervision and is found to work economically.

2. *Colona system*.—This system is prevalent to a great extent in Cuba, nearly 80 per cent. of the cane being raised by this system. In this system cane is grown either by independent farmers or colona on the company's land. They are financed by the company, which loans them money at a certain rate of interest, and the colona in turn, are bound to grow and sell the cane to the factory. They are required to cut the cane whenever the company asks them to do so. It should be remembered, that in this case the land is owned by the company and the colona are not really independent farmers, because they are bound in every-way to grow cane only and sell it to the particular factory which finances them. The only precaution, which the company has to take is to select the proper colona. In this system also only sugarcane is cultivated, no rotation being followed.

3. *Mixed system*.—This system is prevalent in Louisiana, Trinidad, and to a very small extent in Cuba. In this system, the estate grows a part of the cane on its own lands, and at the same time obtain cane from the farmers, who grow cane independently. In this system, the farmer is independent, in that he has his choice to select the factory, to which he can sell his cane, and that he may grow any crop he likes. It is on account of this fact, that the factory grows a part of the cane itself so as to eliminate the uncertainty involved in depending too much on the farmers. In this system a regular rotation is followed in Louisiana. No rotation crops are taken in Trinidad.

4. *Co-operative system*.—This system is in use only in St. Kitts and Antigua. The principle of this system is a joint partnership of the manufacturers and the planters in the profits of the factory. Cane is all grown by the farmers, who are independent in every respect, except that they have to grow a certain area of cane, which they must supply to the factory. The manufacturers, in addition to giving the planters the usual price for cane, give half the profits of the factory as bonus. In this way both the manufacturers and the planters are benefited. The former secure a steady

supply of cane and the latter, without losing their independence obtain a good price for cane, which encourages them to grow cane. This system is the most suitable for conditions in India for reasons previously discussed.

*Advantages and disadvantages of each system.*

From the point of sugar manufacturers only two considerations are necessary—the certainty of a steady supply of cane and a cheaper production.

1. *Estate system.*—As the cane is grown by the administration, it has a perfect control on the cane supply. Consequently there are no stoppages of the mill due to shortage of cane. As regards the cost of production, with the exception of Java, it has not been found possible to raise cane as cheaply as is the case under other systems, because the management of an estate involves an organization, requiring big investment on account of certain expenditure such as quarters for the employee, hospital, schools, churches, places of amusement, stores, workshops, &c. On small plantations such an investment involves a comparatively greater overhead expense. The case of Java is exceptional, and it seems, that is the only system which will make it possible to secure cane for the factories in Java. In this case the cost of cane is not affected by the fluctuations of the sugar market, which is the case with cane grown under all other systems. Consequently, with lower prices for sugar, this system is found to be expensive. With higher prices for sugar, this system will be more economical. It is very difficult to obtain comparative figures to show that the cost of growing cane by this system is high, because in the countries named above, this is the only system in practice. In Cuba I saw both the systems, and there it was found, that with price for raw sugar at 2 cents a lb., the Colona system was economic. There is no doubt, however, that the cost of growing cane in Hawaii, Porto Rico and British Guiana is considerably higher as may be seen from below:—

	Hawaii.					British Guiana.
	I	II	III	IV	V	
Cost of cane per ton at the mill.	\$	\$	\$	\$	\$	\$
	4-27	4-83	4-61	4-13	4-65	4-00
	Rs. 12-81	Rs. 14-49	Rs. 13-89	Rs. 12-39	Rs. 13-95	Rs. 12-00

In Porto Rico, the cost of cane at the mill is in the neighbourhood of \$6 a ton. In Hawaii and British Guiana, the conditions of cane growing were such, that there was no other possible system under which cane could be grown. In the Hawaiian islands, with the exception of the east part of the island of Hawaii, cultivation of cane was impossible without the provision of irrigation water. This needed so much capital that it was not within the means of the farmers. This can be recognized from the fact, that more than 17 million dollars have been spent on irrigation projects in Hawaii. On the island of Hawaii, rainfall is more than enough for growing cane, but there the character of the country presents such difficulties for transportation of cane, that this could not have been secured by the farmers without the help of capital. In British Guiana, the chief question is the drainage. All the land on which cane is grown, is situated along the coast, which is below the level of the high tide of the sea. This needed not only big dams along the estate to prevent the sweeping of the land by the high tide, but it needed a very expensive system of drainage, if cane was to be grown successfully. All this required capital. Besides, British Guiana had practically no population to cultivate sugarcane. It had to import considerable labour from India. This explains, why British Guiana and Hawaii had no alternative but to follow this system. In Porto Rico, on the other hand, there was a farming community, but after the American occupation, American capital found its way to Porto Rico. Land could be bought at that time easily. The result has been, that a farming community is on the point of extinction in Porto Rico. This is a great national loss and on this account in a country where a farming community already exists, it is not good to turn independent farmers into a gang of labourers, who feel no interest whatsoever in the land. In Porto Rico, at present there is plenty of labour, but there is a complaint, that labourers do not take any interest in the cultivation of cane. As a result, cost of cultivation is very high. The case of Java, I have already dealt with.

It will be evident from above, that this system, though it gives a perfect control on the cane supply, is followed in those countries as a necessity. In India, it is not possible to grow cane by this system in the existing localities, where cane is grown, due to the difficulty of obtaining land either by purchase or by lease. Secondly, in India, there is a farming

community, which is already growing cane. There is no doubt, that at present at least on the Deccan canals cane is being grown at a considerably high cost, but I believe, that the competition that will be created by the increase in cane area, will result in the reduction of the cost of production. Thirdly, on account of the impossibility of growing cane without a system of rotation, a considerable area would be required to raise the necessary crop. The rotation crops increase complication and expense.

2. *The Colona system.*—The advantages of this system are many. As the land belongs to the company, and as the colona are bound to grow and sell cane to the factory, there is a certainty of cane supply. Secondly, it saves a good deal of worry and investment. The third advantage is, it leaves all the risk in cane growing due either to less rainfall or cane fires to the colona. This is a great advantage. In Cuba, I have seen the enormous loss caused to the estate by cane fires. On one estate managed by the company, more than 2,000 acres were burnt, of which the company could not recover even one-half. With the Colona system, this loss has to be borne by the colona, who are naturally very vigilant to see that no fire is caused. In this system, as the cane is paid according to the price of raw sugar, it is obtained cheaper with low prices of sugar. With high prices for sugar, colona cane becomes costly, but this does not come in the way of the normal profit of the factory. The schedule of payment is based on a certain percentage of sugar ( $4\frac{1}{2}$  to  $7\frac{1}{2}$  per cent.) in Cuba on the weight of the cane in such a way, that it leaves a fair margin of profit to the manufacturers. In fact, with high prices, both the manufacturers and the colona are benefited. This system is not suitable for conditions in India, as it involves an ownership of the land sufficient for growing the required amount of cane.

3. *Mixed system.*—I have already referred to the advantages of this system. The supply of cane from the farmers under this system, is very irregular, and that is one of the reasons why the factory has to grow its own cane so as to maintain a steady supply of cane. It combines the advantages of both the systems. This will not work well in India, because there is the competition with the gur industry as well as with other crops. In other countries, sugarcane is the most paying crop, and there is practically no competition. There is no alternative for the disposal of the crop, and cane



has to be sold to the factory. Such is not the case in India.

4. *Co-operative system.*—I have already discussed the advantages of this system, and shown why it is the only system, under which it will be possible to secure cane in the existing cane area. This system is in operation in St. Kitts and Antigua, and a short description will be of use.

The factory in St. Kitts is the result of agreements between a group of owners of sugar estates and a company formed in London. Under these, the company agreed to erect and work a sugar factory, and the estate owners agreed to plant a minimum area with cane for a period of 15 years. The capital was raised by shares and debentures. The conditions of cane supply were:—

(1) The planters will receive the price of  $4\frac{3}{4}$  per cent. sugar on cane, the price of sugar being that of 96° test sugar f. o. b. St. Kitts. Payment is made every week, and the average price of sugar for the week is taken for calculation.

(2) After 15 years, when the borrowed capital is supposed to be paid up, the planters will be given shares equal in number to the original shares of the company and a price of  $5\frac{1}{2}$  per cent. sugar on the weight of cane will be paid to the estate owners.

(3) The cane supplied must be of such a quality as to show 1.7 lbs. of sucrose per Imperial gallon in the crusher or first mill juice without dilution.

(4) All cane is to be delivered by the planters to the trucks placed on the nearest switch.

(5) Cane must be well stripped and topped so as to eliminate unripe part of the cane.

(6) The cane must be supplied between 1st February and 31st July of every year in amounts that will be decided by the company.

At the end of each season, they were to receive a bonus equal to half the profits of the factory, after proper charges had been made for working expenses, interest and sinking fund. The latter was planned so as to pay off all the capital in a period of 15 years, so that after that period, the estate owners would have half the interests of the factory.

The chief point of this system is that the planters get half the interest in the factory. In addition to getting the usual price for cane they get a bonus. In actual practice the estate owners obtained so much price for cane, that under no other system they could have obtained so much.

It should be remembered, that when this scheme was first put forth in Antigua, there was much hesitancy concerning its successful operation. Consequently only a limited number of estate owners joined the factory. As the scheme successfully worked in practice even with a limited number of contracting proprietors, the other estate owners clearly saw the advantages and later joined the factory, but they do not obtain the advantage of becoming possessed of shares representing one half of the factory. They are called new contracting proprietors. In Antigua factory at the completion of 15 years, cane was supplied to the factory as below:—

Original contracting proprietors ...	37.70	per cent.
New do. do. ...	57.55	„
Peasants ...	4.75	„
	<hr/>	
	100.00	„

I believe such a co-operative scheme will successfully work in India. It is likely, that many cane growers may not join the scheme in the beginning as was the case both in Antigua and St. Kitts, but time will not be far distant when they would realize the advantages of entering into co-operative partnership of this sort. The pioneer factory will have to pass through this stage, before it will be able to secure the co-operation of all the cane growers.

## VII. Economic Size of Sugar Factories.

The size of sugar factories in different countries shows a great variation. In Louisiana, plants with a daily grinding capacity of 500-1,000 tons are common while in Cuba a modern unit has a capacity of 2,500-3,000 tons. There are quite a few factories in Cuba, which have a grinding capacity from 6,000 to 9,000 tons of cane a day. In Porto Rico,

plants with a capacity of 1,000 tons of cane a day are common, though a few have a capacity from 2,000 to 4,000 tons of cane per day. In the West Indies and British Guiana, majority of plants have a capacity of 500 to 1,000 tons of cane a day. In Hawaii plants with a grinding capacity above a 1,000 tons are common, while in Java majority of the factories have a grinding capacity of 500 to 1,000 tons of cane per day. Out of these, plantation white sugar is directly made from cane only in Louisiana and Java. It is obvious from above, that the minimum capacity for a profitable working of a modern factory is considered to be 500 tons of cane per day. This point is of importance. It should be remembered, that all advantages in modern sugar factories are secured on account of production on a big scale.

It is obvious that bigger plants have a great many advantages over small ones. With smaller plants, the overhead expense, the investment and interest is comparatively much greater, because no matter what the size of the plant is, a minimum supervising staff such as the manager, superintendent, chemist and the engineer will be necessary. With very big plants such as are found in Cuba, grinding upwards of 6,000 tons of cane per day the overhead expenses are much lower, because high salaried men indicated above are not duplicated. This is one of the reasons, why in Cuba the manufacturing cost is low, even though labour has to be paid very high. In Cuba, the big factories consist of 2 or 3 tandems, which afford a special advantage, and that is, the plant is never closed for cleaning. Every Sunday each tandem is closed alternately for a few hours for cleaning. This increases the efficiency of the factory and decreases the supervision charges considerably. It is often said, that with such big factories which involve the duplication of the machinery, the staff is also duplicated. This is true so far as low salaried men are concerned, but the high salaried staff such as the engineer, chemist, superintendent, &c., is not duplicated. Thus big factories have all the advantages over small ones. The chief point with big factories is the economic distance of transportation. In Cuba transportation seems to be cheap and rapid, and factories are able to obtain supplies over a longer distance.

The study of the factories in different countries leads me to think, that the size of the factory mostly depends upon

the amount of cane and the period available for grinding. Cane supply in turn depends upon the size of the estate, the tonnage raised per acre and the economic distance of transportation. So far I saw the biggest estates growing cane anywhere from 30,000 to 60,000 acres only in Cuba. In all other countries, the size of the estate is considerably smaller, the common size being 2,000 acres or more under cane. In Cuba it was possible to have such big estates, as the sugar factories could obtain forest land which is still in abundance in Cuba. In fact, many of the centrals in Cuba opened the country by deforesting land and planting cane. That is the reason, why Cuba has such big estates. The clearing of the forests involved a whole lot of expense, and could not have been carried on a small scale.

With the exception of Louisiana and Java, in all other cane sugar countries, sugarcane is the only crop that is grown on the same land year after year without any rotation. The result is, the cane area is much more concentrated. This is still more helped by the fact, that, except in some of the islands of Hawaii, sugarcane is grown on rainfall alone. Consequently cane can be grown all over the estate on small hills or hollows without any necessity for levelling, which is not possible when cane is to be grown under irrigation. On account of these two facts cane area is more concentrated, which consequently decreases the distance of transportation. This is affected to a certain extent by the low yields obtained under uncertain conditions of rainfall. The only place, where heavy yields are obtained, is Hawaii but there a two years' cane is grown.

With estates growing cane under rainfall alone, the size of the estate depends upon the distance from which cane can be transported economically. Leaving aside Cuba, Porto Rico and Louisiana, where the public rail-road affords very cheap rates for cane transportation, making it possible the factories to obtain cane from distances up to 40 miles, in all other countries the average distance of transportation varies from 6 to 10 miles. This seems to be the economic limit in those countries.

The available grinding period varies in different countries. In Louisiana the period is only 2 months, while in Cuba it is 6 months, though centrals in the eastern part of Cuba can grind 8 to 9 months. In the West Indies the

season lasts for 4 months. In British Guiana, there are two seasons, the total period available for grinding being 6 to 7 months. In Hawaii grinding period is 6 to 8 months, while in Java it is only 3 months. It is obvious that countries, having a short grinding season, will necessarily have to instal bigger factories in order to finish the grinding in the required period. This means more investment and more upkeep, because the machinery is practically idle during the greater part of the year. In Cuba and Hawaii, where longer grinding period is available, the expense for interest and depreciation is much less but it should be remembered, a longer grinding period may result in greater loss in some countries like Java and the West Indies, because in those countries the ripening period is short, which is followed by an over-ripening period. Under such circumstances, if the grinding period is prolonged, it results in obtaining an over-ripe cane, which affects the yield of sugar considerably.

Taking into consideration the above facts, it is impossible to have very big factories above 1,000 tons grinding capacity in the Bombay Deccan. Firstly, sugarcane has to be grown under irrigation for which canal water is necessary. As previously said, almost all the land on which cane is grown is owned by farmers, whose love for land is so well known. Besides 'the extreme fragmentation of land and multiplicity of interests' preclude any hope of securing large areas for the factory. Even in places, where new canals are proposed to be opened, it is very difficult to purchase land from the owners, unless an exorbitant price is offered, which will be very expensive.

Secondly, in the Bombay Deccan the agricultural practice in cane growing districts is to grow rotation crops with cane. It is impossible to grow cane year after year on the same land without a rotation as is so common in Hawaii, where also cane is grown under irrigation for the last 40 years. In the Deccan, where cane is being grown on canals for the same period, it does not pay to take a second ratoon. The rotation followed is a three years' rotation. This means there will have to be three times the area of land to have the same acreage under cane. To this will have to be added some area, which is unsuitable for cane growing for various reasons such as hollows, wastes and swamps, which are commonly met with in the canal area.

Thirdly, as sugarcane is an entirely irrigated crop, lands have to be levelled before irrigation can be practised. It is not possible to follow the system of opening furrows along contour lines, which dispense with levelling as is practised in Hawaii, because that system needs a gradual slope which is not obtained in the canal area. In Hawaii almost all the cane land is situated along the hill sides, which have a gradual slope. In the Deccan all the land above the level of the canal water, cannot be irrigated unless water is pumped and used, which at least under present conditions is too expensive.

All these facts show that an enormous area of land will have to be purchased or brought under control to have sufficient cane, if a bigger factory is to be operated. This will increase the distance of transportation, which will be expensive. There is, however, one advantage in growing cane under irrigation, and that is the average yield will be considerably higher than what is usually obtained under rainfall conditions. While the yields in other countries, where cane is grown on rainfall alone, is between 20 to 25 tons of cane per acre, in Java it is 40 tons while, on the Deccan canals the average is about 35 tons. It is thus obvious how impracticable it will be to have large sized factories of 2,000 tons and over. At the same time, for a profitable working, the minimum size should have about 500 tons grinding capacity.

In the Bombay Deccan, it is quite possible to have a longer grinding season. The dry period, during which grinding is done, extends from November on to the following June. It is quite possible to obtain cane for grinding in December. There is always some cane left over from the previous year, which is usually ground in November or December. This will give a six months grinding season. Deducting the weekly shutdowns and holidays, 150 days will be available for grinding.

Taking 35 tons as the average yield of cane per acre on the Deccan canals and taking 120 days as the average working days during the grinding season, a 500 and 1,000 ton factories would require 1,700 and 3,400 acres under cane respectively which, I believe, is possible to find within a radius of 10 miles. Therefore, for conditions in the Bombay Deccan, a 500 to 1,000 ton plant will be most suitable.

### VIII. Harvesting and Transportation of Cane.

*Harvesting of cane.*—Cane cutting is exclusively done by hand so far. Even though a great improvement in mechanical equipment of cane sugar factories has taken place during the last 25 years, which has secured greater efficiency and economy in labour, so far no suitable cutting machine has come into existence. In the Louisiana planter appears an advertisement of the Luce cane harvester, which is said to do the cutting, stripping and topping operations. During my visits to various sugar estates, I did not come across any estate using this machine. I was told that it was tried in Louisiana and Cuba, but it proved to be a failure. The practical difficulties are (1) it requires a straight erect cane which is rarely met with in the fields, (2) it requires a uniform height of cane to secure uniform topping which is also an impossibility, (3) a more even field is necessary so that cutting can be done as close to the ground as possible.

After the cane is cut, the next operation is to strip the cane of its leaves. This is also done by human labour. In countries, where labour is scarce and dear, it becomes too expensive to strip the cane, and so it is a practice to burn the cane before cutting. In raw sugar manufacture, this does not make any difference so long cane is ground within 48 hours. This practice is very common in Hawaii and the West Indies. In Cuba cane is also burnt, but this is due to incendiary causes. Burning of the cane causes some loss and should not be followed, unless one has to, on account of the labour situation.

After the cane is stripped, it is either loaded directly to the bullock cart or rail road cars or other means of transportation. This is still done by manual labour. Machines are being tried in Hawaii to do the loading. Expensive and heavy machinery would be necessary to do this operation, which would have to travel the entire field to pick up the cane. This would increase the operating expenses. So far no cheaper method has been evolved.

*Transportation of cane.*—Transportation of cane is of great importance in the cane sugar industry. It controls the supply of cane to the mill. In countries, where transportation system is good, a regular and steady supply of cane to the mill is assured. It is this fact, that directly

affects the efficiency as well as the fuel problem of sugar factories. In all transportation systems, it is essential to deliver the cane to the mills in as short a time as possible, after it is cut, because the raw material is of such a character that it is liable to deterioration, which starts from the time the cane is cut. Hence in order to minimize loss through this source, cane has to be delivered to the mill in the shortest time possible. Besides, the raw material is of a bulky nature, and hence cannot be carried over long distances without incurring great expense. So far the maximum distance of transportation from the field to the factory, that I saw, was about 10 miles in Cuba. The greater the distance of transportation the greater the area the factory can command, and the greater will be the size of the factory and the less the overhead expense. On the contrary, the greater the distance of transportation, the more expensive it is to transport the cane. The economic distance of transportation will depend on the cost of transportation per ton of cane to the factory.

In order to know the transportation system that will be suitable for conditions in India, it is necessary to know the conditions under which the different systems work. There are about 6 principle systems in use in the various sugar countries. They are (1) bullock carts, (2) traction car system, (3) cane flumes, (4) wire trolley, (5) canals and (6) railroad.

1. *Bullock carts.*— This system is used to a very limited extent. When cane fields are situated very near the factory, cane is sent directly to the mill through bullock carts. In countries, where portable track is not used as is the case in Cuba, where the maximum distance from the field to the nearest switch may be about 3,000 feet *i. e.*, a little over half a mile, cane is loaded in bullock carts in the field, and carried to the nearest switch, where it is weighed, before it is put in the railroad cars. In Cuba the use of ordinary wheels to cane carts is attended with breaks and temporary stoppages. Besides, when there is mud in the field and on roads due to rain, which sometimes happens, it is difficult to use these carts. To obviate this difficulty, truss wheels are used on some estates. They work like a caterpillar. They carry more load, are durable, and work satisfactorily, even when the fields are wet. However,



the truss wheels are very expensive in first cost and might prove economical in countries like Cuba, where both labour and material is expensive.

The cane is lifted from the bullock carts by passing chains below the cane, and lifting the whole load. For this purpose, an overhead carrier operated either by a team of oxen or an engine is used. As the load is lifted in the air, it is weighed and is then transferred to the car. This weighing is essential, as the planters are paid on this weight. A second weighing is done at the mill to serve as a basis for chemical control.

2. *Traction car system.*—This system is used to a very limited extent in Hawaii. Its use is limited to localities, where railway transportation is not possible. In this system a number of wheel carts loaded with cane, are driven by a traction engine or a motor engine on a public road. This system is an alternative to the railroad system, and is in no way a good substitute.

3. *Cane flumes.*—Fluming is the sole system of transportation used in the north and south Hilo Districts of the island of Hawaii. Considering the topography of the land, and specially the deep gulches that traverse the country, it seems to be the most economical and satisfactory system for conditions in Hawaii to-day. The two necessary conditions to operate this system satisfactorily, are a steep gradient and an abundance of flowing water, both of which are present in the Hilo District. There is plenty of rain, and mountain streams are running most of the time, which can be easily used on the fields on account of the gradient. Cane does not need any irrigation.

Cane flumes consist of V shaped wooden gutters or troughs placed upon light wooden trestles, so graded as to give the necessary gravity to the flow of water, in which the cane is placed. In this way, cane is carried over deep gulches and ravines. Portable flumes are used to transport cane from the field to the main flumes, from which it is taken to the mill. Portable flumes, however, are responsible for the flume jams, which cause an irregular supply of cane to the mill. On account of this, permanent main flumes

are being extended on the estates. One estate has erected an Armco iron flume. It is considered to be an ideal cane flume, as not only it is water tight, but the cane flows more rapidly. It is, however, very expensive in initial cost.

On some estates the flume water is used for generating electric power which operates pumps and centrifugal machines.

The fluming system extends anywhere from 9 miles to as high as 60 miles in length. The comparative cost of transportation on one estate was as below:—

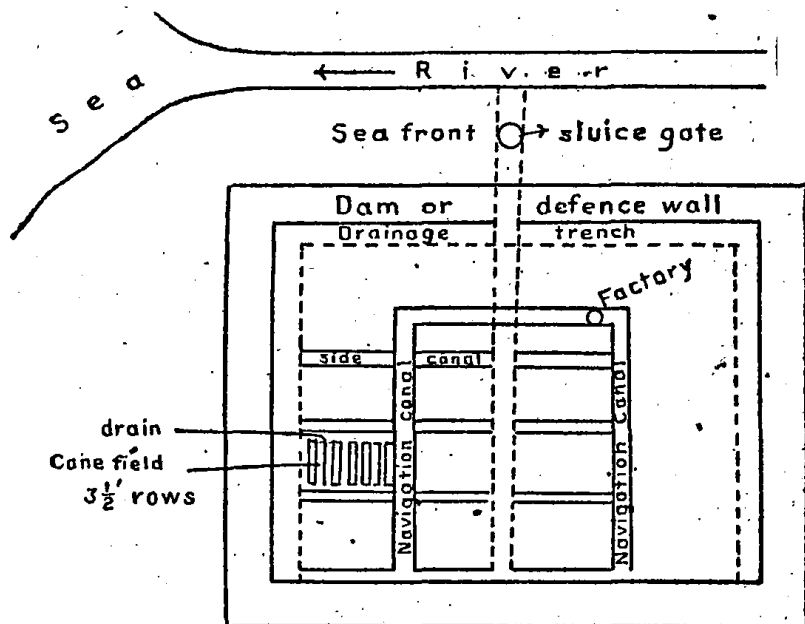
	Track. \$	Portable flume. \$	Main flume. \$
Cost per ton of cane ...	0·470	0·601	0·585

On different estates the cost varies from 50-70 cents per ton. Considering the average distance of transportation, this is more expensive than the rail road system. It is in operation only in Hawaii and cannot be used in other places. This system, however, is much more slow than a railway system.

4. *Wire trolley system.*—On some estates, small loads of cane are transported by wire trollies over deep gullies. The cane is carried to the main station, where it is delivered into railroad cars. This system requires a steep gradient to give a proper speed to the load and is used, where flume system is not practicable owing to shortage of water for fluming. This system is used to a limited extent and is confined to a few estates in Hawaii.

5. *Canals.*—This system is used in British Guiana and to a limited extent in Louisiana, where river transportation is possible. In British Guiana, land on which cane is grown, is situated along the coast, which is below the level of the high tide of the sea. Besides rainfall is much more than is required. Consequently drainage is a big problem in British Guiana. In order to prevent the inrush of tide water on cane fields, sea dams have to be maintained. Besides purposes of drainage, irrigation and transportation, numerous canals, drains, and cross drains have to be maintained. Water is used for irrigation in case of drought. Every estate has generally a reservoir of water, which supplies water to the navigation canal. Drainage is usually obtained by open drains with a natural outflow into the sea or river through sluice gates, which are closed during the

period of high tide. The following sketch gives an idea of a lay of a cane estate in British Guiana:—



The cane is loaded in punts kept in side canals. From the field to the punt cane is carried on head, the distance being not more than 200 feet. Punts are small rectangular shaped barges 8' X 28' X 3' with wooden bottom, each punt holding on an average 3 tons of cane. Usually 6 punts are driven by a mule, which walks along the side of the navigation canal to the factory. It should be remembered, that there is practically no flow to the water in the navigation canal and transportation is easy. This is the cheapest of all the transportation systems, though not as rapid as the railroad system. The cost of transportation per ton of cane on some of the estates was as below:—

		-1	
		Cents.	Cents.
Loading	...	19	10
Labour for transporting	...	3·0	6
Cost of transportation exclusive of cost of punts.		<hr/> 22	<hr/> 16

The essential feature of this system is an abundance of water with as little flow as possible, and a network of navigation canals, which are owned and operated by the company. In India we have irrigation canals owned by the State, but these cannot be used for transporting cane, because the canals are not flowing all the days during the grinding season, which is necessary if they are to be used for transporting cane. Secondly, there is a current to the water; consequently canals can be used for transporting cane only from fields situated to the upper end of the canal to the factory. For fields situated to the lower end of the canal from the factory, cane has to be carried against the current of water, which means more power. Thirdly, a canal will have to be dug from the irrigation canal to the factory for which extra water will be necessary. In case it is not done, cane will have to be carried from the fields to the punts in the irrigation canal, and again transferred from the punts to the bullock carts or any other means of transportation to the mill, because it is not possible to have a net work of navigation canals, unless there is an abundance of water. This loading and unloading of cane will be very expensive. Besides, the presence of water in the navigation canals will affect the drainage of the land considerably. Taking all these things into consideration, the use of irrigation canals for transporting cane from the fields to the mill is not practicable on the Deccan canals.

6. *Railroad system.*—This is the standard system of transporting cane used by majority of the factories. The other systems are used in countries, where railroad transportation is not possible either on account of the topography of the land, as is the case on the island of Hawaii or on account of economy. There is no doubt, that railroad transportation is the fastest, and cane can be brought to the mill in the shortest time possible, thus reducing the loss through deterioration to a minimum.

In the majority of cases, the railroads are owned and operated by the company. In fact the building of the railroad was necessary to transport cane to the factory. In certain parts of Cuba, in Porto Rico and Louisiana, there are public railroads, which are used for transporting cane. In Cuba, it is common under such circumstances to own either locomotives or cane cars or both, in which case the use of railroad is hired. This is done with the object of

having the transportation under the control of the estate so as to be able to regulate the cane supply. In all other countries, railroads are owned by the company. From the point of security of cane supply, the ownership and the operation of the railroad by the company is the best, though it is more expensive than the public or State ownership. Where public railroad is available, it is better to own cane cars and locomotives, so that transportation will be under the control of the company. In Cuba where both the systems are in use, the relative cost of transportation is as below:—

*Cuban railroad.*—35 cents a ton for 40 kilometers (*i.e.*, 0·88 cents per ton per kilometer), less 30 per cent. if locomotives are owned by the company, less 10 per cent. if cane cars are owned by the company. This works at 35, 24·5, 31·5 cents per ton of cane for 40 kilometers or 0·88, 0·61, 0·79 of a cent per ton of cane per kilometer, respectively.

*Company railroad.*—2 cents a ton per kilometer for 25 kilometers. Thus, though the transportation by the company railroad is more expensive, it is considered desirable from the point of securing a control in the matter of cane supply.

The gauge used for the railroad varies a good deal. So far there is no standard practice. It, however, depends upon the size of the factory and upon the gauge used by the public railroad, if it be in the vicinity. The standard gauge is used by very few factories. There are of course many advantages with a standard gauge railroad. The cane cars are big and have a greater capacity, being about 20 tons of cane per car as against 10 to 12 tons with metre gauge cars. Besides, the locomotives have a greater carrying capacity. Consequently the charges of maintenance, interest, depreciation, &c., are comparatively much smaller with standard gauge railroad. It is, however, more expensive in initial cost, and unless the factory is very big, or unless there is a prospect of developing the country and encouraging more traffic, it will be more expensive. In Cuba, where the factories are very big with a grinding capacity of 2,000 to 8,000 tons of cane per day, standard gauge is used only by modern centrals or by centrals situated near the Cuban railroad. All other centrals use the meter gauge, because they were constructed at a time when meter gauge was in common

practice, though it is now recognized that standard gauge is more economic in the end.

In St. Kitts and Antigua, the railroad is constructed by the company. There is no public railroad as the islands are small and there is no other traffic for the railway except the transportation of cane. Under such circumstances, standard gauge would have been more expensive. In these two islands 30" gauge is used. The total length is about 25 miles, the weight of the rails being 30 lbs. per yard. The cane cars are of small size, each carrying about 3 tons of cane. 12 ton locomotives are used for drawing the cane cars, each locomotive having a capacity to draw 60 to 80 tons of cane or about 20-25 cars. For small size plant with about a 1,000 ton grinding capacity, this will be a cheaper system, especially when the railroad can expect to secure no other traffic.

For conditions in India railway transportation is the most suitable. The gauge that should be used depends upon the gauge of the public railroad in the vicinity of the factory. In India railroad can secure lot of other freight besides cane and sugar. Farmers in India do not grow cane only, as is the case in other countries, but grow rotation crops as well. In the sugar cane districts, a great quantity of fertilizer, such as oilcakes, fish and mineral fertilizers, is required which demands transportation. Besides transporting cane, factories will have to ship their sugar through railroad cars to distant places. Most of the factories are and will be situated in the interior, and as all the sugar is consumed in the country, it is desirable to have the same gauge as is used by the nearest railroad so as to be able to ship the sugar and molasses directly without any transshipment to distant places.

In India the construction of a railroad is not an easy matter, because it involves the ownership of land which the farmers are generally unwilling to sell. This is one of the matters in the sugar industry for which a State help is necessary in procuring land for constructing a railroad, which, I believe, can be obtained.

The cost of transportation varies in different countries, depending upon local conditions of labour, material and distance of transportation. The following figures for the year 1922 are given solely as a matter of information:—

On the public railroad in Cuba: 35 cents per ton of cane for 40 kilometers, less 30 per cent. for locomotives, less 10 per cent. for cane cars.

On private railroad owned and operated by the company: 50 cents per ton of cane for 25 kilometers.

On public railroad in Porto Rico per ton of cane.

Kilometers.	cents.
5-10 ...	39
10-15 ...	45
15-20 ...	50
20-25 ...	55
25-30 ...	69
30-35 ...	62
35-40 ...	62

St. Kitts: average distance of transportation 6 miles *i.e.*, about  $9\frac{1}{2}$  kilometers  $\frac{2}{3}$  (shillings) per long ton of cane equal to 57 cents per short ton of cane.

The figures worked on the basis of cost per short ton per mile are as below:—

Public railroad in Cuba . . . . .	1.5 cents (based on 40 kilometers).
Company „ „ „ . . . . .	3.2 cents (based on 25 kilometers).
Public „ „ Porto Rico . . . . .	2.5 cents (based on 40 kilometers).
„ „ „ „ . . . . .	4.0 cents (based on 20 kilometers).
Company „ „ St. Kitts . . . . .	9.5 cents (based on $9\frac{1}{2}$ kilometers).

It is obvious from above that as the distance of transportation increases, the cost per ton of cane per mile decreases, though the total cost of transportation per ton of cane at the mill goes higher. In Cuba, the installation of big factories, unheard of in any other part of the world became possible mainly on account of cheap and rapid transportation, which has made it economically possible to obtain sufficient supply of cane from longer distances, and I believe, the provision of a good transportation system, which will be cheap and rapid, and also under the control of the factory, if that be possible, is an essential factor in the successful operation of a modern sugar factory.

## IX. Unloading of Cane.

When the cane cars come to the factory yard, they are weighed, before they are unloaded. The different unloading devices, in use in different countries are: (1) a grab and a derrick, (2) cane rake, (3) chain sling and a hoist, (4) Wick's unloader, and (5) car dump.

(1) *Grab and a derrick.*—This device is commonly used in Louisiana. It consists of a long horizontal beam mounted on a steel frame, to which a grab is attached. The steel frame, and along with it, the beam, pivots upon a gear wheel, and makes a complete circle, so that cane can be unloaded in any direction. The grab is suspended by wire cables, and moves back and forth by means of 4 wheels moving on the beam. Generally a two cylinder steam engine is used to drive the derrick and the grab. In some factories, electric power is used to operate the derrick.

As the cane cars come in the yard, the grab is lowered from the derrick into the car. Grab consists of curved pointed strong teeth, usually about 8 in number, which can be made to open and close at will. After the grab is lowered into the car, on account of its own weight, and also the sharpness of the teeth, it pierces through the mass of canes, after which the teeth are closed and the grab lifted up, which brings up a load of cane about 3 to 5 tons at a time. This is then delivered to an inclined platform, from which cane is fed to the cane carrier by a simple mechanism.

This system is rather complicated, and requires an intelligent handling. The advantages of this system are: (1) It does not require any special type cars for carrying cane. Any cars, with an open top, can be used. In Louisiana, where the public railroad transports all the cane, and where the grinding season is of a short duration only two months, the use of special cane cars with movable side doors would have been expensive. (2) It becomes necessary to empty the loaded cars, as early as possible, on the public railroad system in order to avoid the charge of demurrage. Many times it is not possible to unload all the cane, either on the raised platform or on the cane carrier, which has, therefore, to be unloaded on an open ground. The grab can be reused to lift the cane to the cane carrier, which cannot be done with other devices.



(2) *Cane rake*.—This device is in use in the West Indies, and to a limited extent, in Hawaii. This consists of a number of chains passing over gear wheels, to which are attached small forks. The rake is either driven by steam engine or a motor through a belt and a pulley or preferably through a sprocket and a chain. As the cane cars come near the cane carrier, the side door of the car is opened and the rake lowered, which, on account of the motion of the chains and the forks, pulls the cane from the car to the carrier. This is a very simple device, easy for operation and usually does not give any trouble. Sometimes either the forks go out of shape or the chain gives way, which causes temporary stoppage. In order to avoid this, the usual practice is to provide a duplicate rake. This device is not so expensive as the grab, but it requires cane cars with movable doors, and can be used only for transferring cane from the car to the carrier.

(3) *Cane sling and a hoist*—This system is used on some estates in Porto Rico, British Guiana and Java. The hoist consists either of the usual derrick or of crane (in Java a travelling crane, used in the mill house, is used for this purpose), which lifts the cane load in a sling. As the cane cars are brought near the cane carrier, about 3 or 4 chains are passed underneath the cane, and the load lifted by the crane and dropped either on the inclined platform made specially for the purpose or on a side cane carrier. In Java, the former is the practice. The cane is then fed to the cane carrier by means of a fork, which is operated by an engine, backwards and forwards. The fork catches the cane and pulls it to the cane carrier. In British Guiana, instead of a crane, a derrick is used, to which, instead of a grab, a cane sling is attached. Chains are passed underneath the cane in the punts, before they are loaded. When punts come to the mill, the chains are attached to the derrick, which lifts the cane, and unloads it directly on a special platform, on which it is weighed, before it is fed to the cane carrier. If the carrier is already full, and if many punts are waiting, the load is left on the ground with the chains, to be refitted whenever necessary. For conditions in British Guiana, where cane is brought in punts, this is an excellent device, as it permits weighing of the cane, which majority of the factories do not care to do. This device requires a number of chains for preparing the slings.

(4) *Wick's unloader or 'Reciprocating mechanical finger'*.—This is to a great extent used in the Hawaiian islands. This is the simplest device, I saw, so far for unloading cane. It consists of a fork consisting of 3 or 4 powerful teeth, the fork being attached to wooden beam, suspended by means of cables. The beam is made to move backwards and forwards by means of a connection of the cable to the engine through pulleys. The direction of the motion is controlled by means of a shifting gear, operated by hand or more conveniently by a foot. The up and down motion is secured by a handle turned by hand. For smaller plants of 1,000 tons grinding capacity or less, this is the simplest and cheapest device. Only one man operates the mechanism which works well. There is nothing to get out of order, except occasionally the beam may break. As the device is not expensive, a spare set can be provided. I did not see this device in use in any other country besides Hawaii. It requires cane cars with movable side doors.

(5) *Car dump*.—This system is used largely in Cuba. All other devices are found to be too slow for the big factories in Cuba, and so far as the rapidity of unloading is concerned, this is the best system so far. After the cars are weighed on a platform balance, they are taken to a tilting platform, to which they are firmly secured by means of two chains attached to the platform and the side of the cane car. The platform is then tilted sideways, when the cars become inclined, and on account of the weight of the cane, the side doors of the cars, which operate on hinges at the top, are thrown open, and cane falls directly on the side cane carrier. The cars hold anywhere from 10-20 tons of cane depending upon the size of the car and the gauge of the railway. It takes about 3 minutes to do this operation. On account of the dumping of the whole car, it becomes difficult to regulate an even feed of cane to the mill. In order to secure even feed, it is a common practice to provide a side cane carrier preferably at right angles to the main cane carrier on which the cane is dumped. It is very easy to regulate the cane feed on the main cane carrier.

There are two systems of cane dump in use in Cuba—the side dump and the end dump. In the former cars are dumped on the sides, and in the latter at the end. The side dump works much quicker and is more convenient and is commonly used. End dump is seen only in old factories and is being replaced by the side dump.

The tilting platform is either worked by a hydraulic ram or by a gear operated by an electric motor. The hydraulic ram is very common. The other device is of recent introduction. The hydraulic power has been found to be satisfactory, in spite of the fact that the leather packings sometimes give way and cause temporary stoppage. The other device does not give this trouble.

The car dump device is the best for bigger plants, where rapid unloading is desired, but will be expensive for smaller plants.

For factories in India, the cane rake or the Wick's unloader will be suitable on account of its ease of operation, simplicity of design, less expense in first cost and ease of repair. Factories equipped with electric power, can use a motor for driving the unloaders with advantage.

#### X. Extraction of Juice.

*Diffusion process versus multiple milling.*—At the present time sugar is extracted from cane by means of multiple crushing in the mills. This is the system exclusively followed in the various cane sugar countries such as Louisiana, Cuba, Porto Rico, West Indies, Hawaii, Java and Mauritius. A few years ago, before the evolution of modern mills, whereby high extraction became possible, the diffusion process, probably, because, of its use in the beet sugar industry was being thought of by a number of factories, and was in operation in quite a few ones. The greatest advantage, that was claimed at that time was the high sucrose extraction of 98-99, thought to be impossible with the mills then in existence, which could hardly extract 90 per cent. of the sucrose present in the cane. With the possibility of extracting so much of the sucrose, and thus ultimately increasing the yields and the profit, the installation of the diffusion process for extraction of sugar was clearly indicated, which set the mill manufacturers to think about improving the mills, as a result, the present system of multiple crushing and maceration was evolved, which completely eclipsed the advantages of the diffusion process, and ultimately led to almost its total abolition in the cane sugar industry.

The two chief advantages claimed with the diffusion process were: (1) the extremely high sucrose extraction and (2) the better quality of the juice. It should be

remembered, that, in the diffusion process, a far greater quantity of water was required to extract 99 per cent. of the sugar in the cane, and, on account of the process of diffusion, which consisted in the passing of the crystalloids through the cell membrane, a better quality of the juice could be obtained. The colloids, which mainly consist of the albuminoids, the colouring matter, pectins, &c., were eliminated, from the diffusion juice due to their impermiability to the cell membrane. With the evolution of cane crushers and shredders, and multiple system of milling together with the system of maceration, which made it possible to use as much as 50-60 per cent. maceration water, extraction of 99 per cent. and more, became possible. The Paia mill of the Maui Agricultural Company in the Hawaiian islands, made a record of 99.35 per cent. sucrose extraction with the use of mills alone. Thus, the important claim of the diffusion advocates was practically set aside by the evolution of multiple system of milling. With regard to the second point, the juice, obtained through milling, was never expected to be as pure as the one obtained through a diffusion process. In fact, high extractions obtained through milling, are accompanied with more impurities in the juice, chiefly due to the complete disintegration of the cells, and, in this respect, the claim of the diffusion advocates still holds good. It should be remembered, however, that in the diffusion process, cane has to be cut into slices, and in actual practice, rupture of the cells is common, which causes the extraction of sugar by the process of dilution rather than that of diffusion, thus increasing considerably the impurities in the juice. Thus in actual practice, this advantage is not secured to the extent that it is claimed.

The chief point, which practically knocked out the diffusion process from the cane sugar industry, is the fuel problem. With diffusion, larger quantity of water was necessary, which demanded more fuel on account of the extra evaporation. Secondly, the cane chips obtained in the diffusion process contained so much moisture, that their use, as a fuel in the furnace, was not possible, unless special means were employed to remove the moisture both by crushing and drying, which was too expensive.

During my visits to various sugar countries, I saw, only one estate Caroni in Trinidad, where a combination of milling and diffusion or more appropriately called 'digestion' was in use. The mill tandem consisted of a national shredder

and 2 mills only. Cane was fed to the shredder, and the bagasse from the 1st mill was taken to a battery of digestors, was then fed to a second mill, from which bagasse was used for burning in the furnaces. The juice from the mills (shredder and 1st and 2nd mill), after it is sulphited, limed, and heated, was used for digestion, dilute juice and water being used later on to exhaust the bagasse. Thus in this process, bagasse was used not only for digestion but also as a filter, for separating the precipitated mud. No filter press was used. This looks to be a very ingenious process, but unfortunately was not giving good results.

*Mill tandem for conditions in the Deccan.*—A mill tandem consists of crushers, shredders, and a number of mills. The number used in each tandem shows a great variation in different countries. In Louisiana and British Guiana a mill tandem consists of a crusher and 3 mills, *i.e.*, 11 rollers in all. In Cuba majority of modern mills are equipped with a double crusher and 5 mills, *i.e.*, 19 rollers in all. In the West Indies, majority of plants use a crusher and 4 mills. The same is the case with Hawaii, while, in Java, a mill tandem of a crusher and 4 mills is getting common.

So far, the limit has gone to the use of a double crusher and 6 mills. The most modern mill in Cuba, Central Jaronu installed in the year 1922, has a double crusher and 6 mills. Leaving aside Cuba where special conditions prevail, the modern tendency is to use a mill tandem of a crusher and 4 mills. This seems to be the economic limit in a majority of cane sugar countries.

The size of the mills, in use, depends upon the capacity of grinding that is desired. After a mill tandem is decided for any particular factory, size is decided according to the desired grinding capacity. Usually, the size of the mills is expressed in inches, the first figure representing the diameter of the roller and the second, its length. The smallest sized mill, I saw, during my travel, was at plantation Providence in British Guiana, the size being 26" x 48". The largest size, so far in use, has 36" x 84" rollers. This is also called the standard 7 foot mill. All intermediate sizes are in 6 inch lengths. A mill tandem, consisting of a double crusher and 6 mills of 36" x 84", can grind up to 3,000 tons of cane in a day. This is the maximum capacity of a mill tandem

obtained so far. When a greater grinding capacity is desired, it is secured by putting another tandem. Thus in Cuba factories, grinding 6,000 to 9,000 tons in a day, have put up more than one mill tandem. So far no attempts to my knowledge have been made to build rollers of larger length than 84". It should be remembered, that, the size of a mill has nothing to do with sucrose extraction, but has to do only with capacity. The following figures, obtained from various mills in use, show how capacity increases with the size. In addition to size, the capacity would depend on the fibre content of the cane, and the amount of maceration water used, figures for which are given in the statement:—

Size.	Equipment.	Tons of cane per day.	Per cent. fibre in cane.	Maceration per cent. cane.
30" x 48"	1—3 RC and 3 mills	450	12.5	35.0
30" x 60"	1 C and 3 mills	600	12.9	35.0
34" x 78"	Do.	1,100	11.0	20.0
30" x 60"	1 C and 4 mills	700	12.0	20.0
32" x 66"	Do.	900	12.9	27.5
32" x 72"	Do.	1,100	12.5	35.0
34" x 78"	Do.	1,300	11.0	20.0
36" x 84"	Do.	2,000	11.4	13.8

R = Rollers ; C = Crusher.

From my study of the different units in use in the various countries, I find, that, the choice of a unit depends mostly on the sucrose extraction, either desired or economically possible, and to a certain extent on capacity. It is known that, when bagasse from the mills is subjected to repeated pressure (it may be the same or increased pressure), at each time it parts with some part of the juice held by it. This is, in fact, the principle of multiple crushing. If, with these repeated pressings, a certain amount of water is used, before the pressure is actually applied, on account of the dilution caused, a greater quantity of the juice, and along with it, a greater amount of sugar are extracted by it. This is the theory of maceration. In this way, the amount of sucrose extraction can be increased to any extent desired, by

means of repeated pressings or in other words, by multiple crushing and maceration. But there is a limit, beyond which it is not economically possible to go. With less number of mills, a great quantity of maceration water will have to be used in order to secure higher extraction, because the number of repeated pressings are few. Besides, in actual practice, it is not possible to use large quantity of maceration water, with a 9 roller mill, as it causes more choking and loss in capacity. As the number of units increase, say, from 3 to 4, 5 or 6, the number of repeated pressings is increased, the possibility of using dilute juices for maceration or also called 'compound maceration', becomes obvious, and consequently a higher sucrose extraction is secured with comparatively very little maceration water. This is of great importance in countries, where high sucrose extractions are necessary, but, where sufficient bagasse will not be obtainable on account of the low fibre content, if a heavy maceration is practised. At the same time, it should be noted, that, the addition of more mills increases the first cost as well as upkeep. That seems to be the chief reason, why a great majority of the factories in all cane sugar countries except Cuba, have not gone above a unit of a crusher and 4 mills.

The economic limit of extraction depends upon many factors, chief amongst which, are the fuel and the price of sugar. It should be remembered, that increased extraction is secured both by the use of more mills and more maceration water. The use of more mills in a tandem means the use of more steam power for driving. More amount of maceration water increases the evaporation on account of the dilution of the juice, which means more fuel. If the factory has surplus bagasse or cane leaves to burn, increased evaporation will not require any expense in fuel, in which case, the economic limit of extraction will be certainly higher. Factories, having cane with a high fibre content, as is the case in the West Indies and Hawaii, practise a higher maceration in order to obtain higher sucrose extraction, but the higher fibre content gives sufficient bagasse to do the extra evaporation. In countries, where cheaper sources of fuel are available, the economic limit of sucrose extraction depends upon the price of sugar. The increased expense of fuel, caused by higher extraction, must be justified by the increased return. The economic limit of sucrose extraction is thus different for each country, depending upon local conditions

of sugar market and fuel supply. Sucrose content of the cane is another factor, which affects the economic limit of extraction.

It would be worthwhile to know the actual conditions obtained in different countries. In Louisiana, the sucrose extraction rarely goes above 91 per cent. In Louisiana, cane is of a low sucrose content, containing a low fibre, and yields a very dilute or watery juice. Even, with this extraction, fuel oil, to the extent of 5-6 gallons per ton of cane, has to be used. Any increase in extraction will be accompanied with a heavy maceration, which will need extra fuel. Besides, a unit of 3 mills does not permit an excessive maceration. Thus the low sucrose content, the poor quality of the cane, accompanied by a low fibre, does not justify a higher extraction.

In Cuba, where the greatest number of mills are used in a tandem, the sucrose extraction does not go above 95 per cent, which is not very high, if the number of mills is taken into consideration, but there, it seems the number of units is increased more for capacity than for sucrose extraction. In Cuba, the factories have much more cane to grind, which must be done within a specified time, and consequently efficiency is sacrificed for capacity. Nowhere else, the mills handle more cane than they do in Cuba. In Hawaii and Java, a slow grinding is the practice. Besides, in Cuba cane contains a low amount of fibre, which does not permit a high maceration, on account of the extra fuel that may be necessary. In fact, the modern practice is to secure a high extraction with as little maceration as possible, by using more mills, and using a higher hydraulic pressure on the mills. Central Alto Cedro, equipped with a double crusher and 5 mills of 34" x 78", extracts on an average 94 per cent. of sucrose in the cane with only 4.8 per cent. maceration, the fibre content of the cane being 10.1 per cent. So far it is not considered economical to extract more than 95 per cent. of the sucrose in cane in Cuba.

Hawaii is the only country, which has established world records with regard to sucrose extraction. While majority of the mills extract more than 98 per cent. of the sucrose in cane, one mill has made the highest record of 99.35 per cent. sucrose extraction. Majority of the mills in Hawaii have only a crusher and 4 mills, and such heavy extractions are



obtained with a maceration of 35-45 per cent. on the weight of the cane. The juices in the Hawaiian islands are rich and of a higher density, and cane contains a high fibre (about 13 per cent.). Consequently sufficient fuel is available to do all the extra evaporation. In case it is not sufficient, a part of the exhausted molasses, which is practically a waste, is used as a supplementary fuel. Thus beyond the expense of doing the extra evaporation, there is no extra cost of fuel. Secondly, in Hawaii a large amount of expense is incurred in raising a crop of cane, chiefly due to high cost of irrigation and high priced labour, and, to my mind in any country, where the raw material is very expensive, a higher recovery is economically necessary. That is the chief reason why Hawaiian manufacturers have to do their best or recover as much sugar as possible. A third special feature of the Hawaiian islands is the market. All the sugar from Hawaii goes to the United States free of import duty, which is itself a big protection. At present United States practically controls the raw sugar market, and Hawaiian manufacturers are therefore, able to get the highest price, that is possible for raw sugar. These facts are of so much consequence as to justify the very high extractions obtained there.

In Java, majority of the mills obtain 92-93 per cent. extraction. Some new mills extract as much as 94-95 per cent. There cane contains about 13 per cent fibre, which consequently supplies some surplus bagasse, but as many factories make white sugar directly from cane, either by the sulphitation or sulpho-carbonatation process, which demands more fuel, there is not so much bagasse as to do the increased amount of evaporation, if more maceration is practised. So far the limit has not gone above 95 per cent. extraction.

With the exception of Hawaii, the economic limit of extraction in all other countries has so far been 95 per cent. of the sucrose in cane, which is obtained with a mill tandem consisting of a crusher and 4 mills.

Cuba seems to be the only country, where more mills are used in a tandem with the purpose of increasing the capacity. This has been secured by using a double instead of a single crusher, and 5 or 6 mills, and by running the mills faster. Incidentally it has increased the average extraction, which was expected on account of the increased number of pressings and a system of triple compound maceration. The following

comparative figures show how both capacity and extraction has been increased by increased number of mills in a tandem:—

Mill tandem.	Size.	Grinding capacity.	Sucrose extraction.	Maceration per cent. cane.	Fibre cane.
		Tons.	%	%	%
1C and 4M	86" x 84	2,000	93.5	13.8	11.4
1C " 5M	"	2,400	94.0	5.5	10.6
2C " 5M	"	2,650	93.9	24.6	11.5
2C " 6M	"	3,000	95.0	17.4	10.8

C = Crusher.

M = Mills.

A problem often arises as to the best means of increasing the capacity of milling in an already established factory. This is usually solved by installing an extra mill, which increases both capacity and extraction.

Taking the above facts into consideration, what will be the suitable unit for conditions in the Bombay Deccan? The cane grown on the Deccan canals, contains 14-15 per cent. sucrose and 10.5-11 per cent. fibre. On account of the low fibre content, and on account of the manufacture of white sugar, which demands more steam, the amount of bagasse will not be enough to run the factory, unless economy in steam consumption is secured, importance of which is discussed in a later chapter. This means, a limited amount of maceration will have to be practised, which may not give an extraction of 92 and above, if only a tandem of a crusher and 3 mills is used. Elsewhere, I have shown how necessary it is to extract as much sugar as is economically possible in the Bombay Deccan, where the profits of the factory would depend upon the difference in sucrose extraction, obtained by the farmers with their bullock driven mills, and that obtained by the factory with modern mills. The more the extraction without the use of additional maceration water, the more is the margin of profit, which is possible with a system of compound maceration. The sucrose content of the cane is high, which will justify a higher extraction. Taking these facts into consideration, the economical unit for Deccan conditions is to have a crusher and 4 mills. With a crusher and 3 mills,

the amount of maceration water required will be more than that required with a tandem of 4 mills if the same extraction is to be secured. The saving of maceration water with a four mill tandem, is not only due to two extra pressings, but with it, a double compound maceration is possible, which is more effective. Thus, in order to satisfy both the conditions, the desirability of obtaining a higher sucrose extraction without much additional water, and the saving of the fuel expenditure that may be necessary, in case higher extraction is obtained by means of more maceration water, the most economical unit will be a tandem of a crusher and 4 mills. In Northern India, where cane is low in sucrose content and fibre content is high, it is not necessary to go beyond 3 mills, but a double crusher will be very helpful in preparing the cane to a satisfactory degree, before it passes on to the mill. This will increase the efficiency of the mill considerably.

As regards the size of the mill, this depends entirely on the capacity that is desired. A mill of 30" x 60" will be sufficient to give a capacity of 500 to 700 tons of cane a day.

*Cane Carriers.*—After the cane is unloaded from the railroad cars, it is elevated to the crusher chute by means of cane carriers. These consist of inclined horizontal continuous aprons made of either wooden or steel slats with steel plate sides. In order to secure a regular feed to the crusher, it is necessary, that the supply of cane be regulated on the cane carrier itself. The irregular feeding of cane to the crusher causes choking, sometimes cane slip in the first mill, and may even cause temporary stoppage. In Louisiana and Java, the supply of cane to the cane conductor is regulated by providing an inclined platform, on which the cane from the cars is unloaded, from which it is fed to the carrier. In Cuba, where the whole car is dumped right on the cane carrier, regularity of feeding is secured by the provision of two cane carriers, the cross cane carrier on which the cane car is dumped, and the main cane carrier, to which cane is regularly fed from the side cane carrier. Usually the side cane carrier is at right angles to the main cane carrier. This is the best system for big plants. In the West Indies and Hawaii, though cane is unloaded directly on the carrier, the feed is partially regulated by means of unloaders, and partly by means of rotating knives, which cut irregular pieces of cane and help to secure an even feed to the crusher. This is the best

system for smaller plants, especially when cane supplied to the mill is not straight, but is expensive both on account of power required to drive the same as well as on account of upkeep. Any piece of iron or stone coming with the cane, dulls the edges of the knives and may even break the same.

The cane carrier is usually driven by a separate engine, usually a two cylinder engine, through a set of gears. In some cases, the cane carrier is driven through a connection to the crusher. The former method is very good, as it is very elastic and feed control is very good. In the latter method, the speed of the cane carrier cannot be regulated, as it depends upon the crusher. In both the cases, feeding can be stopped at any time very easily.

The cane, as it comes from the field, is accompanied with a lot of dirt, consisting of dry leaves, and earth. The latter impurity causes a great trouble later in the evaporators. Though it is true, that a part of the mud, that enters the factory along with cane, is removed with press cake, a part of it goes along with the juice, and is ultimately deposited in the evaporators as a silica scale, which is difficult of removal. In Louisiana, where on account of the rains prevailing during the grinding season, cane is very dirty on account of the mud accompanying it, a few factories wash the cane by means of perforated water pipe fixed across the cane carrier. This washes the cane, as it passes along the cane carrier on to the crusher chute. In British Guiana, where similar conditions prevail, only one factory recently started this method of washing the cane, with the result, that the factory was able to remove 157 lbs. of solids containing 40 lbs. of silica per hour from about 45 tons of cane. This is certainly a great improvement, as it eliminates, to a great extent, impurities, which would be ultimately deposited as a scale in the evaporators. It will be to the greatest advantage, if factories, making white sugar, wash the cane on the carrier before grinding. The device consists in providing a perforated pipe across the cane carrier. The flowing water, from the pipe, washes the cane, as it passes along the cane carrier. In Hawaii, I noticed the difference between the juice from the flumed cane, which is necessarily washed, and hence is clean, and that from the unflumed cane, which is not washed. The juice from the former is light coloured, while, that from the latter is dark coloured due to dirt. The device is so simple and inexpensive, that very few manufacturers have

paid any attention to this point. Its importance is obvious, specially when white sugar is to be made, which demands early elimination of the impurities.

*Regulation of the feed.*—The feeding of cane to the crusher is usually regulated by controlling the steam valve, which supplies steam to the engine that drives the cane carrier. A separate man is placed near the crusher, whose sole duty is to regulate the cane feed, which he does by opening or shutting the steam valve. This system is inexpensive and works alright, so long the man is attentive. In Cuba, where large mills are used, and where control of the feed is highly necessary due to large load of cane on the carrier, an automatic device is coming into use. This consists in suspending the cane hopper which directly controls the steam valve by its own weight. As soon as the weight of the hopper exceeds a certain limit, which is set once for all for the mill, it closes the steam valve, which stops the engine and thus the cane carrier. It works very well and is suitable for large plants.

In Hawaii it is a common practice to use a set of knives in order to secure an even feed for the crusher. The knives are set on a horizontal shaft, along which they rotate at high speed from 400 to 600 R. P. M. As the knives rotate, all the cane that comes within their path, is cut by the sharp edge. Any irregular piece of cane, that may be sticking out, is cut and a uniform layer of cane is secured. It is a common practice to use a double set of knives one set near the feed end of the carrier, and the other near the crusher chute. The number of knives varies in each set from 18 to 36. In Hawaii cane is of 20-22 months' age and is consequently crooked. Under such conditions knives seem to be a necessity. There is no doubt, that a set of knives secures a uniform feed of cane to the mill. In no other country, the use of knives is so common. In Cuba I saw only one modern mill, which was using a set of knives driven by a  $7\frac{1}{2}$  H. P. motor. This was used only for levelling the cane so as to secure a uniform feed. In Trinidad one mill was using a cane cutter consisting of 17 knives, running at 685 R. P. M., driven by a 25 H. P. motor. There is no question, that this is an excellent device for securing a uniform feed of cane to the crusher, thus securing good mill work, and reducing the stoppages. But the disadvantages are the expense and the upkeep. As the knives rotate at high speed, an electric drive becomes a

necessity. In smaller plants this is not possible. In Hawaii, where this device is very common, an electric drive is common. In one mill I saw steam engine being used for this purpose. In this case, a complicated system of transmission has to be used. This becomes expensive, and results in more loss of power. On account of this reason, the use of knives, though desirable, is not possible in factories, where electric power is not used.

The knives demand much power for driving. Besides, the edges of the knives constantly get dull, and many times are ruined by pieces of iron or stone coming along with cane. This increases the expense for upkeep. Where a fairly straight cane is obtainable, which is usually the case with a yearly cane, there is not so great a necessity for their use.

*Preparation of cane for milling.*—In order to secure smooth running of the mill, without any stoppages, due to choking, as well as, to secure efficient work with regard to sucrose extraction, it has been found quite necessary to prepare the cane for milling. In all modern mills high extractions have been obtained with the help of maceration water. In order to secure the best effect of the maceration water, a complete disintegration of the cane is necessary, so that water can well mix with the juice present in the bagasse. This preparatory work, so essential to good milling work, is secured by crushers or shredders or both in all modern mills. Crushers are used practically all over the world. Shredders are common in the Hawaiian islands only.

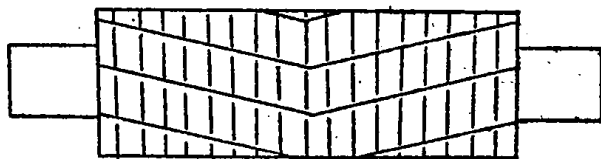
*Crushers.*— These consist usually of two rollers, set one above the other. They are usually set at an angle of about  $20^{\circ}$  or more to the vertical so as to ensure a perfect feed of cane to the rollers. The cane feed chute is also set up at an angle of about  $45^{\circ}$  so that a constant feeding of cane to the crusher rollers is secured. Pinions are placed on end of the crusher roller shafts in the same way as the mill roller shafts.

The grooving of a crusher roller is quite different from that of a mill roller. It is done in such a way as to secure cutting of cane into small pieces as well as to secure a partial disintegration. The way the rollers are grooved, is different in several types. The two most common types in use are the Krajewski and the Fulton. The Krajewski crusher has

diagonal meshing grooves on two opposite rollers. They are arranged in the form of V as shown below:—



The grooves in the two rollers are so arranged, that, when the crusher is set, the teeth of the bottom roller intermesh with those of the top roller. The bottom roller is also provided with deep fairly wide circumferential grooves, which pass across the V shaped grooves. These allow the escape of the expressed juice. In the Fulton crusher, the grooves are circumferential all along the surface of the roller. The grooves are wide having a pitch of 2 to  $2\frac{1}{2}$ . The ribs are cut across at a certain distance in such a way, that it forms the shape of a wide  $\vee$  across the roller as given below. The cuts in the ribs give a good grip to the cane as well split and tear the cane on account of the sharp edge. The grooves of the bottom roller are made deeper so as to secure an outlet for the expressed juice. Other designs such as the Dimond rollers, McNeil rollers, &c. are seldom used. I have seen the work of both the types of the crusher, and I find the work of the Fulton type is superior to that of the Krajewski. Not only it disintegrates the cane much better due to wide grooves and sharp cross cuts, but at the same time, it expresses a greater percentage of juice. In the Krajewski; cane is merely flattened. Though the object of the crusher is mainly the preparation of the cane for milling, some juice is always expressed by the crusher. The more the juice expressed by it, the better the milling obtained with the first mill, so that greater benefit is secured with maceration.



So far, the common practice to secure the preparation of cane for milling, is to instal a single crusher. This is considered sufficient. In Cuba, double crushers are commen-

used. There the mills have to do fast grinding so as to finish the same before the monsoon starts. The double crushers are used mainly with the object of increasing the capacity.

The following figures obtained from Cuban mills show how the double crusher has increased the capacity:—

	Tons of cane per hour.	Tons of cane per day.
Single crusher and 5 mills	107	2,568
Double do.	111	2,664

A double crusher naturally does better disintegration of the cane, and helps to a certain extent in obtaining better extraction. When a double crusher is used, very coarse grooving with 3" pitch is used for the first crusher, and little finer with 2" pitch is used for the second. So far I saw only one factory in Cuba using a triple crusher. This was also done with the object of increasing the capacity.

For conditions in the Bombay Deccan, where cane contains a low fibre, a single crusher is quite sufficient. Even in countries, like Hawaii and Java and the West Indies, where the fibre content is as high as 13-14 per cent., a single crusher has been found to be sufficient. In Northern India, where the fibre content goes as high as 16-17 per cent., a double crusher will probably be advantageous in securing better disintegration for the subsequent milling.

The crushers are divided into two general types according to the way they are set up, the high type and the low type. In the high type, the crusher is set up much higher than the first mill, so that the crushed cane is discharged to the first mill by an inclined chute without any intermediate carrier. In the low type, the crusher is set up practically at the same level as the mill and the crushed cane has to be lifted by means of intermediate carrier to the feed opening of the first mill. The high type is commonly used. It is much better than the low type, as it eliminates the use of a carrier.

*Shredders*.—As their name implies, they shred the cane only and do not extract any juice. The only type, which has so far been successful in the cane sugar industry, is the 'Searby' shredder. As said previously, Hawaii is the only country where a number of plants are equipped with 'Searby' shredders. In the West Indies, I saw it in use at one factory in Trinidad. Neither in Cuba nor in Porto Rico I saw it in use.



A 'Searby' shredder consists of a number of hammers fixed on hammer rods, which rotate at tremendous speed, usually at 1,200 R. P. M. As the cane is fed to the shredder, it is subjected to the hammering action between the anvil and the hammers, which shred the cane. So far as the work of preparation of cane for milling is concerned, this does a better work than any other mechanism known so far, and in the choice of a shredder one has to go in carefully into the question, how far economic it will be. The chief advantages of a shredder are:—

(1) *Better preparation of the cane for milling.*—So far this point is concerned, no other mechanism so far approaches the 'Searby' shredder. Naturally with better preparation of the cane for milling, the other advantages, such as smooth milling and increased extraction, are secured to a certain extent.

(2) *Increase in extraction.*—As explained above with the use of a shredder, a higher extraction is quite possible. In actual practice, however, I found that in Hawaii there were mills which were obtaining an equally good extraction without a shredder. It was thought impossible to obtain extraction of 99 without a shredder. The mill in Hawaii, which made a record extraction of 99.35 per cent. is not equipped with a shredder. The following figures obtained from the Hawaiian islands show the comparative work of mills with and without the shredders:—

	Sucrose in cane per cent.	Fibre in cane per cent.	Maceration per cent. cane.	Sucrose extraction.
Crusher, shredder and 4 mills.	12.18	12.83	39.0	98.79
Crusher and 4 mills ...	12.21	12.85	41.6	98.84
Crusher, shredder and 5 mills.	14.03	12.03	23.5	97.79
Crusher and 5 mills	13.22	12.46	23.98	97.69

(3) *Increase in capacity.*—This is another advantage claimed by the advocates of the 'Searby' shredder. In actual practice, I did not see the capacity increased to any extent. In this case a comparison is made of a

mill, without a shredder and one with a shredder, without taking into consideration the fact that a shredder is practically equal to an extra crusher or a mill. When compared on this basis, the capacity is not found to increase.

The chief disadvantage of a 'Searby' shredder is the expense. As the shredders require a very high speed from 1,150-1,200 R. P. M., an electric drive through a motor or a turbine drive is a necessity. In Hawaii I found most of the shredders were driven by motors directly driven. Besides, the power required to drive a shredder, is high, which increases the expense. In Trinidad, the Searby shredder of 42" x 72" size, is driven by a motor of 300 H. P. This does not mean that the shredder requires all the power the motor is capable of developing, but during the operation of shredding, a high power is required at times P. In Hawaii a 250 H. P. motor is commonly used.

The second disadvantage is the upkeep. On account of the high velocity, with which the hammers rotate, they get out of order soon, specially when pieces of iron go through. For this purpose a number of hammers must be kept in stock.

There is one point which has not been investigated so far. On account of the use of the shredder, the bagasse is so finely powdered that finer particles of bagasse are likely to go through the chimney without proper burning in the furnace, which is thus a loss. How much is lost through this source, is not so far determined.

Thus, on account of the tremendous power required to drive the shredder, as well as the cost of upkeep, the shredder is found to be expensive. When it is possible to obtain such high extractions without the use of shredders, the use of such expensive machines becomes of doubtful economy. It is on account of this fact that many mills in Hawaii, are still not equipped with the 'Searby' shredders. For conditions in India, their use is obviously out of question.

Shredders have so far been used in addition to crushers. Nowhere have they been used singly. The question, as to whether shredder should precede the crusher or follow it, is still disputed. Both the arrangements have certain advantages. When shredder is put before the crusher, an advantage of the extraction of the juice by the crusher is secured,

which helps considerably the first mill. This arrangement seems to increase the extraction. Against this is to be considered the fact, that if any pieces of iron go through the shredder along with the cane, which happens at times, it will cause so much damage to the hammers, that new ones will have to be replaced. For this reason, the other arrangement is preferred. Any piece of iron, that may pass through the crusher, can be detected by the noise it makes, and can be removed, before it goes to the shredder. It is this advantage which has brought this arrangement—crusher followed by a shredder into common practice in Hawaii.

*Milling.*—The partially crushed cane from the crusher or the shredder is then fed to the mills. The number of mills in a unit varies from 3 to 6 in different factories, the most common unit consisting of 4 mills. Each mill consists of 3 rollers, the top roller, the feed also called front, and the discharge also called back roller, all horizontally placed. In between the feed and the discharge rollers, but below the top roller, is placed a trash turner, which guides the bagasse from the feed to the discharge roller. - It is thus obvious, that in each mill two crushings are obtained, a light crushing between the top and the feed roller, and a heavier one between the top and the discharge roller. The addition of one mill, therefore, secures two more pressings.

Each roller consists of a shell surrounding a central shaft, prolonged on both the sides of the shell. The shaft is usually fixed into the empty shell under hydraulic pressure of about 600 tons, by heating the shell previous to forcing the shaft. It is held in position by a key. Pinions are placed on one or both the ends of the shaft, which interlock with the pinions of the other rollers, and thus transmit power. The top roller is usually connected to the train of gearing, which receives power from the engine. When the rollers get worn out, the shaft is removed and a new shell put. Removable thin shells were tried in Hawaii. The advantage claimed was, that when rollers were worn out, a new removable shell which is not so expensive could be easily put. With the introduction of deep juice grooves, removable shells have been discarded, being found to be unsuitable.

The top roller is usually provided with flanges on both the sides to prevent the bagasse getting out of the mill, and falling on the bed plate below. The flanges may be cast integral with the shell, or may be bolted. The latter arrangement is now getting common. This makes it possible

to interchange the upper and lower rollers, and for this reason it is preferred. The lower rollers are provided with steel juice guards on both the sides to prevent any of the expressed juice reaching the shaft journals.

The dimensions of the rollers are expressed in inches, the first figure representing the diameter, and the second figure, the length. The length of the rollers varies from 48" to 84" in different factories, depending upon the grinding capacity. All intermediate sizes are made in 6" length only. As the length increases, the diameter also increases. Thus with 48" length, may be used 26" or 30" diameter, with 54" and 60", 30", with 66", 72" and 78" lengths 32" or 34", and with 84" length, 36" diameter. These are the standard dimensions used for the rollers in the cane sugar mills.

*Grooving.*—All the mill rollers are grooved. The object of grooving is two fold, to offer a good grip, so that a partially crushed cane will not slip, and at the same time to offer a passage for the expressed juice. In order to secure a good grip, it is a practice in quite a few factories to have specially grooved top rollers. Across the ordinary circumferential grooves are formed horizontal grooves, which run along the length of the roller. These are said to secure good grip. In Java, it is a common practice to have specially grooved top rollers. Elsewhere, special top rollers have not come into use. In Java, the practice of milling is to have a thick feed, which is liable to cause slippage. It is probably on account of this reason, that there the special top rollers have come into general use. In other countries specially in Cuba, a thin feed is the practice but in order to secure capacity, a higher speed of the mills is followed. On account of the thin feed, this difficulty is not so much felt as to instal special top rollers in other countries. The special grooving of the top rollers cannot be done on a lathe and has to be done by hammer and chisel, which is expensive.

The most common grooving is a number of triangular circumferential grooves, usually about  $1/8$ " deep with  $1/2$  to 1 inch pitch, the number varying from 2 to 6 in an inch. Different factories use different number and there is at present no unanimity in this practice. The Fulton mills have 3 grooves to an inch, which seems to be the best, because not only they last longer, but they afford an easy passage for the expressed juice. Some factories use coarser grooves for the first mill, and use finer ones for the later mills in succession. Thus there is a gradual increase in

the number of grooves per inch from the first to the last mill. This is also a good practice but a difficulty arises, when the rollers are to be interchanged. On account of this difficulty, a uniform grooving is considered desirable.

Along with these grooves, deep, wide circumferential grooves called drainage or "Messchaert" grooves are provided specially for the feed rollers. These may be spaced every three to four inches. The size used is about  $1\frac{1}{4}$ " deep,  $\frac{1}{4}$  to  $\frac{3}{8}$  inch wide. The Messchaert grooves help the draining of the juice very effectively, and prevent its reabsorption, thus increasing the extraction and capacity. The use of Messchaert grooves, so common in Hawaii, has largely contributed to the obtaining of high sucrose extractions there. Factories, using a heavy maceration so common in Hawaii, will find it to the greatest advantage to use Messchaert grooving specially for the front roller. A few factories are using it even for the discharge roller, though its use is not found to be of much consequence. In Hawaii, it has resulted in the saving of 1 to 3 per cent. of sugar in the cane. In Java, Messchaert grooving has not come into use. Probably no necessity for the same has been felt on account of the light maceration practised there. A few factories tried it without any benefit and it did not prove successful.

In order that the drainage grooves should properly function, it is quite necessary to keep them free from adhering bagasse. A set of scrapers, mounted on a long horizontal bar, is provided which keeps each groove clean as the rollers rotate. This is very important, as the grooves would get clogged with bagasse very soon, and prevent the draining of the juice. On account of the scraping action, the scrapers have a tendency to bend and go out of action. It is, therefore, important to have a proper type of scrapers. Secondly, as the scrapers function, lot of bagasse accumulates on them, which must be removed from time to time. If the scrapers be mounted on a rigid support, this cleaning has to be done by hand. A movable support does the work of cleaning in a short time by just taking the scrapers out of position by a pivoting action. This also prevents the bending of the scrapers, but an obstruction in one groove keeps the whole set out of action. It is, therefore, necessary to watch the operation of the scrapers from time to time.

The Messchaert grooves can be made in any factory in the same way as the regular grooving. When new grooves are made, they are not made so wide, as they get self-widened by use. The only disadvantage with

Messchaert grooves, is that they get worn out soon, but the practical advantages thus secured outweigh this consideration.

*Mill housing.*—The rollers are placed in their position by means of proper housing erected on bed plates. The latter are firmly secured to the ground by means of a proper foundation and bolts, and serve to receive the juice from the mills, which flows out, through juice outlets made in the bed plates, to the juice strainers. In the housings are provided the bearings, on which the roller shafts are placed. The rollers are then kept in position by means of caps bolted together. There are different kinds of housings in use at present. In the old type housings, the bolts for the top cap were long and used to pass through the whole body of the housing. The result was, that the feed and the discharge rollers could not be placed closer. Consequently the trash plate, which is in between the front and the back rollers, was much wider. This causes more friction and consequently demands more power. In certain factories I found instead of long bolts, U bolts were used for keeping the rollers in position, on account of which it became possible to set the front and the back rollers closer, which resulted in the reduction of the size of the trash plate.

On account of the smaller opening kept between the top and the back rollers during setting, a greater pressure is caused between those two rollers during milling with the result, that the top roller is thrust against the jaw of the top gap on the front side. In order to obviate this difficulty inclined housings were designed, but they have not come into general use. The type of housing is really a question for the mill engineers, and sugar manufacturers have practically very little to choose in this respect.

*Mill settings.*—There is at present a great variation in the settings used in different countries, and also in different factories in the same country. Since the use of hydraulic pressure in sugar mills, the setting does not offer such difficulties, as are met with rigid mills. At present, almost all the sugar mills have been provided with hydraulic accumulators. The object of the setting is to keep a sufficient opening for the bagasse to pass through smoothly without any choking, and secondly, to extract as much juice as possible at the same time, under pressure. The opening towards the front end is adjusted so as to receive the feed without any choking. It should be remembered, that the feed, before it enters the mill, is under expansion, and assumes a greater

volume, but after it enters the mill rollers, it is subjected to pressure between the rollers, at the same time extracting juice by pressure only. In a rigid mill, the opening will be constant, and therefore, it will be necessary to pass a constant volume of fibre through the mill. If the feed increases, the mill would not take it, and there will be choking, unless the mill is speeded up to handle the extra feed. Increased speed means more steam and more power, which becomes expensive, and is not possible under usual operating conditions. It is thus obvious, that in rigid mills, there is a greater chance of getting chokes, unless a constant feed is secured, which is difficult of accomplishment in actual practice.

The opening of the mills depends upon the volume of the fibre, that is required to pass through the mill. It is the fibre in the cane, that offers a resistance to the pressure of the roller, the juice in the cane being expressed under pressure. So in setting, it is necessary to take into consideration the amount of fibre that is to pass through the mill, and not the amount of the cane. With mills, using hydraulic pressure for the rollers, a certain opening is set at the time of mill setting, and a certain constant pressure is maintained. Whenever the pressure exceeds due to more feed, it will result in lifting the roller, which causes a greater opening, and allows the cane to pass through, though this is done at the cost of more power. This is the greatest advantage of the hydraulic pressure. There will be no choking, and there will be no breaking of the parts of the mill. The utmost that may happen on account of the extra feed, will be the tearing of the leather used in the ram, which, however, can be easily replaced. The extraction in a hydraulic mill will, therefore, depend on the pressure that is put on the rollers, which is constant, no matter what the feed is. It will thus be seen that, with such mills, no matter what the settings are, the opening will automatically adjust itself with greater feed on account of the lifting action of the rollers, when the pressure is exceeded. The openings are, therefore, set more to secure an easy and smooth feed.

As said previously, with hydraulic pressure there is a constant pressure on the top roller. As the bagasse enters the rollers, it is under pressure. If the fibre offers greater resistance than this pressure, the top roller will be lifted. This upward pressure exerted by the resistance of the bagasse against the top roller is not equal on both the sides of the mill. The opening between the top and the back rollers is comparatively smaller than is the case with the front opening.

Consequently, the upward pressure in the back opening is more, than is the case with the front opening. The result is, an unequalization of pressure, which eventually acts on one side of the bearing of the top roller. It should be remembered, that the front roller is mainly regarded as a feed roller, while the back is regarded as the one which does the extraction. There seems to be a difference of opinion amongst the engineers on this point. The following settings, followed in certain typical mills, are given more or less as a matter of information to serve as a guide:—

No. 1 Mill in Louisiana; crusher and 3 mills.

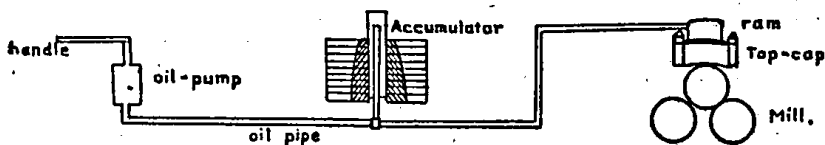
" 2	"	Cuba	;	"	4	"
" 3	"	St. Kitts	;	"	4	"
" 4	"	Trinidad	;	"	4	and a shredder.
" 5	"	Hawaii	;	"	3	"
" 6	"	Java	;	"	3	"

	1	2	3	4	5	6
No. of rollers for crusher.	2	2	2	2	2	2
" " " mill ...	9	12	12	12	9	9
Size of the rollers ...	34"×84"	32"×72"	34"×72"	34"×78"	32"×60"	36"×84"
Feed opening 1st mill ...	5" 8"	3" 2"	1 1/2" 1 3/8"	1" 1 1/8"	1/2" 3/8"	1 7/8" 2 7/8"
2nd " ...	3"	2 3/8"	1 3/8"	1 1/8"	3/8"	3 1/8"
3rd " ...	1 1/4"	1 3/8"	1 1/8"	1 1/8"	3/8"	3 1/8"
4th " ...	...	1 3/8"	1 1/8"	1 1/8"	...	...
Back opening 1st mill ...	1 1/8"	1 1/4"	1 3/8"	1 1/8"	0	2 1/8"
2nd " ...	1 1/8"	1 1/8"	1 3/8"	1 1/8"	0	3 1/8"
3rd " ...	1 1/8"	1 1/8"	1 3/8"	1 1/8"	0	7"
4th " ...	iron to iron	tin plate	1 1/8"	1 1/8"	0	3 1/8"
Distance between trash plate and top roller—		iron to iron	0	0	...	...
1st mill ...	1 3/4"	2 1/4"	2 3/4"	...	1"	2 1/8"
2nd " ...	1 3/8"	1 1/4"	2 1/8"	...	3/4"	1 1 5/8"
3rd " ...	1"	1"	2"	...	1 5/8"	1 3/4"
4th " ...	...	3/4"	2"	...	...	...
Hydraulic load in tons—						
1st mill ...	278	...	420	334	380	285
2nd " ...	474	...	440	334	380	249
3rd " ...	474	500	490	334	380	249
4th " ...	...	500	525	334	...	...
Hydraulic load in tons per foot length—						
1st mill ...	39	...	70	51	76	37.8
2nd " ...	68	...	73	51	76	35.6
3rd " ...	68	80	82	51	76	35.6
4th " ...	...	80	87	51	...	...



*Hydraulic accumulators.*—In all modern mills, hydraulic accumulators are used, whereby, a constant indicated pressure is maintained on each crusher and mill. As explained previously, on account of the constant pressure, no over-strain is caused to the mill, thus securing a long life. Whenever a bigger feed enters the mill, it lifts the top roller on account of the pressure exerted, which acts against the hydraulic ram. It is the leather in the hydraulic ram, against which the hydraulic pressure acts, and, on account of its elasticity, it stands a certain minimum pressure, which, if exceeded, results in tearing the leather. The leathers of the ram can stand a pressure up to 4,000 lbs. per square inch,

A complete outfit for a hydraulic pressure consists of (1) an oil pump, (2) a set of weights suspended on a hydraulic accumulator. This consists of an upright hollow rod, which is in communication with the oil pump. Over the rod is a cylinder, which supports a number of removable weights resting on the flange, (3) hydraulic ram over the bearings of the top roller of the mill, to which pressure is communicated from the accumulators, by the oil through a pipe. A rough sketch is given below:—



Oil is first pumped, until the set of weights held on the accumulator remains suspended. The pressure on the oil is due to the suspension of weights. Thus the pressure on the oil is regulated by the total weight suspended on the accumulator. The pressure is then communicated to the hydraulic ram placed above the bearing of the top-roller. The ram exerts a pressure on the journals of the roller, which are resting on the bearings. It is thus obvious, why the journals should be strong so as to stand the pressure of the hydraulic accumulators. The maximum pressure, that is considered safe, is 1,100 to 1,300 lbs. per sq. inch on the journals. Beyond this pressure, there is a chance of breaking the journals.

It will thus be seen, that with this device the pressure on the top-roller can be regulated by means of weights on the

accumulators. The more the weight, the better the crushing but there are practical limitations, beyond which it is not safe to go. They are: (1) the pressure on the journals should, in no case, exceed 1,300 lbs. per sq. inch. Beyond this pressure, the journals might break. (2) The leathers of the ram cannot stand a pressure above 4,000 lbs. per sq. inch. Beyond this pressure, they give way.

The hydraulic pressure is used only on the top roller. In old designs, the pressure was communicated to the back roller through the oil pipe, which used to enter the ram from below. This was very inconvenient, as in case, the leathers give way, considerable time was required to put a new leather. In modern mills the rams are used only for the top cap. The oil pressure is communicated by the oil pipe, entering the ram either at the top or at the side. A new leather can be easily put by removing the plug placed on the top cap. This is found to be the most convenient arrangement.

It has been said above, that the hydraulic accumulators exert a pressure on the top rollers through the journals. On one end of the journals, are placed the pinions, intermeshed with the pinions, of the front and back rollers. This causes an unequal pressure on the two ends of the journal due to the side thrust of the pinions. This has been remedied by either of the three methods (1) the provision of pinions on both ends of the roller shaft, (2) provision of different size rams for the two ends of the journal, smaller ram being provided for the pinion end, (3) provision of separate accumulators for each side, less pressure being used for the pinion side.

The first arrangement is common with the Fulton mills, and seems to be the simplest and best. In the second arrangement, the relation between the unequal pressure caused by the side thrust is fixed, which may vary in actual practice. In this case, different size leathers have to be kept in stock.

The third arrangement is obviously expensive and is not in favour amongst the sugar engineers.

The hydraulic pressure, used in actual practice in different mills, varies a good deal. The two common practices are (1) the gradual increase in pressure from the first to the

last mill, (2) a constant pressure from the first to the last mill. It is very difficult to state which is the best system, though both of them are working very well in practice, and the choice mostly depends upon the engineer in charge. The following figures give an idea as to the actual practice in some mills. For comparison I have given the lbs. of pressure per square inch. The total pressure, used on the top roller, depends upon the size of the journals, which, in turn, depend upon the size of the rollers. Only pressure, used on the top roller of the last mill, on which maximum pressure is usually used, is given below:—

Size of the roller.	Size of the journal.	Pressure in tons on top roller.	Lbs. pressure per sq. inch on journals.	Lbs. pressure per sq. inch on roller.
1. 34" x 34" ...	16" x 24"	474	1,097	392
2. 32" x 72" ...	...	500	...	432
3. 34" x 72" ...	...	525	...	443
4. 34" x 78" ...	17" x 22"	334	1,000	282
5. 32" x 60" ...	...	380	...	396
6. 36" x 84" ...	16" x 24"	285	737	...
Only in Cuba, I saw higher pressures being used in a few mills. They are as below:—				
7. 36" x 84" ...	18" x 24"	542	1,254	358
8. 34" x 78" ...	18" x 24"	700	1,620	463

The last mill was obtaining an extraction of 94 per cent. with only 5 per cent. maceration water. This must have been due to such a heavy pressure on the rollers. It is obvious, that the higher the pressure, the more the sucrose extraction, but this is usually limited by the pressure, the journal is able to carry. For better extraction, it is desirable to carry as much pressure, as will be consistent with the strength of the journal.

*Calculation of the journal pressure or the total pressure on the roller.*—In order to know how much pressure a roller can safely carry, it is necessary to know the dimensions of the journals. It has been already said, that the pressure, allowed per square inch on the journals, is 1,100

to 1,300 lbs. The pressure, that a roller can carry with safety, is calculated as below :—

Pressure on the journal =  $d \times l \times$  lbs. pressure per square inch on the journal.

Where  $d$  = diameter of the journal in inches.

$l$  = length of the journal in inches.

Pressure =  $18 \times 24 \times 1,300$

= 561,600 lbs. or 280·8 tons (short).

As there are two journals to a roller, the pressure of safety for the roller, will be  $280·8 \times 2$  or 561·6 tons.

In this way calculation can be made for any size journals.

*Toggle gear.*—In almost all modern mills, a system of hydraulic accumulators is being used for exerting the pressure on the rollers. In St. Kitts, I saw, toggle gear being used instead. The toggles—a set of movable bent pieces—are set above the top cap, and held in position between the top cap and the “yoke” by the two king bolts. The toggles are connected by a horizontal bar, upon which the ends of the toggles play. The bar carries a spring, a pressure on which, is controlled by the nuts. The pressure on the rollers is regulated by the compression on the springs, which is adjusted by the tightening of the nuts. The exact pressure, exerted by the spring, is known from the width of the spring under compression. A scale is provided by the manufacturers, which indicates the pressure corresponding to the width of the spring.

Whenever a higher pressure is caused due to heavy feed, the roller is lifted, which, in turn, acts against the toggles through the bearings. The toggles are forced out against the pressure of the springs. This is said to have worked well in St. Kitts factory. There are, however, some disadvantages with this system. Firstly, all the pressure on the rollers is due to the compression of the springs which are likely to be weakened with use. It is, therefore, necessary to get them tested every year so as to know, whether the original scale, provided by the manufacturers, is correct. Secondly, it is difficult to know, whether the toggles are working properly, as the vibrations caused are so little, that only a trained eye sight can detect it. Thirdly when for any reason, the top roller is to be taken out of the mill, it takes a long time to do so, as it has to be lifted high due to the long King bolts, which are necessary on account of the toggles. The only advantage, with toggles, is the absence of leather packings

used in connection with hydraulic rams, which at times give way. In spite of this disadvantage hydraulic accumulators are preferred by all modern mills on account of other advantages.

*Trash turner.*—This consists of a plate which is placed between the front and the back roller, and below the top roller. The object of the trash turner is to direct the partially crushed cane from the front to the back roller without causing any unnecessary choking. The trash turner is the most important part of a sugar mill, on which, mostly depends the smooth working of a mill. The trash plate consists of a long steel piece sufficiently wide called the "knife" (the width, depending upon the distance between the front and the back rollers), with a sharp edge grooved on lower side in such a way, as to fit in with the grooves of the front roller, against which it rests. The trash turner, besides guiding the bagasse to the back roller, acts as a scraper for the front roller, and hence the grooving on the lower side is necessary. The knife is supported on a horizontal bar by means of bolts, which in turn, either rests on the pockets provided in the housing, or on separate legs bolted to the mill housing. A rocking trash bar is used in modern mills, which permits better adjustment for different settings.

The width of the trash turner is very important, because, a great pressure and consequently great wear is caused to the plate, which increases with the width of the trash turner. It is, therefore, considered desirable to reduce the width as much as possible. This cannot be done, unless the front and the back rollers are put nearer to each other. In the old type housing, where long straight bolts were used for the top cap, the rollers could not be placed closer. In recent designs, the long bolts are placed at an angle, converging at the bottom and widening at the top. In some mills U bolts are used, which pass underneath the bearing. This has resulted in placing the front and back rollers nearer and reducing the width of the trash turner.

The distance, between the lower surface of the top roller and the trash turner, is of importance, as most of the choking is caused by the faulty distance between the two. This distance varies with different settings. This has been already given in the statement on page 82.

*Intermediate carriers.*—These are placed between the mills to carry the partially crushed cane or bagasse from one mill to the other. The importance of a suitable type of

intermediate carriers, can be realized, when it is known, that nearly 75 per cent. of the stoppages in a mill are traced to some trouble with the intermediate carriers. It has also been found, that the loss of sucrose caused through milling, is mostly due to the dirty condition of the intermediate carriers, which are full of yeast and other fermenting material. It is, therefore, important, that in selecting the type of an intermediate carrier, one should not only look to such types as would cause the least stoppages, but also to such as can be kept clean.

There are at present three kinds of intermediate carriers in use in the various mills. They are (1) the slat carrier, (2) Ewart's patent carrier, (3) Maenecke carrier.\*

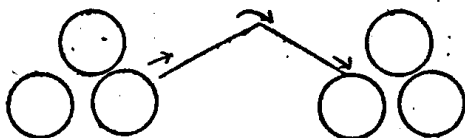
(1) *Slat carrier*.—This type is commonly used in most of the cane sugar countries. It consists of overlapping metallic slats joined together to form an endless belt. It is operated by a chain and sprocket drive. This type of carrier causes many troubles in actual operation. Sometimes, due to overlapping parts, the slats get entangled, and bent, resulting in choking and sometimes breakage. A part of the bagasse falls through on the bed plate. This carrier does not permit workmen to do any work between the mills while they are running. The greatest objection with this carrier is, that it is very difficult to keep it clean. The dirty condition of the carrier tends to promote inversion, and fermentation of the juice, resulting in a loss of sucrose. In order to keep the chain free from fermenting material, I found, a slight modification was in use in Java. In this the chain was kept outside the steel plate sides. This, however, does not reduce the stoppages, which are so common with this type of carrier.

(2) *Ewart's patent carrier*.—This type is in common use in the Hawaiian islands. Between the mills, runs a slightly inclined steel trough, over which run wooden scrapers attached to chains at certain distances. As the scrapers move, they drag the bagasse along with them on the steel platform, and deliver it to the next mill. As in this case, there are no overlapping parts, there is no chance of causing any entanglement, so common with the slat intermediate carriers. Consequently stoppages are reduced to a minimum. On account of the fixed steel trough, no bagasse falls through on the bed plate. Consequently, the workmen can work below the steel trough, during the operation of the mill. On

the whole, this carrier has resulted in reducing the stoppages and general cleanliness in the mill house and for this reason it is preferred. In Cuba this is coming into use now.

(3) *Maenecke intermediate carrier*.—This carrier is patented by Mr. Maenecke, the Chief Engineer of the Maui agricultural company. This is the latest design, and is coming into general use in the Hawaiian islands. It is also reported, that it proved to be a success in one central in Cuba, and many more centrals are contemplating the installation of these carriers.

This carrier consists of two inclined steel troughs joined together in such a way, that it forms the shape of an inverted V as shown below:—



As the bagasse comes out of the mill, it drops on the steel trough. The incoming bagasse, simply pushes it up, until, when it reaches the top, it drops on the other side, from which it automatically feeds the next mill. It is thus obvious, that there are absolutely no moving parts in this carrier. Consequently, there are no stoppages due to entanglements. On account of the absence of moving parts, the carriers can be kept very clean. This is the simplest type I have seen so far.

There are one or two points which need explanation. They are: (1) as the bagasse moves by the push of the incoming bagasse, a certain inclination to the carrier, is quite necessary. Also in order to get proper feeding, the two inclined parts of the carrier must be set up at a certain angle. It is, therefore, necessary, that the mills be as close as possible. In old factories, where individual drive for mills is used, resulting in the installation of mills at longer distances, and consequently of long intermediate carriers, this type does not offer any chance of success. (2) As the bagasse moves only by the push of the incoming bagasse, it becomes necessary to move the bagasse to the next mill by hand, when the grinding is stopped for the day. This is its only drawback, but it is immaterial, as mills are stopped only once a day for

cleaning. Recently I find from the advertisement, that a certain arrangement has been made to remove this difficulty. On account of the simplicity of design, no wear and tear due to the absence of moving parts, and also less expense, this carrier will come into general use in future.

Besides the above three, I saw in one factory in Hawaii another type of intermediate carrier in use. This consisted of an endless belt made of canvas and rubber. This was working well, but it is considered to be expensive in upkeep.

*Juice strainers.*—As the juice comes out of the mill, it carries a lot of *cush-cush* along with it. In order to separate it from the juice, a strainer is used. It consists of a narrow deep trough, with a strainer of 250 to 400 holes per square inch, usually made of brass or copper, over which, runs a trash elevator. This has usually a drag type of chain to elevate the separated trash and *cush-cush*, from the screens to the cross conveyer, which is placed over the intermediate carrier. This is driven from the mill roller shaft. Usually a screw type conveyer is used for this purpose, which slides the trash, and well distributes it over the intermediate carrier. The juice strainer is another source of loss of sucrose through inversion and fermentation. The chains are full of dirt, and fermenting material, and, in actual practice, it is impossible to keep them clean. The only way to reduce the loss through this source, is to clean the same at certain intervals either by water or preferably by steam.

In order to meet this difficulty, a slight modification is in use in Java. The strainer, which consists of a perforated plate, is mounted on a grass hopper, which, automatically, strains the juice, leaving the *cush-cush* on the strainer. On account of the motion of the grass hopper, the *cush-cush* travels to the end of the strainer, and drops on a plate in a completely drained state, from which, it is elevated to the cross conveyer. As the chain elevator does not come into direct contact with juice, as is the case with the ordinary type of juice strainer, a greater cleanliness is secured, which has resulted in the reduction of losses of sucrose through this source. This modification is decidedly better than the usual type of juice strainers.

*Bagasse Conveyers.*—The bagasse, as it comes out of the last mill, is carried by means of a conveyer to another conveyer, from which it is directly fed to the furnace through a



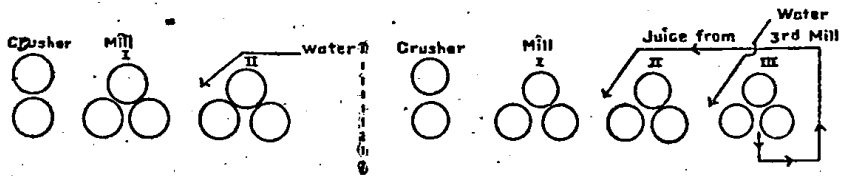
hopper, or it is taken near the furnace and fed by hand. The conveyer consists of wooden scrapers, carried on chains at certain distances. The bagasse is dragged by the scrapers on its forward motion. In Java, instead of scrapers, a rake is used. In Java, the bagasse is not reduced to as fine a condition as is the case in other countries, and consequently, this type of bagasse carrier works well in Java.

*Maceration.*—It has been previously said, that with multiple crushing, a system of maceration is necessarily followed in all sugar mills. The process consists in diluting the juice remaining in the bagasse with water, before the latter is subjected to pressing in the mill. As a result, the juice, left in the bagasse, after each maceration and pressing, becomes more and more dilute until the sucrose, left in the bagasse from the last mill, is the lowest.

In order to secure best results from maceration, two conditions are necessary. They are : (1) a good dry pre-crushing, and (2) better disintegration of the cane before the maceration water is applied. With a good dry pre-crushing, the amount of juice, left in the bagasse, is very little, which, consequently, reduces the amount of maceration water without prejudicing the sucrose extraction. With a low dry crushing, the amount of water required is excessive, if the same extraction is to be secured. It is desirable that the required sucrose extraction should be secured with a minimum amount of maceration water, so as to reduce the amount of evaporation. Better disintegration of the cane, before the maceration water is applied, secures good admixing of the water with bagasse. Water would mix much more quickly and more efficiently with bagasse in a finer condition, than with coarse bagasse, and thus dilute the juice remaining in the bagasse. This action should be secured more quickly, because, in modern mills the time, available for the admixture of water with bagasse, and the consequent dilution of the juice remaining therein is little due to the fact, that the mills are run faster, and the intermediate carriers are short. For this reason a finer condition of bagasse is very helpful, in securing the best results with maceration water. With modern mills, a good dry pre-crushing is usually obtained with a crusher and one mill, with cane containing a medium amount of fibre. With hard cane containing a high amount of fibre, say from 15 per cent. and up, as is the case in Northern India, a double crusher and a mill will be helpful

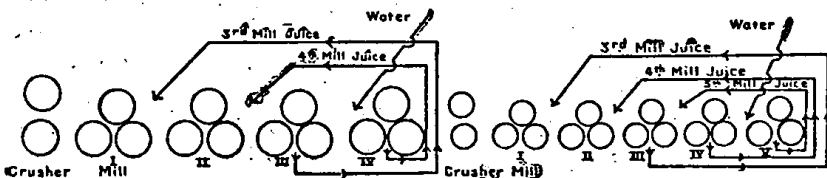
in securing a good disintegration of the cane, and consequent better dry crushing. In the Bombay Deccan, cane contains a low amount of fibre—10·5-11 per cent., and consequently, a crusher and one mill will be sufficient to secure the required dry crushing, before the maceration water is to be applied.

The systems of maceration or imbibition in use are: (1) the simple and (2) compound. In the former system, water alone is used in saturating the bagasse. It is called single, double, triple, &c. Simple imbibition depending upon the number of mills, to which it is applied. In the latter system, dilute juices are used in succession, before the water, which is used only before the last mill, is used for maceration, which secures better results with a minimum amount of water. There is no question, that best results, as regards sucrose extraction, are obtained with a compound system of maceration with minimum amount of water, and at present, that system is in general use. The single maceration is followed in tandems of a few mills. Factories, having mill tandems of a crusher and two mills, can only follow single maceration. With three mills, a compound maceration is made possible, as the juice, from the last mill, can be used for maceration after the first mill, water being applied after the second mill. This is obvious from the sketch given below:—



With tandems of a crusher and three mills, some factories follow only simple maceration, using water both after the 1st and 2nd mill.

With more than three mills, dilute juices can be used more than one time, and, for this reason, the system of maceration is called double compound, triple compound, and so on. This is obvious from the sketch below:—



The advantages of a system of compound maceration are obvious. Noel Deerr has admirably shown on theoretical considerations, the obtaining of greater extraction with this system in his book on 'cane sugar' from which, the following figures are quoted :—

*Computed sucrose extraction with cane, containing 11 per cent. fibre and imbibition water from 10 to 30 per cent. on cane, obtained with different system of maceration dry crushing 87.7 per cent.*

	Water 10 per cent.	20 per cent.	30 per cent.
Single, simple imbibition ...	93.6	95.7	96.6
Double „ „ ...	94.11	96.6	97.7
Treble „ „ ...	94.4	97.0	98.2
Single compound „ ...	93.6	95.7	96.6
Double „ „ ...	95.4	97.9	98.9
Treble „ „ ...	97.3	98.9	99.6

The above table shows the superiority of compound maceration, specially when the number of mills increases. The above figures are of academic interest, and do not represent actual facts.

The one consideration, that is required to be made, is that the juices of the subsequent mills are more dilute, and are subject to souring, and, for this reason, should be used as rapidly as possible. In countries, where the climatic conditions are more favourable for souring, a simple system of maceration is for this reason preferred.

*Method of applying maceration water.*—At present there are three systems in use:—perforated pipes, troughs, and the Ramsey macerator. In all methods it is considered desirable to apply water or dilute juice to the bagasse, as soon as it comes out of the mill, because, at this time, the bagasse is still under the effect of compression, and is not fully expanded. Water mixes more quickly with bagasse in this condition, than, when it is applied, after the expansion of the bagasse. For this reason, water is applied in such a way, that a jet directly falls on the bagasse, as it begins to come out of the mill.

*Perforated pipe.*—This is placed as close to the back opening of the mill as possible, so that the jet of water can fall directly on the incoming bagasse. The perforated pipe works alright with water, but, when dilute juice is to be used for maceration, the perforations are more or less a nuisance, as choking is caused by the cush-cush present in the juice. It is for this reason that a trough is preferred.

*Trough.*—The trough is placed over the intermediate carrier, and the dilute juice comes out as an overflow, and falls on the bagasse down below through a perforated pipe. With this system, it is necessary to see, that there is a good distribution of juice. For this reason, the trough must be placed level. Otherwise juice falls in one sheet, which results in uneven distribution. Troughs are generally used for juices. There is one disadvantage with troughs, and that is they cannot be placed as close to the back opening of the mill as perforated pipes can be.

It should be remembered that, in the two systems described above, water or juice falls in the form of a jet or sheet only on the upper surface of the bagasse, and it is expected, though it is never achieved in practice, that, as the bagasse moves further, the water or the juice would permeate the whole blanket of bagasse. In actual practice, it is found that water permeates the upper layer of this blanket, leaving the lower portion quite unaffected. This causes irregular dilution of juice. It is obvious that the thicker the blanket, the greater will be this irregularity. The Ramsey macerator obviates this difficulty. In this case water or juice is sprayed on both the surfaces of the blanket, which thus secures complete admixture of water with the juice. This macerator consists of a double scraper, each provided with a set of jets, between which the blanket of bagasse moves. In this system water is used, when the bagasse is still under compression. In the Hawaiian islands, the Ramsey macerator is in common use, and the general opinion is, that it secures a complete admixture of water more efficiently than any other system known so far. With thicker blanket, its use is of far more advantage.

*Hot or cold water for maceration.*—It is still a disputed question, whether hot or cold water be used for maceration. So far sucrose extraction is concerned, no difference is observed, whether hot or cold water is used, but there are

certain advantages and disadvantages with each. In Java, it is a common practice to use cold water for maceration. In Hawaii, Cuba and the West Indies, hot water of 160°-180° F is commonly used. The chief advantage of using hot water for maceration is that the resulting bagasse is much hotter, and as it passes on to the furnace, it loses a part of the moisture, which improves the thermal value of the bagasse. It should be remembered, that the moisture in bagasse involves a dead loss in thermal value, as all moisture has to be raised to the furnace temperature and is ultimately lost through the flue, carrying away all the latent heat of steam. The reduction of moisture in the bagasse, thus, directly increases the furnace efficiency. Besides, additional advantage is secured, on account of the high temperature of the bagasse, before it enters the furnace. With cold water maceration, there cannot be any of the above advantages. The furnace efficiency is consequently low. In Java, it is a practice to provide an additional furnace, which is an extension of the usual step grate furnace, in which wood is burnt. The hot gases, from the wood, heats the bagasse, as it enters the furnace. This preheating partially dries the bagasse, thus securing better combustion.

The disadvantage with the use of hot water for maceration is, that it heats the rollers, which causes more wear and tear. I was told in Java, that this sometimes causes the loosening of the shaft from the shell. In Hawaii, where hot water is commonly used, I did not notice this effect, and, even though the use of hot water makes the rollers hot, no damage beyond the ordinary wear is noticed. It seems, therefore, that the use of hot water for maceration is the best, if a greater furnace efficiency is desired.

The hot water used for maceration is usually the condensed water, also called 'sweet water' from the 2nd and later bodies of the evaporator. This water is already hot, and no more steam is required for heating it. When double or treble maceration is practised, it is necessary to keep all the dilute juices separate. This necessitates the provision of separate pumps for each juice.

*Motive power for mills.*—The power used for driving the mills is either the steam engine or electric motors. The use of electric drive for mills is of recent date only. During my visits to various cane sugar countries, I saw one mill

electrically driven in Louisiana, 3 in Cuba and one in Jamaica. Both in Hawaii and Java, I did not come across with any mill electrically driven. In Cuba, the most modern central—Jaronu—erected in the year 1921, has electrically driven mills. Cunagua is another central, with electrically driven mills, of the same company built in the year 1917. It should be remembered, however, that there are other modern centrals erected in Cuba since then, which have installed steam driven mills, though all the other accessories, such as the pumps and the centrifugals, are electrically driven. In Java, the latest mill—Tjomal—built this year (1923) has installed steam driven mills. In Hawaii, where the factories are operated at a higher efficiency, the manufacturers have not yet taken up the electric drive. It is thus obvious, that the electric drive has not yet gained favour with the cane sugar manufacturers, doubtless due to the fact, that electric drive for mills is considered more expensive than the steam drive.

There is no question, that the steam consumption with electric drive is higher than with steam drive. It should be remembered, that, with electric drive, there are two conversions of energy. First of all, the steam is converted into electric energy by means of turbines. The electric energy is then converted into mechanical energy by means of motors. With steam drive there is only the conversion of steam into mechanical energy. At each conversion, some power is lost. With electric drive, there is, therefore, greater loss of energy in conversion. Secondly, the steam consumption with non-condensing turbines is higher per B. H. P., than with the steam engines. There is a third fact, which considerably affects the power factor with electric drive. The motor, which supplies the power for driving the mills, must be capable of developing the highest power that the mill may demand over a limited period. It is known, that, with electric drive, highest efficiency is secured, when motors are run at their maximum capacity. With electric drive, the motors run at maximum capacity only for a short period at certain intervals, when the mills demand more power probably due to the irregularity in feed. On account of these three causes, the steam consumption with electric drive is higher. To this, should be added the first cost, in which practically there is no saving, as electric drive does not dispense with any part of the machinery, except the engines;

which are replaced by turbines. According to Noel Deerr, the steam consumption with Corliss type engines, comes to about 30 lbs. per B. H. P., and with non-condensing turbines, it is 33 lbs. per B. H. P. There is another factor, which increases the steam consumption. With electric drive, it is a common practice to run each mill by a separate motor. The collective power of all the motors taken together for one tandem, is considerably higher, than is the case with steam drive, in which case the collective drive is very common. This considerably affects the efficiency. These facts explain the reason, why electric drive for mills has not yet gained favour in the cane sugar industry.

There are, of course, other advantages with electric drive, and that is, the flexibility of the drive, a better control on the mills, compactness of the plant, and a better quality of the exhaust steam. As said previously, with electric drive, each mill is provided with a separate gearing and a motor. Consequently, the speed of each mill can be regulated as required. This becomes necessary, when there is an irregularity in feed, to prevent choking. Some engineers, think, however, that there is no necessity of so much flexibility of the drive, and that the speed of the mills should be uniform, and no choking would occur, if good care is taken in securing a uniform feed. With the devices to control the feed as outlined previously, it will not be difficult to secure uniform feed. The flexibility of the drive is, therefore, a question of opinion, about which there is no agreement amongst the mill engineers.

With electric drive, there is of course a better control on the mill. As all the adjustment is secured by just turning the switches, one man can regulate the operation of the mill very easily. It is this ease of operation, which has appealed to many engineers. With engine drive, the control is not so easy and rapid.

As the motors, on account of their size, take comparatively much less space than steam engines, the compactness of the plant is easily secured.

The exhaust steam from the turbines is free of lubricating oil. Also, as superheated steam is used for driving the turbines, the exhaust steam is comparatively much drier. There is not so much loss in condensation. Consequently, the

exhaust steam, from the turbines, has a greater capacity for heat transmission. With steam engines, the steam directly comes into contact with lubricating oil. The exhaust steam, therefore, contains some oil. Besides, as only saturated steam is used, which is usually wet, exhaust contains some condensed steam, which is practically a loss so far as the utilization of latent heat is concerned.

On account of these advantages, it is likely that the electrification of mills will become common in future.

As said previously, with electric drive each mill is provided with a separate motor and a herring-bone gearing to transmit the power to the roller shaft. Central Jaronu has two mill tandems of a double crusher and 6 mills of 36" x 84". Each crusher and a mill is driven by a 200 H. P. motor of slip ring type, with a speed of 450 R. P. M. The electric power is generated in a turbo generator of 1,500 K. W., with a turbine speed of 3,600 R. P. M. The current used is alternating, triple phase, 60 cycles (55-70) and 480 volts. The turbo is run by superheated steam of 80-100 lbs. pressure, the back pressure being 8-10 lbs. In Jamaica, I saw one mill, electrically driven, in which a collective drive was used. The mill tandem consisted of a crusher and 4 mills of 30" x 60". The crusher and first two mills were driven by one motor, and the last two by another motor. This arrangement is practically the same as is usually found in steam driven mills, and is considered more economic than the individual drive. This is the only electrically driven mill, I saw, which had a collective drive.

*Engine drive.*—This is the most common drive with cane sugar mills. There are three types of engines, in use—the slide valve, the Corliss valve and the valve engines. The British manufacturers favour the slide valve engine probably, on account of its simplicity of adjustment and operation. In countries, where skilled workmen are not available, this type of engine is considered to be suitable. The chief disadvantage of the slide valve engine is its higher steam consumption. As there is no automatic cut off for the steam, it consumes more steam per horsepower. It is found, that it consumes about 40-45 lbs. of steam per B. H. P., which is considerably high.

The American manufacturers favour the Corliss valve engine. The engine is provided with two valves, and an



automatic cut off. The steam consumption with Corliss engine has been found to be 30 lbs per B. H. P., which is 25 to 30 per cent. less than that obtained with slide valve engines. This is of considerable importance specially in countries, where cane does not furnish sufficient fuel to run the factory. Some engineers think, that economy in steam consumption of engines is useless, so long as all the exhaust is used in the factory. This reasoning is not correct, because, though a low steam consumption may not give enough exhaust steam, as may be the case with Corliss valve engines, live steam can be used much more efficiently and economically to do the heating, and evaporation by means of pre-evaporators. Thus, the substitution of more economical engines give a greater chance for economy in steam consumption by means of pre-evaporators.

The Corliss type engine requires greater care in adjustment, but when once the valves are set right, there is no further trouble. There is the same ease of operation, as is claimed with slide valve engines. The adjustment of the valves does not present great difficulties, as every factory has a competent engineer to see that the valves are set right. There is, therefore, no valid reason, why British manufacturers should not favour the Corliss engine specially when its economical operation is taken into consideration.

The valve engines are in common use in Java. These engines are provided with double valves, which operate mechanically by means of a cam shaft connected to the crank shaft. The valves operate in the same way as the ones in internal combustion engines do. These engines are considered to be economical, though actual figures with regard to steam consumption are wanting. But the very fact, that, in Java many factories are running on bagasse alone, shows, that the engines are economical in steam consumption.

So far no compound engines are in use in any of the sugar factories. I saw compound engines in use in Hawaii, only for pumping plants. The compound engines are very economical in steam consumption, as the steam is used more than one time, but their first cost is very high. So long there is a scope for the utilization of exhaust steam, as is the case with cane sugar mills, there is no advantage in the use of compound engines. All the benefits of a compound engine are secured at a high first cost, which cannot be justified unless the fuel problem is serious.

In operating any of the above engines, saturated steam is commonly used. It is known, that superheated steam gives more efficiency. I consider, a moderate degree of superheat for power purposes would be of great advantage. This will reduce the loss through cylinder condensation as well as in the exhaust pipe. I saw one factory in Java, using a superheated steam (60 degree of superheat) for the mill engines. The exhaust steam in this case is decidedly of a better quality. The pressure of the exhaust steam was purposely adjusted to  $1\frac{1}{2}$  atmospheres, and all the juice heating, evaporation and boiling were done without any live steam. The factory was running so economically, that, even though cane contained 11.5 per cent. fibre and the factory was making white sugar by the sulpho-carbonatation process, some bagasse was saved.

*Collective drive versus individual drive.*—In all old installations in Cuba and Java, I noticed each mill was driven by a separate engine through a separate gearing. In all modern installations, the practice is to drive as many units, as is possible with a common engine, or in other words, a 'collective drive' is the practice. There are a great many advantages in this practice. They are: (1) low steam consumption, (2) less operating expenses, (3) low first cost. In the old system, on account of the individual drive, greater amount of steam was consumed doubtless due to the fact that there is more loss through cylinder condensation. In such a system, the amount of exhaust steam is many times far in excess of the requirements of the factory, which is ultimately blown off to the air. This is wasteful. As the problem of fuel became more and more serious, the question of economy in steam consumption became more apparent, with the result, that all modern installations, except those using electric drive, have given up the individual drive. The second advantage is evident, when the saving in expense for attendance is taken into consideration. The collective drive reduces the first cost to a certain extent, though this would not be of so much consequence, if individual drive would not have caused other disadvantages.

The only advantage, that is claimed with the individual drive, is the flexibility. The relative speed of different mills can be regulated, which is not possible with collective drive. As has been said previously, while discussing the electric drive, it is the opinion of some engineers, that so much flexibility

is not necessary and that no choking would occur if good care is taken in securing a uniform feed. In actual practice, I find, that the place, where choking commonly occurs, is between the crusher and the first mill, and for this reason, many engineers prefer to have a separate engine for the crusher. There is no doubt, that this gives a better control on the feeding of the first mill, and reduces to a certain extent the stoppages caused by the choking of the first mill.

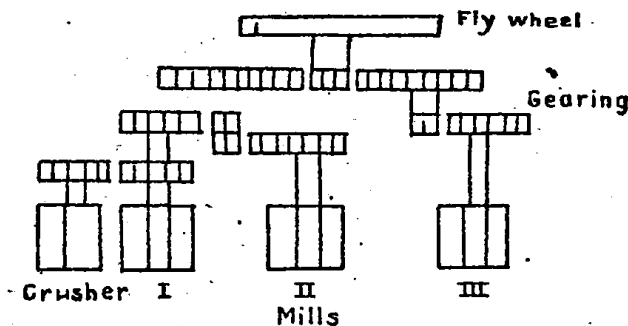
In actual practice one, two or three engines are used for driving the mill tandem. In Louisiana, I saw mill tandems of a crusher and 3 mills driven by only one engine. This is more economical, but still the engineers prefer to have a separate engine for the crusher for reasons given above. In Cuba, where the greatest number of mills are used in a tandem, three engines are used, one for driving the double crusher, second for the first 3 mills, and the third for the last two mills. In one modern central in Cuba, I noticed only two engines being used, one for a single crusher and 3 mills, and the other, for the last two mills. The maximum limit, so far, seems to be to drive a crusher and 3 mills by one single engine. Another factory, using a triple crusher in Cuba, has also 3 engines for driving the mill tandem, one engine for the double crusher, 2nd for the third crusher and 3 mills, and the third for 2 mills. There is no doubt, that collective drive secures saving in steam and operating expenses.

*Speed of the engines and the gearing ratio.*—The limits of speed of the engines are from 40 to 60 R. P. M., 40 to 50 being the common practice. The speed of the mills is reduced through suitable gearing, the ratio of the engine speed to mill speed—also called the gearing ratio—being from 17 to 25:1. In the case of the crusher, this ratio may be 13:1. Generally crushers are run at high speed, 3 to 4 R. P. M. being common. Mills, on the contrary, are run at a speed of 2 to 3 R. P. M.,  $2\frac{1}{2}$  being common practice. It is also a practice to reduce the speed of the mills in succession from the first to the last mill.

I saw high speed engines in use at central Tjomal in Java, which is the latest factory in that country, being built in the year 1923. The speed variation of the engines was from 70 to 140 R. P. M., the common speed used being 120 R. P. M. The gearing ratio in this case was 65:1, the speed of the mills being 1.9 R. P. M. In Java

mills are run at slow speed, but this is attended with a thick feed. Contrary is the practice in Hawaii and Cuba, where thin feed accompanied with greater speed is the practice. It is the opinion of some engineers in Java, that a slow speed is necessary for obtaining more extraction, to secure which, sufficient time must be allowed for the juice to drain. In order to secure capacity, a thick feed is practised but this results in slippage. That seems to be the reason why special top rollers are used in Java. In Hawaii, where the highest extractions are obtained, no difficulty has been felt in draining the juice on account of the Messchaert grooves. In Java the latter is not looked upon with favour, reasons for which I could not ascertain. However, whatever practice is followed, the ultimate result seems to be the same. As for capacity the Cuban mills, on the whole, grind much more cane in a given time. At the speed given above, the factory Tjomal grinds about 1,625 tons of cane in a day with a mill tandem of a crusher and 4 mills of 36" x 84". The same size mill in Cuba grinds about 2,000 short tons or 1,780 long tons of cane in a day. This is the only factory I saw, where high speed engines were in use.

*Gearing.*—The object of gearing is to reduce the speed from the engine to the shaft of the mill roller. This is secured by a double reduction compound gearing consisting of spurs and pinions. The gearing as applied to a tandem consisting of a crusher and 3 mills is given below:—



### XI. Juice weighing.

After the juice is extracted by the mills, it is either weighed or measured. It is a practice in quite a few factories to measure the juice in tanks provided with an

overflow. This is attended with many corrections, which, in actual practice, are rarely determined, but more or less assumed. These assumptions vary with the individual opinion of the chemist. This vitiates the chemical control. The basis of a chemical control must be an accurate weight of cane, juice, sugar, molasses, &c. In volumetric measurement besides the calibration of the tanks, attention is required to be paid to the following points: (1) Allowance must be made for the juice remaining in the tank after emptying, (2) Allowance for suspended matter in the juice, and (3) allowance for air. In actual practice, this work of measurement is left to such class of men, that accuracy is scarce to be expected, and for this reason, weighing of the juice should be always preferred. In most of the factories, where greater attention is paid to the exercise of chemical control, juice is weighed. There are at present three machines in use for weighing the juice. They are the beam scales, the Richardson automatic self-recording machines, and the Leinert meter.

*The beam scales.*—These are in use in Cuba, Hawaii and Java, the most common being the Howe beam scales. There are usually two weighing tanks, one filling and the other emptying. In small houses, only one tank is used, but in this case a storage tank, to receive the juice, is provided. These scales are provided with appliances, which punch the weight of the juice on the ticket at each weighing. What the man in charge has to do, is simply to counterpoise the scale, and punch the ticket to get the weight. In order to have a check on the number of tanks weighed, it is a common practice to provide a counter to each tank, which automatically records the filling and emptying of the tanks. There is, therefore, a good control on the man in charge of weighing. The scale balances are the most reliable and simple in operation, and for this reason, are preferred.

*The Richardson automatic self-recording machines.*—These are in use in quite a number of factories in Cuba. With these, both the filling and emptying are done automatically. They are provided with counters, which record the number of weighings. They give satisfactory work, as long as they are kept clean. When they are dirty, they do not automatically empty at the right time. On account of this reason, many prefer to use the beam scales.

*The Leinert meter.*—I saw this type in use in some factories in Java. A few factories in British Guiana also use this. This consists of two tanks of equal capacity, balanced on a knife edge. Each one is provided with a siphon pipe, which discharges the juice. The juice to be weighed, flows first into one of the tanks, and, as soon as it gets sufficient weight of the juice, it tilts, stopping at the same time the juice flow, which is diverted to the second tank. When the tank tilts, the siphon begins to operate, discharging all the juice. There is an automatic recorder to register the number of fillings. This type is reported to be giving good service.

## XII. Clarification.

After the juice is extracted by the mills, it is subjected to such treatment as will secure the elimination of most of the non-sugars. The non-sugars in cane juice, mostly, consist of albuminoids, pectins, organic acids and colouring matter, such as anthocyan, saccharetin and chlorophyl. The usual substances, used for clarification, are lime, mostly in the form of lime cream, and either sulphurous acid, or carbonic acid gas. When raw sugar is to be made, only lime is used, but when plantation white is to be made, lime alone is not sufficient to eliminate the necessary amount of non-sugars. Most of the gummy and colloidal matter, including the colouring matter, cannot be removed, unless an excess of lime is used, which cannot be practiced in the treatment of cane juice due to the presence of glucose, with which, it forms a compound, easily decomposable at high temperature, resulting in the formation of organic acids of a colouring nature. Colour is an enemy in the making of white sugar, and not only its elimination is desirable in the beginning, but its reformation during manufacture should be avoided as far as possible. In order to make it possible to use large quantities of lime, it is necessary to use either  $\text{SO}_2$  or  $\text{CO}_2$  to neutralize the excessive lime.

*Elimination of bago-cellulose.*—Cane juice besides containing the ingredients named above, contains fine particles of bagasse, usually called "bago-cellulose" or cush-cush. This mainly comes through the disintegration of cane fibre during milling, which cannot be separated by the usual juice strainers. It is obvious, that in countries, where high sucrose extractions are obtained, and, where consequently

the bagasse is practically reduced to a powdery condition, as is the case in the Hawaiian islands, the amount of bago-cellulose is very high. The screens, usually used for the juice strainers, are of 16-25 mesh, which do not remove the finer particles of bago-cellulose usually obtained. Few factories have realized the importance of removing, as much of the fine cush-cush as possible at an early stage of the process. Its elimination before the juice is treated with lime, is necessary, as the latter has certain undesirable effects on the bago-cellulose. The latter, at high temperature, is attacked by lime, and partially converted into a gummy substance called dextran, which gives trouble later during the boiling of low grade products, resulting in a high purity final molasses. In one factory in Porto Rico, the elimination of bago-cellulose by means of finer strainers, made it possible to boil the crystallizer massecuite to such a low purity as 54-55 instead of the usual 60, giving the final molasses of an apparent purity of 27. Nowhere in the tropics, where the juices are of a high purity, I noticed the exhaustion of final molasses to such a low purity.

The second effect of the presence of bago-cellulose in the juice is its appearance in the sugar. The finer particles of bago-cellulose are held in fine suspension in the juice, which do not settle along with the mud in the clarified juice, giving a turbidity to the latter. The particles of bago-cellulose, which escape the attack of lime, ultimately go through the sirup into the pan and the massecuite, and are retained by the centrifugal screens along with sugar grain. The keeping quality of sugar, and, to a certain extent, its filtering quality is greatly affected by the amount of suspended matter in the sugar, which mostly consists of bago-cellulose.

One difficulty has been noticed in the elimination of bago-cellulose from the raw juice, before it is treated with lime, and that is, the difficulty of filtering the mud through the press. The press cake, obtained with the usual process, consists of 65 to 75 per cent. of cush-cush, which helps the formation of a porous cake, easy of filtration and washing. With the elimination of cush-cush from the raw juice, a slimy precipitate is obtained, difficult to be filtered and washed. This difficulty has been solved by heavily liming the mud from the juice subsiders to distinct alkalinity, which gives voluminous precipitate. No difficulty has been met to filter and wash the cake obtained therefrom. The filtered

juice from the presses in this case should be sent back to the raw juice for redefecation owing to the fact, that it contains some lime salts in solution, which forms a precipitate on its addition to clarified juice. The distinct alkalinity of the mud is not desirable, when white sugar is to be made, as it imparts a dark colour to the juice. But in making white sugar, excessive liming of the mud is not necessary owing to the fact, that a voluminous precipitate is obtained owing to excess lime being used for clarification.

If factories find it impossible to obtain mud, easy of filtration on account of the removal of the bago-cellulose from raw juice, there is no reason why it should not be removed from the clarified juice before the latter is turned into sirup. It will be to the greatest advantage, if bago-cellulose is removed from the clarified juice before the latter is boiled into sirup. This will reduce the amount of scaling in the evaporators, and also suspended matter in the sugar. It will also reduce the gummy nature of the low grade products, making it possible to boil final massequite of a lower purity.

In the making of white sugar either by the sulphitation or carbonatation process, where a heavy amount of lime is used, there will not be any difficulty of filtering the mud, even if bago-cellulose is removed from the raw juice previous to its being treated with lime or sulphur, as the excess lime will give a voluminous precipitate mainly consisting of  $\text{CaSO}_3$ , which is not difficult for filtration. In factories, making white sugar without filtration of the juice, it is of the highest importance to eliminate the bago-cellulose as early as possible. Even when juice is filtered, it is desirable to eliminate the bago-cellulose, before the raw juice is treated with either lime or sulphur to prevent the reactions already referred to. The presence of bago-cellulose in plantation white sugar is one of the causes, which affects its keeping quality due to its moisture absorbing property.

*Method of removal of bago-cellulose.*—Most of the bago-cellulose can be easily removed by straining all the juice through finer mesh wire screens. It has been found possible to remove much of the bago-cellulose by straining the juice through a 100 mesh screen. This does not remove all the bago-cellulose. Some finer particles still pass through. One factory in Hawaii is using 100 and 120 mesh screens to remove the bago-cellulose from the clarified juice. It may



be possible to use a 150 or 200 mesh screen, which is expected to remove the bago-cellulose completely. In using screens finer than 100 mesh, one has to use two or three screens of different mesh, varying from 100 to 200 mesh. If only one screen of 200 mesh is used, it will cause constant choking of the screen, requiring constant attention, though it may eliminate all the bago-cellulose. Straining the cold juice reduced in one factory suspended matter in the cake from 30 per cent. to 1.7 per cent., and reduced the amount of cake by 40 to 45 per cent.

I saw two kinds of automatic continuous strainers, which are used to separate the bago-cellulose from the juice either raw or clarified. One is the Carter automatic strainer, and the other, Peck strainer used in Hawaii. The Carter automatic strainer is a closed cylindrical chamber, containing three cone shaped screens of 40, 60 and 80 mesh, attached to a central rotating shaft. The juice enters at the top, and passes successively through the three screens, removing the bago-cellulose to a central well, from which it is removed to the mud tank, if it be used for straining the clarified juice or is sent to the juice strainer of the mill, if it be used for straining the raw juice. This apparatus does good work. No extra power is required to rotate the central shaft, as this can be done with gravity flow of the juice through a height of 8—10 feet. Different meshed screens can be put to suit the requirements of any factory. This strainer, however, is expensive in first cost. The screens are also found to wear quickly.

The Peck strainer, on the other hand, is very simple in design and cheaper in first cost. It consists of a 100 mesh monel metal rotating screen fixed in the form of a horizontal cylinder with a shaft in the centre. This is connected through a gearing to a driving pulley. It rotates at 4 R.P.M. The raw juice is allowed to fall on the rotating screen, through which, the strained juice flows, while the mush remains on the screen, which is scraped off by automatic scrapers.

In countries, where labour is cheap, as is the case in India, long rectangular screens of 100 mesh can be used to strain all the juice, the mush, that is accumulated on the screens, being removed once in a while by the attendant. This is the simplest and the cheapest device and can be prepared by any factory if a proper mesh screen is available.

*Defecation for making raw sugar.*

1. *Liming.*—The strained juice is immediately treated with a lime cream of 12°-15° Baume, and is thoroughly mixed with the same either by compressed air or by paddles, the former method being preferable. It is desirable to mix the lime thoroughly well, before the limed juice is sent through the heaters for further treatment. With improper mixing a certain portion of the juice becomes strongly alkaline, which gets dark coloured in the juice heaters through the decomposition of lime compounds of reducing sugars. A part of the juice, which remains strongly acid due to this improper mixing of lime with juice, is subjected to inversion in the juice heaters. This improper mixing of the juice will thus result in both inversion of sucrose and destruction of glucose-reactions, which cannot be detected from the purity or the glucose ratio of the treated juice, when both the reactions go on simultaneously.

The amount of lime, required to be used for defecation, depends upon the fact, whether an acid or alkaline clarification is desired. At present, there are two practices, either of which is followed by the sugar factories. In both the cases, the juice is kept as neutral as possible by lime,—with this difference, that in one case, the juice is run on the acid side, and in the other case, on the alkaline side. In Cuba and Louisiana, the former is the practice, while, in the Hawaiian islands the latter is the practice. Different claims have been made by the advocates of these practices. While the alkaline clarification tends to increase the dark colour in the juice and sirup, and ultimately darkens the sugar to a certain extent due to the destruction of glucose by lime, it is found to give a better recovery due to minimum amount of inversion. The latter is true to a certain extent, because even though loss through inversion is minimum, it increases the viscosity of low grade molasses due to the presence of lime salts, resulting in a poor boiling of the low grade massecuite, and yielding final molasses of a much higher purity. Thus while the undetermined loss, which represents the loss through inversion, is lower with alkaline clarification, this has been compensated to a certain extent by the increased loss in molasses. In Cuba where an acid clarification is practised, the loss in undetermined is high, but the loss in molasses is low. While in Hawaii, a retention of 90-91 (sucrose in sugar per cent.

sucrose in juice) has been obtained with alkaline clarification, in Cuba, even higher retention has been obtained with an acid clarification. Which clarification should be followed by any particular factory, depends upon the glucose content of the juices. In the Hawaiian islands, the glucose in the juice is very low not above 0.50 per cent., while in Cuba it is about 1 per cent. and in Louisiana it is 1.50 to 2.00 per cent. It will be risky to run an alkaline clarification with juices containing a higher amount of glucose. This explains, why Hawaii, Cuba and Louisiana follow different practices. In India, where the juices contain a higher amount of glucose than what is found in Hawaii, an acid clarification is the safest.

The reaction of lime on the organic acids of the cane juice is controlled by different indicators, which have caused a good deal of confusion at the present time on account of the different sensitiveness and the different point of neutrality they indicate. A solution, neutral to litmus, is not neutral to phenolphthalein, while one, neutral to the latter, is not neutral, if its pH value is taken into consideration. It is therefore of the utmost importance to select the proper indicator. The use of litmus as an indicator is not reliable even though it affords simplicity of operation, because it is difficult to be obtained pure, and is not so sensitive to organic acids, with which one has to deal in sugar manufacture. Its use, in an atmosphere, saturated with  $\text{SO}_2$  or  $\text{CO}_2$ , is unreliable. Phenolphthalein is sensitive enough, and is much preferable to litmus, but it does not change its colour, unless the solution is distinctly alkaline. Thus a solution, neutral to phenolphthalein, is not really neutral but is alkaline.

The control of reactions referred to above, is necessary to prevent two evils, namely, inversion caused by acids, and destruction of glucose caused by lime. Both are undesirable and while it is impossible to prevent them completely, it is possible to minimize their effect. In the making of plantation white sugar, colour is of the utmost importance, and an alkaline clarification is distinctly harmful, and is hence never followed, even though it results in greater loss through inversion. In the making of raw sugar, colour is not of so much consequence, if the latter can be kept within certain limits.

The present method, for controlling this reaction, is a titration of 10 c. c. of juice with N/10 alkali (usually caustic

soda) or acid (HCl) against phenolphthalein as an indicator. The number of c. c. required to develop or to discharge the colour of the indicator, is designated as the acidity or alkalinity of the juice respectively. In Java, it is expressed as the number of milligrams of CaO or SO<sub>2</sub> per litre of juice. This method merely shows the total acidity or alkalinity of the juice without giving any indication as to the concentration of H or OH ions, which are chiefly responsible for inversion of sucrose and destruction of glucose respectively. For instance, a N/10 acetic acid solution, and a N/10 HCl acid solution, would require the same number of c. c. of N/10 caustic soda for neutralization, but there will be a marked difference in inversion with the same amount of the two acids. It is well known that the organic acids, with which the sugar manufacturers have to deal, possess a very low power of dissociation, which affects the concentration of the H ions. What is, therefore, desired in the control of the reaction, is not the total acidity or alkalinity, but the 'activity' of the acid, or in other words, the concentration of the H or OH ion.

The concentration of the H ion may be determined in two ways, electrometrically and colorimetrically. The former is the most accurate, but is attended with the practical difficulties due to the presence of suspended impurities and colloidal matter in the cane juice, which affects the electrodes. The colorimetric method, on the other hand, is easy and rapid, and fairly accurate, and the procedure is as simple as a litmus paper. This method of determining the H ion concentration depends upon the changes of colour or hue, which occur, when solutions of various indicators are subjected to gradual changes of H ion concentration. Dr. Brewster, of the Louisiana sugar experiment station, has evolved a colorimetric method, which consists in adding one drop of the indicator solution to 3 drops of the test solution, and the colour, produced, is matched with the standard buffer solution, whose pH value is known. The pH value of the buffer solution, that matches with the colour of the test solution, is then the same as the pH value of the test solution. The buffer solutions can be easily prepared from standard buffer tablets, which are available on the market.

The pH value of a truly neutral solution is 7.0. Any solution showing a pH value below 7.0 is acid, when it is above 7; it is alkaline. In controlling this reaction, therefore,

one has to bring the pH value of the juice to as near 7 as possible. This method is the most rational, reliable and accurate of all the methods followed so far. This will be evident from the fact, that, while the acidity of the juice after its treatment with lime in a raw sugar factory in Louisiana is 0.2 to 0.3 c. c. of N/10 NaOH with phenolphthalein as an indicator by the titration method, according to Dr. Brewster, colorimetrically its pH value is approximately 7 or slightly less, showing that the juice approaches true neutrality, and is not acid as will be supposed from the titration results. Dr. Brewster recommends the following H ion indicators in cane sugar factories:—

(1) for testing raw juice: Methyl red (Ortho carboxy benzene azo dimethyl aniline) Con. 0.02 per cent; pH range from 4.4 to 6.0; colour change, red to yellow.

(2) for testing the neutrality of either limed or sulpho-limed juice; Phenol red (phenol sulfon phthalein), con. 0.02 per cent.; pH range 6.8 to 8.4; colour change yellow to red.

(3) for testing the acidity of the sulphited juice: Brom Phenol blue (Tetra bromo phenol sulfon phthalein), Con. 0.4 per cent.; pH range 3.0 to 4.6, colour change yellow to blue.

Full details as regards the theory of colorimetric method, as well as the theory of indicators, are given in Dr. Clark's book on the determination of H ions.

In Louisiana, the acidity is usually determined by the titration method with phenolphthalein as an indicator. The raw juice is limed to 0.2 to 0.3 c.c. N/10 NaOH. In Cuba the juice is kept faintly acid to litmus paper. In the Hawaiian islands, the juice is limed to a slight alkalinity to litmus paper. As has been said previously, litmus as an indicator is not sensitive and is unreliable. It is far better to use phenolphthalein as an indicator. An acidity of 0.2 to 0.3 c.c. of N/10 NaOH with phenolphthalein as the indicator, is the best from the point of minimum inversion.

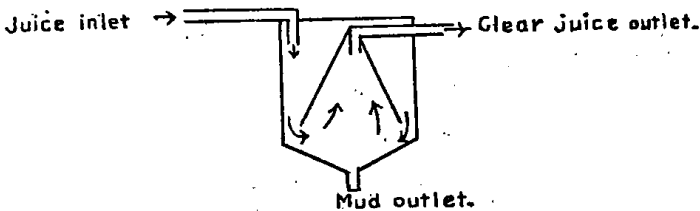
2. *Juice heating*.—After the juice is limed and well mixed, it is passed through juice heaters, in which it is heated to a temperature of 200° to 220° F. Factories, following an acid clarification, usually superheat the juice to 215°-220° F which gives a better settling. Factories, following an alkaline clarification, usually heat the juice to 200° F, and

also get good settling. In this case, a higher temperature is thought undesirable, probably on account of the possibility of glucose destruction.

The juice heaters commonly used are the horizontal, multi-pass, juice tube type. The tubes are either of brass or copper, about 2 inches in diameter and 20 feet or more in length, through which the juice is pumped at a pressure of 40 lbs. The juice flows at the rate of 400 feet or more per minute. In order to prevent scaling, a velocity of 500 feet per minute is thought desirable. Modern tendency is to run the juice at a higher velocity to minimize scaling. For juice heating, mostly exhaust steam of about 4-5 lbs. pressure is often used, though, in many factories, it is partially supplemented or completely replaced by live steam, when sufficient exhaust steam is not available.

3. *Settling*.—The next operation is to pass the heated juice into settling tanks. These may be either rectangular or cylindrical in shape. They are sometimes provided with heating coils inside, in order to heat the juice to cracking point, before it is allowed to settle. This is followed in factories, where juice cannot be heated to 212° F in the juice heaters. In modern factories, heating coils have been found to be unnecessary, as the juice can be heated to 215°-220° F, easily in the juice heaters. The importance of insulating these tanks, so as to promote better settling, has not been so well understood by sugar manufacturers. Only in the Hawaiian islands, this point has been well attended. There not only are the tanks well insulated on the sides, but even the tops are covered and insulated. When tanks are not insulated, convection currents, set up by the rapid cooling of the juice at the surface, as well as the sides, interfere with the process of settling. Not only, therefore, is there a loss of heat through cooling of the juice, but in addition, a poor settling is obtained. Modern practice is to provide insulated tanks. The time, required for settling, is about an hour. Delivery cocks are provided at different levels to decant the clear juice to the storage tank, while the mud, that settles at the bottom of the tanks, is sent to separate mud tanks for further treatment. This is a discontinuous process of settling, which is the easiest and simplest in operation, and is by far very common. It gives a clear good juice provided, it is properly attended to. It involves personal element, which affects the quality of the work.

In countries, where labour is scarce and dear as in Louisiana and Cuba, continuous settlers are coming into general use. The old type of the continuous settler is the Demming's. This consists of an insulated verticle, cylindrical tank with an inverted cone inside as below:—



The juice enters at the top in the outside vessel, goes to the bottom, where it deposits the mud, which is intermittently removed through the pipe at the bottom, while, the clear juice goes above through the cone, and ultimately comes out through the pipe at the top. The Demming's settler has one defect and that is, it is not sufficiently elastic, so that the rate of flow of the juice can be changed, which is sometimes necessary, when juices, which settle with difficulty, are met with. All modern installations have abandoned this practice.

There is at present on the market another continuous settler, which is being looked upon with great favour in Cuba. It is the Dorr clarifier, which was tried in Cuba at centrals Mercedita, Violeta, Manati, and Elia to the satisfaction of sugar manufacturers. In Cuba, anything that will save labour, has a great future.

The \*Dorr clarifier not only saves labour, but provides a continuous automatic system of settling, requiring very little attention. It consists of an insulated covered cylindrical steel tank, which is divided into 3 or more compartments by inclined steel trays, over which the mud is deposited. Over each tray rotates slowly, at one revolution per 4 minutes, a scraper, which directs the mud to the central well, from which it sinks to the bottom, where from it is continually withdrawn by a pump. There is also a scum scraper attached at the top to remove the floating scum. The hot juice from the heaters is directly pumped into the clarifier, from which the clear juice comes out continually as an over-flow. The

\* See figure on page 119.

juice remains in the clarifiers for about 2 hours, by which time, most of the suspended matter is deposited. The advantages of the Dorr clarifier are:—(1) It, being a continuous process, saves labour as well as space. (2) It gives a continuous flow of clean bright juice without any appreciable loss of heat in the clarifier due to its being insulated, which means a saving in steam consumption. In Cuba, juice could be easily supplied to evaporators at 200° F. (3) The mud, that is continually withdrawn, is dense, and consequently contains less juice. This is required to be diluted with little water, before it is pumped for filter press; without further liming and heating. The dilution of the mud with water, reduces the sucrose loss in press cake. The amount of mud is reduced from 10 to 5 per cent., which is also responsible in reducing the loss in press cake, thus increasing the retention. (4) It gives a bright clear juice of better quality, as it reduces the irregularity due to human element to its minimum.

In central Mercedita, the results, obtained since the installation of Dorr clarifiers, are very encouraging indeed. Not only the quality of the sugar was markedly improved by the reduction of suspended matter in it (it was reduced from 0.10 per cent. to 0.06 per cent.) but the sucrose retention was increased. The amount of extra fuel saved per day was 50 per cent., while labour was considerably reduced. The following figures give an idea:—

	Defecation.	
	Ordinary.	Dorr clarifier.
Miligrams of insoluble matter in sugar ...	87	69
Cleanliness of sugar ...	5.5	7.5
Sucrose in cake per cent. ...	6.75	5.5
Consumption of coal tons per day ...	16.2	8.8

For conditions in India, where labour is comparatively cheaper, the use of discontinuous insulated tanks will be economic. Though Dorr clarifier gives on an average a clearer juice on account of the elimination of the personal element, its first cost is very high, and its introduction into India, so long labour is cheap, is of doubtful economy.



4. *Treatment of the mud.*—The mud, obtained from the settling tanks, is then usually treated with more lime, heated to boiling and is then either allowed to settle, or directly passed through the filter press. The object of adding lime to mud again, is to promote better settling and obtain an easily filterable mud. So long, the mud is not made alkaline, this practice is not open to any objection, but usually, the addition of lime to mud is carried to distinct alkalinity, which is objectionable on account of the destructive action of excess lime on glucose, rendering dark colour to the filter press juice. Besides due to alkalinity of the mud, the clear juice, obtained therefrom either by settling or filtering through the press, contains some lime in solution, which precipitates some more of the non-sugars on its addition to the clarified juice. This precipitate is ultimately deposited in the evaporators as a scale, which considerably affects their evaporation capacity. It is, therefore, desirable, that the juice, obtained after reliming of the mud either by settling or filtering through the press, should be sent back to the raw juice for redefecation. When plantation white sugar is to be made, it is necessary to avoid the excess of lime for treating the mud so as to prevent the formation of dark coloured compounds. In order to promote better settling and filtering, filter-cel is used in some factories, but its use has not become general probably due to its cost.

Most of the factories resettle the mud. The clear juice obtained therefrom, is usually mixed with the clarified juice, which is not a good practice for reasons given above. The mud, obtained from the resettling of the first mud, is then directly pumped to the filter press. Factories, having sufficient filter press capacity, do not resettle mud, but directly pass it through the press, after it is treated with lime and heated. Usually factories are not provided with sufficient filter press capacity, in which case, resettling of the mud becomes a necessity in order to cut down the work of the press.

The mud, obtained from the settling of the juice or resettling of the first mud, is then filtered through a press so as to separate clear juice from insoluble solids. For this purpose, plate and frame presses are used in all the cane sugar factories. These work fairly well, but require constant attention owing to leaks through cloth. The press consists of alternate plates and frames, pressed together by means of a gear. In new designs, instead of a gear, hydraulic closure is

used. The thickness of the cake depends upon the thickness of the frame, which in turn determines its filtering capacity. A thicker frame gives a thicker cake, which in turn gives more trouble for washing.

In a press generally, two kinds of plates—called the juice plates and water plates—are provided. There are also provided two side feeds, one for the juice, and the other for the water, the direction being reversed in the latter case in order to secure a thorough washing. Between the plates and frames, are stretched the cloths. Each plate is provided with a channel and a cock, through which the filtrate runs out. When water is used for washing the cake, the cocks on the water plates are closed so that water has to travel through the cake into the juice plate, before it runs out of the press. This secures better washing. The press is, therefore, set in the following order: filter head, frame, juice plate, frame, water plate, frame, juice plate, frame, &c.

A few houses in Louisiana are equipped with Sweetland presses. They are leaf presses, are self cleaning but are expensive in first cost. On account of self cleaning device, they can be cleaned in a short time and reused. So far, I noticed them in a few houses in Louisiana, but no where in the Tropics they have been used. Their use is getting more extended in the refineries.

The mud is pumped through the press by means of a duplex pump or a centrifugal pump in electrified houses at a pressure of 49-60 lbs. It is not safe to exceed this limit, as it may result in breaking the plates. Even a pressure of 40 lbs. is not desirable, as it forms a compact cake difficult for washing owing to the formation of channels in the cake. In Cuba and Porto Rico, washing the cake has not resulted in reducing the sucrose content of the cake to such an extent, as is obtained in the Hawaiian islands, where the presses are usually run at a low pressure. On account of the compact nature of the cake, obtained through high pressure, at which presses are run, water used for washing does not permeate the cake but forms channels resulting in partial washing. In Cuba, due to insufficient press capacity, cake is sometimes not washed, but is hardened and dried by either steam or air, before the press is dumped. The sucrose, in the press cake, amounts to 8-10 per cent. Even when washing the cake is practised, the sucrose, in the cake, has not gone below 4 per cent. In the Hawaiian islands, press cake rarely shows more

than 1.5 per cent. sucrose. These presses are usually run at a pressure not exceeding 25 lbs. In some cases, mud is fed to the presses by gravity alone, for which a verticle fall of about 10 feet is used. A low pressure gives a porous cake, which is easy for washing. Water for washing is, however, forced through the press at a pressure of 40 to 60 lbs. It is, therefore, desirable to run the presses at a low pressure not exceeding 25 lbs. so as to form a porous cake easy for washing. There is also another advantage. Presses running at a low pressure do not leak so much, and give a long life to filter cloths.

After the press is full, which is recognized by the slow running of the filtrate, and also by the increase in pressure, it is usually washed with hot water, which is fed in the opposite direction. In factories, where presses are run at high pressure, washing results in the formation of channels. In some of the factories in order to reduce the losses in press-cake, double filtering is practised. For this purpose, cake is not washed in the 1st filter press but is simply dried by air, is then dumped, and the cake pugged and mixed with water, and the mixture is again filtered through another press. This is the most effective method of reducing the press cake loss, but demands an increased press capacity, which is usually insufficient in most of the factories. In Porto Rico, one factory was able to reduce the sucrose content of the cake from 5 to 1.5 per cent. by means of double pressing. The chief advantage of double pressing, is the reduction of the amount of water required for washing, which requires not only extra fuel to evaporate all the water, but is attended with a loss of sucrose through inversion and fermentation.

It has been known that, one of the sources of undetermined loss in sugar manufacture is the washings from the presses, which are very susceptible to inversion and fermentation. Factories, using plenty of water for washing the cake, suffer this loss indirectly as it cannot be determined directly. A low sucrose in the press cake, obtained with the use of plenty of water, is, therefore, no indication that the sucrose thus obtained is recovered in sugar. In order to minimize this loss, washing of the cake should not be continued over a long time, as is usually the case, a period of one hour being considered safe. It is claimed by the advocates of the Dorr Petree process, that washing the cake has another disadvantage—that it redissolves some of the precipitated

impurities, which again enter the house. How far this is true, has so far not been verified.

The filtrate obtained from the press is usually clear but slightly dark coloured. This clear juice is usually mixed with the clarified juice, before it is charged to the evaporators. This practice is not desirable, because (1) the filter press juice is usually alkaline, which, on addition to clarified juice, imparts turbidity to the latter, on account of the precipitation of some of the non-sugars. This precipitate causes scaling in the evaporators reducing their capacity considerably; (2) the presses many times leak, which is not detected in the ordinary course. The result is, a dirty juice mixes with the clarified juice, causing rapid fouling of the evaporators. As a matter of precaution, it is better to send back this juice to the raw juice tanks for redefecation. Some factories in Cuba follow this practice as a matter of precaution with consequent increase in evaporation capacity.

After the cake is washed with water, it is dried either with steam or compressed air, after which the press is dumped.

5. *Dorr Petree process.*—This is a new process of clarification originally patented in 1916 by Messrs. Thomas and Petree, the chief inspecting chemist and engineer of the Colonial Sugar Refining Company of Australia. The chief point, which has attracted the attention of the sugar technologists all over the world to this process of clarification, is that it completely eliminates the filter press station in a modern sugar house. To those, who know the amount of labour, investment and upkeep involved in the filter press station together with its attendant troubles and dirt, the introduction of a process, that will eliminate this station altogether, will come as a blessing. In this process, the mud obtained from the subsidors, is sent to the mill, instead of being further treated and passed through the press. In order to get a denser mud and thus reduce its quantity, a special continuous subsidor called the 'Petree volute flow subsidor' was designed. This consists of conical shaped insulated vessel, in which the clear juice runs out in continuous stream by an over-flow, while the mud, which settles at the bottom, also runs continually by a separate over-flow pipe. This subsidor gives mud of a greater density than that obtained with ordinary defecation, making it possible to be directly applied to

the bagasse of mills. Recently, Petree has recommended the use of Dorr clarifiers, instead of his original subsidiers, which are no doubt more efficient, and give a mud of still greater density, and consequently of less volume. The recent success of the Dorr clarifiers in Cuba, has brought this process into greater prominence.

The following are the details of the process:—

“The juice from the 2nd mill (which contains most of the gummy and colloidal impurities, expressed in the heavy second and later crushings) is preliminarily defecated and separately settled and decanted.

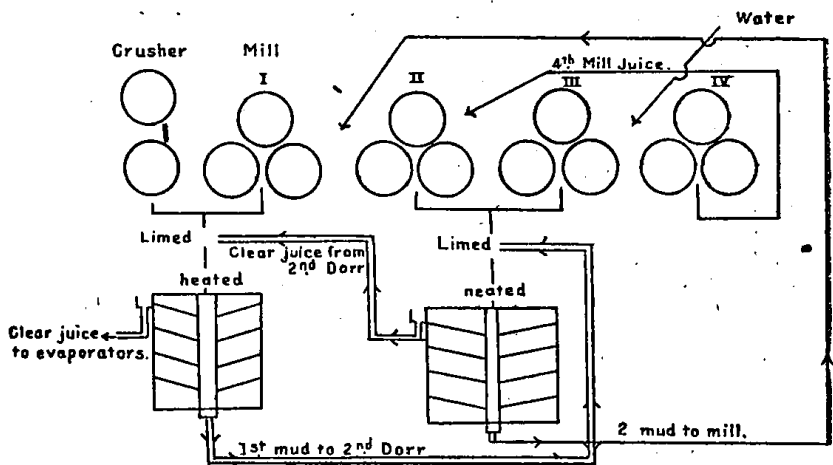
“The resulting clarified juice joins the first mill juice, and this rich mixture is defecated and settled.

“The rich mud from the settling of this mixed juice joins the second mill juice prior to its being preliminarily defecated and settled.

“The clear juice resulting from the settling of the defecated mixed juice is sent to the evaporators.

“A special mud from the settling of the second juice plus rich mud, is returned to the bagasse at an early stage of the crushing without prejudice to the efficiency of extraction at the mills.”

A rough sketch is given below to explain the process:—



When 4 mills are used, the juice from the last mill is not defecated, but is put on to the bagasse from the 2nd mill, water being applied to bagasse after the 3rd mill.

This process is in use at present in a number of factories in Australia, at Uitvlugt plantation in British Guiana, central Soledad in Cuba, Paia and Punene plantations in Hawaii. The results, so far obtained, are not conclusive. Doubtless there are some difficulties, which need solution before definite results can be obtained. Some of the difficulties are:—

(1) *The effect on sucrose extraction.*—In all the new installations of this process, both in Cuba and Hawaii, it has been noticed that sucrose extraction has been reduced by over 1 per cent. The returning of the mud to the bagasse, which is richer in sugar than the juices of the subsequent mills is bound to affect the extraction to some extent, unless it is accompanied with more maceration. Central Soledad obtained a slightly higher extraction with this process, to secure which, the maceration water has to be increased by 25 per cent. A loss of 1 per cent. in sucrose extraction does not compensate for the saving in press cake, which, in well equipped factories shows little loss. In the Hawaiian islands where the press cake contains a little over 1 per cent. sucrose, a loss of 1 per cent. in extraction is a heavy loss. At Paia, where record has been made for the highest sucrose extraction so far obtained with milling, the following comparative figures have been obtained:—

	1921 Old Process.	1923 New Process.
Sucrose per cent. bagasse	0.73	1.42
S in juice per cent. S in cane	98.90	97.54
S in press cake	1.16	...
S lost in press cake per cent. S in cane	0.22	...
S in cane	14.16	13.97
S lost in extraction per cent. 100 S in cane	...	1.96
Sucrose saved in press cake per cent. 100 S in cane	...	0.22
Net loss per 100 S in cane	...	1.14

S = Sucrose.

Assuming, that 1,000 tons of cane are to be ground per day, and that cane contains 13.5 per cent. sucrose,

the total sucrose entering the mill is 135 tons, out of which, 1.5 tons of sucrose is lost due to this process every day.

(2) *Upsetting of the chemical control.*—On account of the return of the mud back to the mill, it is not possible to obtain raw juice samples without an admixture of the juice from the mud, which is in continuous circulation. The chemical control, therefore, starts with the weighing of the clarified juice. The sucrose extraction is based on the sucrose in the clarified juice, in which case, no account is taken of the loss of sucrose during heating and settling. Secondly, in the old process, no account of the fibre in the crush-cush, that finds its way in the juice, is taken into consideration. With the Petree process, all that finds its way in the bagasse. On account of the above two reasons, the sucrose extraction, obtained with the Petree process, is shown higher than what is actually the case, while, that obtained with the old process, is shown lower than what is actually obtained.\* On account of the upsetting of the chemical control, it is practically impossible to get comparative figures.

(3) *Effect on extraction with tandems of few mills.*—Factories, having only a crusher and 3 mills, comparatively suffer more loss in sucrose extraction, and it is doubtful, whether it will be economic to instal this process in tandems of less than 4 mills. Even factories, having 6 mills in a tandem, have suffered in extraction.

(4) *Effect of the amount of maceration water.*—Factories, using a low amount of maceration to the extent of 15-20 per cent. are likely to suffer in extraction as well as in capacity. The former can be increased if more maceration is practised, but it will decrease the milling capacity. Factories practising over 40 per cent. maceration, may not suffer in extraction and capacity to the same extent as the ones practising a lighter maceration.

These difficulties will no doubt be overcome as more experience is gained. The Dorr Petree advocates, on other hand, claim a higher boiling house recovery, but it is open to question, how far that is due to the Petree process alone. In

\* According to Mr. McAllep, about 2 to 2.5 per cent. less sucrose is credited with Petree process.

Cuba, Dorr clarifiers alone have increased the boiling house efficiency to the same extent, and it is, therefore, probable, that most of the benefits, obtained with regard to boiling house efficiency, may be due to the use of Dorr clarifiers.

In India, where labour is much cheaper, the installation of a Dorr clarifier will be very expensive on account of the first cost. Without the Dorr clarifiers, the Petree process cannot be worked successfully. Besides, the process demands a royalty. Taking these facts into consideration, there is not much chance for its economical operation in India at least at the present time.

The above outline represents the general practice of defecation for manufacturing raw sugar from cane. When cane juice contains more silica, due to the alkalinity of the soils, on which cane is grown, as is reported to be the case on the Rosehall estate in British Guiana, a slight modification of the process is necessary in order to eliminate the silica. The sugars, made on that estate, were found to offer great difficulties in refining which was traced to the presence of silica in the sugars. The silica, which is present in the form of organic compounds in cane juice, is not precipitated by ordinary defecation. The superheating of cane juice before liming, has been found to precipitate the organo-silica compounds. The modified process, followed at the said estate, is as follows:—Raw juice is heated before liming to 240°-250° F, after which it is passed through an explosion box, and is then limed to litmus neutrality. Lime is thoroughly mixed with the hot juice, after which the mixture is heated to 210°-215° F, and is then sent to settling tanks. The further process is the same. This method proved to be successful in removing a great part of silica. The amount of inversion, that is likely to be caused, by the superheating of the juice, which is distinctly acid, is not known. Laboratory results show that the loss is inappreciable.

#### *Clarification for making plantation white sugar.*

The importance of removing fine particles of cush-cush before liming by means of strainers has been already referred to. There are at present 3 or 4 methods of making plantation white sugar directly from cane, that are in use in the various cane sugar countries of the world. They are: (1) sulphitation, (2) carbonatation—single or double, (3) sulpho-carbonatation or acid thin juice process, and (4) kieselguhr-



char process. Out of these, the sulphitation is common in Louisiana, Mauritius, and also to some extent, in Java. The second and third processes are followed in Java, though the sulphitation is getting common. The last one was tried in Louisiana but proved to be commercially unsuccessful.

A few considerations have to be made, before the suitability of any of the above processes to meet the special conditions in any country is decided. Of the above processes, sulphitation is by far the cheapest and simplest process, for making plantation white sugar directly from cane. In the sulphitation process, much more lime is used than what is usually used in the ordinary defecation process, the excess lime being neutralized by sulphurous acid gas generated by burning sulphur in special stoves. This process is usually attended with the settling system, the mud being pressed through the press, while the clarified juice may be filtered through gravity filters—called bag filters. On the other hand, in carbonatation process, a far greater amount of lime is used, which is neutralized with carbonic acid gas, instead of with sulphurous acid gas, generated by burning limestone. The amount of lime used per ton of cane is 1 lb. or less with defecation,  $1\frac{1}{2}$ -2 lbs. with sulphitation and 10-15 lbs. in carbonatation process. It is thus obvious that the amount of lime used in carbonatation is 10 times that used in sulphitation. This becomes expensive. Dr. Geerligs, in comparing the two processes, estimates that, in the sulphitation process, the cost of lime and sulphur per 1,000 tons of cane is £ 5-11-2, while in the carbonatation process, the cost of limestone alone comes to £ 16-0-3, while the cost of limestone and coke together comes to £ 26-13-8. It is, therefore, evident, why it is essential to have a cheaper limestone available in the vicinity of the factory. Against this, it should be remembered that, carbonatation process gives a decidedly better grade of sugar, because, on account of the excess lime used, there is a greater energetic action of lime, whereby, a great part of the suspended matter together with gums and pectins, are precipitated, rendering the juices readily filterable. On account of the filtering of all the juices, the resulting juice is bright and clear. It is also said, that the process gives a greater yield of sugar, which cannot be easily demonstrated. Dr. Geerligs, in his book on 'Plantation White Sugar Manufacture', gives 100.32 as the yield from the double carbonatation process, against 100 by the sulphitation process. In the sulphitation process, on account

of the acid medium, a greater loss due to inversion is quite likely. This increase in the yield of sugar is not large enough to justify the installation of a carbonatation process, which is very expensive.

On account of these facts—large amount of lime required, the necessity of a greater filter press capacity, and the filtering of all the juices 2 or 3 times, the process becomes expensive. Besides a carbonatation process is accompanied with a troublesome and complicated lime kiln system, while, in the sulphitation process there is a system of repeated settling, which is comparatively much simpler. To run a kiln for burning limestone, in order to generate carbonic acid gas, as well as prepare lime for the factory, it is necessary to have cheaper supply of coke, which also adds to the cost appreciably. Taking all these things into consideration, and specially simplicity of operation and cheapness, sulphitation is the most suitable process for making plantation granulated sugar in India.

Acid thin juice process is of recent introduction, and has replaced the carbonatation process in Java. This process is practically the same as the double carbonatation process, in which the excess lime is neutralized with carbonic acid gas in two stages, with this difference, that the clear juice is again neutralized with sulphurous acid gas. The neutralization of lime with carbonic acid gas is accompanied with the formation of potassium carbonate, a salt, which possesses the greatest capacity for decomposing glucose, resulting in a darkening effect. In sulphurous acid saturation, potassium sulphite is formed. This has a decided bleaching action. On account of this reason this process is preferred. This process, however, is equally expensive as the carbonatation, as it, in no way, saves the amount of lime or the press capacity.

Kieselguhr-char process was tried in Louisiana. With the advent of the decolourizing carbons, specially Norit, a great hope was entertained with regard to the preparation of white sugar directly from cane by the use of Norit. The excessive amount of Norit, required for this process, and the difficulty of filtering the juices, made the process economically unsuccessful.

1. *Sulphitation process.*—There are two methods of application of this process, that are in use at the present time. They are liming first and sulphiting afterwards and

*vice versa*. The former is common in Java and the latter in Louisiana and Mauritius. The obvious reason for sulphiting first, and liming afterwards is the presence of a very high amount of glucose in juices in Louisiana. While, elsewhere, the amount of glucose rarely exceeds 1 per cent., in Louisiana it varies from 2-3 per cent. It is well known, that lime combines with glucose in the cold to form glucosates, which decompose at a temperature below 70° C, forming glucinic and saccharic acid salts. The former are unstable, and decompose on heating, forming brown coloured products. This spontaneous decomposition is chiefly responsible for the dark colour of the juice, as well as for the resulting acidity of an originally alkaline or neutral juice. If care is taken not to heat the juice above 55° C, it forms lactic acid, which is more stable. In order to lessen this danger, and escape the detrimental effect of lime on glucose, sulphiting is done first chiefly on account of a high glucose content in Louisiana. Sulphiting has, besides, an antiseptic action on the juice preventing fermentation. In Northern India, where the juices contain a high amount of glucose, it will be safer to sulphite the juice first, and lime it later on. In the Bombay Deccan, and in Southern India, where the juices are fairly rich, and contain a low amount of glucose, liming first and sulphiting afterwards, will be as good or even better. When sulphiting is done first, it becomes very difficult to control the amount of lime to the extent one would desire, because this depends on the acidity of the juice, to which it is sulphited, which cannot be increased beyond a certain limit, due to the low absorbing power of the sulphurous acid gas, unless an excess of the gas is used, which consequently goes to waste. On the other hand, when liming is done first, the quantity can be controlled to any extent, one would desire, neutralizing the same with sulphurous acid gas, the quantity of the latter depending on the amount of lime used. The greater amount of lime gives a better clarification.

(a) *Lime sulphitation*.—The raw juice, after it is weighed, is first limed, for which 15° Be. cream is used. The amount of lime used varies from 6-10 or even 12 litres of 15° Be. cream to 1,000 litres of raw juice. After the juice is thoroughly mixed, it may be heated to a temperature 50°-55° C. This preheating is considered beneficial. In Java, preheating the juice, before liming to about 65° C is practised. The juice is

then sulphited to neutrality to phenolphthalein. The acidity varies from 80-120 milligrams of  $\text{SO}_2$  (=0.31 c. c. N/10 NaOH to 10 c. c. of juice). The neutralized juice is then heated to boiling to a temperature of  $102^\circ$ - $104^\circ\text{C}$  ( $215^\circ$ - $219^\circ\text{F}$ ) in juice heaters, after which it is taken to the settling tanks. Harloff and Schmidt claim, that a reheating of this juice to boiling in open juice heaters or eliminators, promotes better settling, and a good quality of juice is secured. It is better to have insulated tanks for settling. This is the process followed in Java.

(b) *Sulphitation liming*.—This process is followed in Louisiana and Mauritius. The raw juice, as it comes from the mills, is taken to a sulphur box. This consists of a verticle rectangular wooden chamber, usually of  $6' \times 6'$ , the height varying from 12 to 20 feet. At intervals within the box, are placed slanting perforated wooden partitions placed horizontally, which break up the juice into fine shower. The juice enters at the top, and is divided into fine shower by the perforations, while the sulphurous acid gas enters at the bottom either under suction or air or steam injector. The sulphurous acid gas in its upward movement in the chamber, meets with the shower of juice, which absorbs the gas. The acidity of the juice is increased to 3-4 c. c., *i.e.*, 10 c. c. of juice is neutralized by 3-4 c. c. of N/10 NaOH solution with phenolphthalein as an indicator. This is the simplest mechanism used in Louisiana for sulphiting the juice. About one lb. of sulphur is required per ton of cane.

The sulphurous acid gas is generated in a special stove. This consists of a cast iron box with a movable door. Sulphur is burnt on a movable plate, the burning being started by a red hot piece of iron. Sulphur is fed intermittently either through the movable door or through special opening at the top. The latter system is better, as feeding can be done without opening the box, thus preventing the cooling of the sulphur furnace. In order to promote proper burning, compressed air is supplied to the furnace, and the gas is forced through the sulphur box on account of its pressure. On account of the high temperature produced in the furnace, it is provided with a water jacket for cooling. A part of the sulphur escapes burning and sublimes. In order to prevent the choking of the pipe by the sublimed sulphur, a sublimator

consisting of a big cast iron pipe is provided, which condenses the sublimed sulphur. There are 3 or 4 things quite essential in running a sulphur stove properly. These are: (1) water cooling device, both for cooling the furnace in order to keep up the temperature, as well as to cool the gas, before it enters the sulphitation tank; (2) a sublimator, to prevent the escape of sublimed sulphur to the pipes which get choked; (3) drying of the air by means of passing air through quicklime. This is quite essential, as moist air promotes the formation of sulphuric acid, which is decidedly injurious both to the pipes as well as to the cane juice; (4) regulation of the air supply. Compressed air at a pressure of 15-20 lbs. is usually supplied. Insufficient air causes an incomplete combustion of sulphur, resulting in sublimation. An excess of air, on the other hand, causes the dilution of the gas, which affects the sulphitation.

The sulphited juice, is then treated with lime cream of  $8^{\circ}$ - $10^{\circ}$  Be., until the acidity is brought to 1.1 c.c. which later, after heating, comes to 0.9 to 1.0 c.c. In Louisiana a high acidity is maintained with the object of obtaining a light coloured sirup, and ultimately obtaining a better grade of white sugar. Also viscosity of low grade products is reduced considerably. It is likely, that greater loss through inversion may result, though the undetermined loss in Louisiana factories is not higher than that obtained in the Java factories, where a low initial acidity is maintained. Dr. Brewster has recently shown, that the acidity of 1 c.c. of N/10 NaOH shown by the Louisiana juices after sulphitation and liming, corresponds to a pH value of 6.8 which is pretty near neutrality. The presence of calcium sulphite acts as a buffer against dissociation. This will indicate, that the acidity, maintained by the Louisiana houses, is within the safety zone. The only difference, I noticed on account of the high acidity, is that, the evaporators get scaled much more quickly with Louisiana practice, on account of the presence of calcium sulphite, which require constant cleaning, while, in the Java practice, the evaporators do not get scaled so quickly.

The mixed juice is, then sent to the juice heaters. The process of heating, settling, treatment of the mud, and the filter press work, is quite the same, as is detailed for raw sugar defecation, and so only a few points to be borne in mind are detailed below.

When plantation white sugar is to be made by the sulphitation process, a greater capacity of juice heaters is necessary. On account of the presence of a far greater amount of precipitate, the juice heaters get soiled very quickly, which require cleaning either by scraping or preferably by HCl. On account of this reason, extra juice heaters will be of great service. In raw-sugar factories, this is not necessary, as the heaters may be cleaned once a week during general cleaning. Similarly white sugar factories require greater settling capacity, as it is desirable to obtain as bright a juice as possible. A cloudy or turbid juice causes trouble in the evaporators.

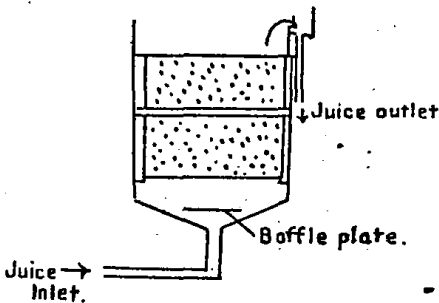
With regard to the treatment of the mud, reliming of the same is objectionable on the ground, that this results in making the juice alkaline, which causes darkening of the juice. Besides the juice, on addition to the clarified juice, becomes turbid due to the precipitation of non-sugars by the excess lime held in solution. A few factories use only filter-cel for the mud, instead of lime to prevent this danger. In Java, some factories resulphite the mud so as to keep it faintly acid. In the making of white sugar, it is best to send all the press juice as well as the juice obtained from resetting of the mud back to the raw juice for reclarification on account of reasons already given.

The clear juice, obtained from the settlings, still contain fine particles of cusc-cusc in suspension. The importance of removing the same by straining through screens of 100 mesh or more, is already referred to. The juice, as it comes out of the strainers, still contains fine matter in suspension, which imparts a slight turbidity to the juice. In order to remove this fine matter, juice is filtered through filter bags, in some factories. In Java, no filtering is practised.

The bag filters consist of rectangular verticle chambers, made usually of iron with a head perforated with a few holes. From each hole is suspended by means of a nipple a double bag. The outter bag is made of loosely wooven cord, about  $6\frac{1}{2}$  feet long and 6" in diameter, and serves as a support to the inside bag, which is much wider (usually 24" across and 3 feet long) and is made of cotton tweel fabric. The inside bag, being loosely crumpled in the outside bag gives an appearance of a fluted filter paper. The clarified juice from

the settling tanks is run to the top of the bag filters, from which it filters through, leaving the suspended matter in the bags. The juice, from the bag filters, is very bright and clear, free of suspended matter or turbidity. The work of the bag filters is slow, and there is a chance of getting inversion.

*Excelsior filters.*—In one factory in Louisiana, I noticed the juice and the sirup were filtered through the excelsior filters, instead of through bag filters. These consist of small circular tanks fitted with either one or two baskets 22" high containing wood shavings. Each basket has a removeable wire screen on one side and a fixed one on the other, between which the excelsior is placed. The two baskets are placed one above the other as below:—



Juice enters at the bottom, where it meets the baffle plate, passes through the excelsior filter, which retains the suspended matter and fine cush-cush, and the clear juice runs as an overflow. The filters are first used for filtering

sirup for about 6 hours, after which clarified juice is passed for another six hours. The excelsior is then removed, washed with sweet water from the evaporators, and is again used. In this way, excelsior can be used for about a week. These filters are very simple in construction and operation, and give fairly clear juice. It cannot, however, remove the turbidity, and so, the juice filtered through these filters, is not so brilliant and clear. The clear juice is then sent to the evaporators, while the washings are sent to the mud tanks for further treatment.

In Java, no bag filtration is practised, in which case, greater attention is required to be paid to the operation of settling. This demands more settling capacity.

*Lime.*—As the lime is the principle material used in cane juice clarification, it should be of a certain purity. For making plantation white sugar, it is desirable to have lime containing upwards of 90 per cent. slaked lime. The impurities in lime cause a great trouble in clarification. The impurities, which should be carefully looked before lime is

purchased, are magnesia, iron oxide, alumina and silica. The insoluble in hydrochloric acid should not exceed 2 per cent.

The troublesome impurity in lime is magnesia. It should not exceed 2 per cent. It retards the slaking action of lime and affects subsidence. The juice settles with great difficulty, and contains suspended matter, which, later on, forms scale in the evaporators. It also causes the darkening of the juice in the process. For these reasons, lime should be tested for magnesia.

The other impurities, iron oxide and alumina, and silica give rise to the formation of scale in the evaporators. Each of these impurities should not exceed 2 per cent. in lime.

In cane juice clarification, lime has to be applied in the form of milk of lime. It cannot be used in unslaked state, as is common in beet sugar manufacture, on account of the presence of glucose. The temperature of the juice, while it is still alkaline, should not rise above 50° C on account of the harmful effect of lime on glucose. If unslaked lime is used for clarification, glucose will be attacked by lime during slaking on account of the heat liberated on hydration. For this reason, use of unslaked lime in cane juice clarification is never followed. At the same time, good attention must be paid to the preparation of lime cream so as to eliminate the unhydrated particles from remaining in the cream; for, they get softened and disintegrated either during mixing or in the press, which subsequently causes slaking with a liberation of heat, which causes the destruction of glucose.

The slaking of lime is dependent on time and temperature. The longer the milk of lime is allowed to stand, and the higher the temperature at which slaking is done, the more homogeneous is the milk of lime. In order to generate high temperature, as little water be used for slaking as possible. Too much water causes the cooling of lime. In order to maintain high temperature, insulation of the slaking drum against loss of heat is suggested. With all the proper precaution, a certain amount of unslaked particles still persist, which should be removed by straining through proper size screens, before it is used. This part of the operation is essential to prevent the complications, which unslaked lime particles are bound to cause.

The density of the lime cream is usually brought to 15° Be. in raw sugar factories. In white sugar factories,



where a certain acidity has to be maintained, a dilute cream of 10-12 Be., ensures better control.

2. *Carbonatation process.*—It has been pointed above, that this process is not suitable for conditions in India, and hence only an outline is given to show, how it differs from the sulphitation process. In this process, a great excess of lime is used not only with the object of precipitating the colouring matter, but also with the object of rendering the juice easily-filterable. No subsidation is followed in this process, but all the juice is filtered. There are two methods in this process, the single and double carbonatation :—

(a) *Single carbonatation.*—In this process, the neutralization of the juice is done in one operation. The raw juice, from the mills, is treated with lime cream, the quantity depending on the quality of the juice. The usual quantity varies from 7 to 10 per cent. of milk of lime of 20° Be., by volume of the juice. Sufficient lime must be added in order to render the juice easily filterable. The limed juice is then sent to the carbonatation tanks, which are filled only half, because during carbonatation, the carbonic acid gas combines with lime and sucrose to form 'calcium hydrosucro carbonate'  $C_{12}H_{22}O_{11} \cdot 2Ca(OH) \cdot 3CaCO_3$ . This is a viscous compound, which offers such a great resistance to the absorption of the carbonic acid gas, that it causes much froth, which results in an overflow. This compound is ultimately broken. During the reaction the temperature gradually rises to 50°C. The reaction is carried on, until a slight over carbonatation is attained. The juice is then heated to 70°C, and is then filtered through the press, the clear juice being sent to the charging tanks. This juice shows a faint pink reaction to phenolphthalein, though a neutral reaction is desired. In this process, there is only one filtering, and so it is not so expensive as the double carbonatation.

(b) *Double carbonatation.*—The raw juice is treated with the same amount of lime, and is treated with carbonic acid gas in the first carbonatation tanks, until the juice shows an alkalinity of 400 milligrams of CaO per litre of juice (*i.e.* = 4 c. c. of N/28 acid or about 1.4 c. c. of N/10 acid to 10 c. c. of juice). This is distinctly alkaline to phenolphthalein. This is then filtered through filter presses, the resulting juice being

termed 'first carbonatation juice'. This is again treated with carbonic acid gas, until a neutrality to phenolphthalein is obtained. This is then heated to 70°C, and is again filtered, and the resulting clear juice is sent to the evaporators.

Double carbonatation is followed in preference to single carbonatation, because it is a safer process. Any errors, caused through negligence or carelessness in single carbonatation, can be rectified in the double process. But against this the cost due to extra filter press work and labour should be taken into consideration.

3. *Acid thin juice process.*—This has replaced the carbonatation process in Java. In this process, the clear juice obtained either in the single or double carbonatation process is treated with sulphurous acid gas, until it becomes neutral to phenolphthalein, before it is charged to the evaporators. On account of the use of sulphurous acid gas, instead of potassium carbonate, potassium sulphite is formed, which is not injurious. On the contrary, it has a bleaching action. Besides iron salts, which are present in the ferric state in carbonatation process, are reduced to ferrous state by the sulphitation, which are colourless and remain so in the acid medium. Consequently, the sirup obtained with this treatment, is not so much coloured as the one with carbonatation treatment.

The raw juice, after being heated to 65° C, is treated with a 7½ per cent lime cream of 20° Be. by volume of raw juice, and carbonated simultaneously to an alkalinity of 300-500 mgms. of CaO per litre of juice, filtered and is again carbonated to neutrality to phenolphthalein corresponding to 30-40 mgms. of CaO per litre of juice. The juice is then heated to 95° C, and again filtered. The filtered liquor is then sulphited to 100-150 mgms. of SO<sub>2</sub> to a litre of juice, which corresponds to 0.32 to 0.45 c. c. of N/10 NaOH to 10 c. c. of juice with phenolphthalein as the indicator.

At Central Guanica in Porto Rico, where plantation granulated was made of the same quality as the refined granulated, a slight modification of the acid thin juice process was followed which was as below:—

Raw juice is limed to an alkalinity of 0.032 for 10 c. c. of juice by lime cream of 20 Be. This corresponds to 2½-3 per cent. lime (CaO) on the weight of cane. The limed juice is then filtered without heating, refiltered

and then carbonated to neutrality and again filtered. It is then sulphited to slight acidity (about 0.3 to 0.4 c. c. of N/28 NaOH) heated to 180° F and again filtered. The clear juice is then heated to 210° F on its way to the evaporators by special pre-heaters. The sirup is later on filtered. Thus there are 4 filtrations for the juice and one for the sirup. The amount of lime used is far more than even the carbonatation process in Java. On account of filtrations, the quality of the sugar is decidedly superior. The process is very expensive and is out of question for conditions in India.

4. *Kieselguhr-char process.*—In this process, no lime or sulphur is used. The raw juice is treated with kieselguhr, a diatomaceous earth at the rate of 1 per cent. on total solids, is brought to boiling and is filtered through the press. Kieselguhr aids considerably the filtration, but on account of the slimy precipitate the presses do not run longer, the cake obtained is not thick and hard. This prefiltration with kieselguhr is done with the object of helping the carbon treatment so as to reduce the amount of carbon, which is very expensive. The slimy precipitate destroys the filtering as well as the decolourizing property of the carbon very rapidly and increases trouble in revivifying. The filtered juice is clear, but is still coloured. This is then treated with Norit at the rate of 1 per cent. on total solids, is brought to boiling and is again filtered. There is not much difficulty in filtering the carbon treated juice. The resulting juice is water-white and brilliant. On evaporating the juice to sirup, some of the colour reappears, and the sirup becomes cloudy due to some colloidal matter not absorbed by the carbon. On account of the high price of carbon and kieselguhr, the large quantity required with this process, and the difficulties of filtering and revivifying, the process has been abandoned. These attempts, however, gave an impetus to the use of vegetable carbons in the sugar refining industry, and at the present time, their use for refining purposes has become successful in Louisiana.

### XIII. Evaporation.

The clear juice, obtained after clarification, is then concentrated to a sirup of 50-65 Brix in special evaporators. For this purpose, a system of multiple evaporation is used, wherein, steam is used to do the evaporation two or more

times according to the number of cells in the evaporator. The evaporator consisting of two bodies or cells is called the double effect, of three bodies, the triple, or 4 bodies, the quadruple and so on. In the cane sugar industry, triple and quadruple effects are commonly used. Quintuples are used by a few factories in Cuba. In the beet sugar industry quintuple and sextuple effects are very common. In Cuba along with quadruple, a pre-evaporator is now-a-days used to supplement the exhaust steam.

In the multiple system of evaporation, exhaust steam from the engines is used for evaporating the juice in the first body. The vapours from the latter are used for heating the second body, those from the 2nd, used for heating the 3rd body, and so on. Noel Deerr shows by theoretical calculations under certain specified conditions in his book on Cane Sugar, page 319, that, the maximum possible evaporation in a quadruple is 4.702 lbs. ( $1.006 + 1.055 + 1.165 + 1.476$ ) per lb. of steam against 3.4-3.5 lbs. with the triple. In this, it is assumed, that the condensed vapours from each cell pass on to the next cell without any loss of heat. If condensed water is removed separately from each cell as is usually the case in actual practice, the maximum theoretical evaporation per lb. of steam is 4.3 to 4.4 lbs. of water with the quadruple, 3.1 to 3.2 lbs. with the triple. In actual practice this limit is never reached.

It would thus be seen, that the original exhaust steam can be made to do the work of evaporation a number of times, which depends on the number of bodies used in the system of evaporation. In the cane sugar industry, the maximum limit has so far gone to sextuples in Cuba. There are of course limitations, beyond which it is not economical to go, because greater number of bodies means an increase in the first cost as well as upkeep. In countries, where cane does not supply enough fuel and where extra fuel is expensive, as is the case on some estates in Cuba, the installation of quintuples and sextuples is justified on account of the saving in fuel caused thereby.

It should be understood, that the multiple system of evaporation in the cane sugar industry is always practised under a system of vacuum on account of two reasons. Firstly, at high temperatures, sugar is destroyed resulting in the formation of caramel, which is not only a loss, but presents considerable difficulties due to colouring of the sugar. In

the making of plantation white sugar, this directly affects the colour of the sugar. With raw sugar, it presents difficulties during refining as caramel is not absorbed by bone-char. This necessitates the evaporation at low temperatures. Secondly, in cane sugar factories, a low pressure steam usually the exhaust from the mill engines is available in large quantities, the utilization of which, for evaporation in the multiple system, is only possible under reduced pressure. Thus starting the evaporation in the first body usually at atmospheric pressure with an exhaust steam of 4-5 lbs. pressure, the pressure in the 2nd body is decreased to partial vacuum, until in the last body evaporation takes place at a vacuum of '26"-28". In order to maintain vacuum, a system, of condensers and vacuum pumps is necessary, which becomes more complicated and expensive as the number of bodies are increased.

The limit, to which any factory in any locality can go in this multiple system of evaporation, depends upon certain conditions. They are (1) the amount of fuel supplied by cane whether it is sufficient to do the heating, evaporation and boiling, or in other words, to run the factory, (2) the availability of cheaper fuel in the vicinity and (3) the amount of exhaust steam available in the factory.

*The amount of fuel.*—This mainly depends upon the fibre content of the cane. The lower the amount of fibre, the less the fuel. This means in countries, where cane contains a low fibre, the use of quintuples and sextuples may be justified provided cheaper fuels are not available. In Louisiana, where cane contains a very low fibre, anywhere from 9 to 10 per cent. and, where the juices are of low density due to under-ripe cane, one would expect to find quintuples and sextuples in use, but the limit has gone to the use of quadruples only. With this the amount of fuel is not found sufficient, and fuel oil has to be used to the extent of 4-6 gallons per short ton of cane. In Louisiana fuel oil is cheap and its use is probably more economic than the installation of a quintuple or sextuple. In Cuba, where the fibre content is 11 per cent. or a little higher, the use of a quadruple with a pre-evaporator, though common, has not been found enough to run the factory on bagasse alone, even though a light maceration to the extent of 15-20 per cent. is practised. There fuel oil to the extent of 2-4 gallons per ton of cane is found necessary. A few recent installations in Cuba have,

therefore, thought it fit to put up quintuples and sextuples. This has reduced the consumption of fuel considerably. In Porto Rico, where cane contains about 12 per cent. fibre, and where a higher maceration is practised to the extent of 30-35 per cent. limit has gone to the use of quadruples. In Hawaii, cane contains higher fibre to the extent of 13 per cent, yielding a greater amount of bagasse, but this is compensated to a certain extent by the heavy maceration, that is practised (40-45 per cent). The use of a quadruple, together with a pre-evaporator, is very common. Even with this, factories are not able to run on bagasse alone, which is usually supplemented with final molasses as fuel. In Java, cane contains about 13 per cent. fibre, and the maceration practiced is not over 20 per cent. Still bagasse alone is not found sufficient, which is usually supplemented with dried leaves (trash of cane). In other countries, cane is usually burnt, and hence trash is not available. In other places, where cane is not burnt, it is found expensive to transport trash to the factory, and hence it cannot be used. In Java, on account of plenty of cheap labour cane is not required to be burnt before harvesting. It is usually stripped, and the trash sent to the mill, whenever necessary. I saw one factory in Java installed in the year 1923, which was making white sugar by the acid thin juice process. Even though cane contained only 11.5 per cent. fibre, and maceration to the extent of 17 per cent. was practised, the factory was operating on bagasse alone. This was made possible by the use of quintuples and superheated steam in special 'valve' engines and doing all the heating, evaporation, and boiling on exhaust steam alone.

In St. Kitts and Antigua, factories were operating on bagasse alone. There cane contains a high amount of fibre about 15 per cent. In these factories, triple and quadruple were used. With the exception of Louisiana and Java which make plantation white sugar directly from cane, all other places mentioned above make raw sugar, which does not demand so much steam, as a white sugar factory does, and in all these factories with the exception of a few in Cuba, which use quintuples and sextuples, the use of a quadruple is common. Of course, when exhaust steam far in excess of the requirements of heating, evaporation and boiling is available, the addition of any more cell to the existing evaporator cannot be justified, unless it is done for increasing the capacity. However, such conditions have not been noticed by me in any of the factories except in

St. Kitts. The chief reason of increasing the cells in a multiple system of evaporation, should always be the saving of fuel expense, at least to the extent of the expense required in installing an extra cell.

The availability of cheaper fuels in the vicinity of the factory, as is the case in Louisiana, where oil wells are in abundance, may not permit the use of quintuples and sextuples.

The amount of exhaust steam available in the factory has a direct influence on the choice of a number of cells in the multiple system of evaporation. When exhaust steam, far in excess of the needs of the triple is available, it will be foolish to put an extra cell, unless it is done with the object of increasing the capacity. However, such a condition is rarely met with in modern factories chiefly on account of the use of Corliss type engines, which use much less steam, collective drive for mills, and also on account of the use of exhaust steam for vacuum pans. The latter has become possible with the introduction of calendria pans in the cane sugar industry. In most of the factories I visited, on account of the above facts, exhaust steam is not found enough, and a pre-evaporator has been found necessary to generate sufficient exhaust steam to do all the heating, evaporation and boiling. Old factories, using slide valve engines, and having an individual drive for the mills, usually carry a much greater exhaust steam, which occasionally is discharged to the air. This is due to the fact, that such factories have no arrangement to use the excess exhaust steam either for juice heating or sugar boiling. Usually, such factories are equipped with coil pans, which do not boil fast enough if exhaust steam is used, thus reducing the boiling capacity and blocking the house. I have noticed in one factory in the West Indies that, when such a condition arises, live steam is used to hasten the boiling, while exhaust steam is turned to the atmosphere. In modern factories such conditions do not arise. Factories, having fuel supply far in excess of the requirements of the factory, due to high fibre content of the cane, are very few, and will not find it economic to increase the number of cells in the existing evaporators, unless it is done for increasing the capacity. So far I know, such a condition exists at the present time in St. Kitts and Antigua. Nowhere else, the question of an excess fuel has arisen. So far, the quadruple effect has

become the standard unit, but, as the question of fuel becomes more and more serious in the future, quintuples and sextuples will come into general use.

*Pre-evaporator.*—This is used as a device to produce a low pressure steam to supplement the exhaust steam from the engines. In the old system of evaporation and boiling exhaust steam was used mostly for evaporation purposes, and occasionally for juice heating, while the excess was turned to the atmosphere. With the advent of calendria pans, the utilization of exhaust steam to do the boiling has become possible. So long factories were equipped with slide valve engines, which usually consumed much more steam—40-45 lbs. per B. H. P., and each mill was driven by a separate engine, exhaust steam was available in greater quantities, on account of which, a part was wasted to the atmosphere. It could not be used for boiling in the pans, as the boiling was slow, which used to decrease the boiling capacity. The calendria pan was originally designed to use this excess exhaust. With the use of corliss valve engines and the substitution of collective drive for mills, the amount of exhaust steam available was decreased, and juice heating and sugar boiling had to be done by live steam, the exhaust steam being insufficient. In this, live steam is used as a single effect for heating and boiling. In order to still further economize steam consumption, a generation of low pressure steam, is found necessary. In order to generate low pressure steam an independent cell is installed, which operates at a slightly higher pressure than the atmospheric and the steam generated is either discharged into the exhaust main, from which it is used for the evaporators, juice heaters and pans, or a part of the same is used directly for juice heaters, and the rest discharged to the main exhaust line. In this way, economy of steam consumption is secured, as the steam is used many fold times. A pre-evaporator is, therefore, meant to generate low pressure steam to supplement the exhaust so as to do all the heating, evaporation and boiling, and consequently has no place in factories having an excess exhaust steam. It is evident, that, the greater the amount of work done by the evaporators, the less the steam consumption, and hence, if the steam consumption of mill engines in the factories is reduced by substituting or installing more efficient engines, such as the corliss valve engines, the greater is the chance for economy



in steam consumption by the use of pre-evaporators. This shows, how more efficient engines ultimately save steam in the factory, notwithstanding the opinion of some engineers that, saving in steam consumption is useless, so long all the exhaust is used in the factory.

For conditions in the Bombay Deccan, a quadruple effect will be quite necessary. This much may not be enough, and a pre-evaporator will be necessary to supplement the exhaust steam to do all the heating, evaporation and boiling, the necessity for which is explained below: Pundia cane in the Bombay Deccan contains about 10.5 per cent. fibre. Assuming, that a maceration of 15 per cent. is practised, and bagasses contains about 46 per cent. fibre and 49 per cent. moisture, this will yield 22.8 per cent. bagasse on cane. Under normal conditions, one lb. of bagasse containing 49 per cent. moisture will give an equivalent steam F and A 212° F of 2.5 lbs. Thus 22.8 tons of bagasse gives  $22.8 \times 2,000 \times 2.5 = 114,000$  lbs. of steam, which will be obtainable per 100 tons of cane ground. This much is not enough to operate the factory equipped with a quadruple only. According to Prof. Kerr, who conducted tests in a white sugar factory in Louisiana to determine the actual steam consumption, 1.75 B. H. P. is required per ton of cane ground in a day. For conditions in the Bombay Deccan, this comes to about 1.70 B. H. P. (for calculations, see chapter on steam consumption). At this rate 100 tons of cane will demand  $100 \times 1.70 \times 34.5 \times 24 = 140,760$  lbs. of steam. Thus there will be a deficit of 26,760 lbs. of steam per 100 tons of cane, or of 13.4 per cent. on cane. The above calculation, based on actual figures obtained in a Louisiana factory, shows that cane, containing 10.5 per cent. fibre, as is the case in the Bombay Deccan, will not give enough fuel to operate the factory under usual conditions. In the factory in Louisiana, only a quadruple is used, for which exhaust steam is utilized, while the juice heating and pan boiling is done on live steam. In order to reduce the steam consumption, a pre-evaporator will be quite necessary so as to supplement the exhaust. According to same calculations, the amount of steam per cent. cane for conditions in the Bombay Deccan will be as below: —

[See next page.]

Steam % cane.

Total steam required 66.96 based on 1.70 B. H. P. per ton of cane.

Raw juice heaters	11.80	} 44.3 per cent. steam on cane required for heating evaporation and pan boiling.
Thin juice „	2.00	
Quadruple effect	16.00	
Vacuum pan	14.50	

The amount of exhaust steam available will be 31.2 per cent. in the case of slide valve and 24.80 per cent. in the case of corliss valve engines (these figures have been calculated, *see* page 190). Thus in both the cases, the exhaust steam will not be enough to do all the heating, evaporation and boiling. This clearly indicates the necessity of a pre-evaporator to economize steam consumption, as fuel is expensive and not easily obtainable in the Bombay Deccan. In India, cane is stripped off of its leaves and not burnt, and therefore, trash will be available to supplement the bagasse.

In the above calculation a maceration of only 15 per cent. is assumed, which is lower than may be necessary. The fibre content of Pundia cane may rise to 11 per cent. as is occasionally found. So if a heavier maceration is practised in order to increase the extraction, the necessity of a pre-evaporator will be still more felt. For these reasons, a quadruple, with a pre-evaporator, will become a necessity in factories grinding softer cane, as will be the case on the Deccan canals.

In Northern India, where 60 per cent. of the cane crop of India is grown, the fibre content is above 15 per cent. which is high and a pre-evaporator may not be found necessary. Considering, that white sugar is to be made, which demands more steam, it will be safer to instal a quadruple so as to be able to operate the factory on bagasse alone. It seems, that at present in Northern India, most of the factories are using a lot of extra fuel, which is considered to be due to the irregular supply of cane. Factories, having considerable exhaust steam far in excess of the requirements of evaporation will not secure any benefit in changing a triple into a quadruple, unless it is done for increasing the capacity.

The method of working a quadruple evaporator is as follows:—The quadruple consists of 4 cells which work in a battery mutually connected, the last cell being connected to a

condenser and a vacuum pump. The juice is fed to the 1st cell or body, where it is heated to boiling by the exhaust from the engines. The juice continually circulates from cell to cell, until it is pumped out of the last cell as sirup. The admission of juice in the first and the pumping out of sirup from the last cell are controlled by means of separate pumps. The vapours from the 1st body are carried to the 2nd body where it heats the juice, the vapours from the 2nd, being carried to the 3rd body, and so on, until the vapours from the last body are condensed and removed either by a condenser or a vacuum pump. The vacuum usually maintained is as follows: 1st body usually at atmospheric pressure, 2nd at a vacuum of 5"-7", 3rd body at about 14"-16" and the 4th at 26"-28".

*Types of evaporators.*—There are several types of evaporators in use in different countries, which mainly fall into two classes. They are the submerged tube and the film evaporators. Each of them are sub-divided into two sub-classes—the verticle and horizontal. So far I saw the standard verticle, the Sandburn, horizontal submerged, the Lily and the Kestner in actual use, out of which the standard verticle is by far very common. All modern installations have exclusively put up the standard verticle. The horizontal submerged was seen by me only in one central in Cuba, which was used, only when the evaporation capacity was found to be insufficient, and seemed to have been practically abandoned. Sandburn is another verticle submerged tube evaporator differing from the standard in one respect that the juice, instead of being in the tubes, is outside the tubes, while the steam is inside. Inside each tube, is a perforated pipe, through which, incondensable gases from the steam are removed by a simple connection to the air pipe of the condenser. This type was noticed by me only in one central in Cuba.

*The standard verticle evaporator.* - This is a submerged tube evaporator, consisting of a cast iron shell of great height up to 20 feet. In the lower part of the shell is a calendria, formed by verticle tubes held together by tube plates. Inside the calendria is admitted steam, while the juice is in the tubes. The most important points, which decide the superiority of any evaporator, are: (1) circulation and juice distribution, (2) removal of incondensable gases, (3) steam distribution and (4) removal of condensation water. In the standard

verticle, the juice is admitted at the bottom below the lower tube plate, which is preferable to other mechanism, in which juice is introduced at the top above the upper tube plate. The circulation is usually effected by the provision of a central tube of big diameter usually called 'down-take', the juice coming up through the tubes and going down through the down take. The down-take is very important, as it defines the passage of the juice, which considerably aids heat transmission. There are other types, in which the down-take is placed eccentrically or at the side in the form of a segment. Circulation is also helped by inclining the calendria or arranging to have the tubes slightly above the upper tube sheets. All these are different mechanisms patented by different makers with the object of helping circulation, and there is practically very little to choose between them. The standard verticle seems to be the simplest, and in actual practice works very well.

*Removal of incondensable gases.*—It is usually effected by means of pipe running from the calendria to the vapour space of the next cell, from which it is ultimately connected to the condenser. As the pressure in the successive cells gets less and less, the incondensable gases travel from cell to cell on account of the higher pressure in the previous cell. In some cases, the pipe from each cell is directly connected to the condenser, in which case, all the steam, that accompanies the gases, is completely lost. The former practice is very common. The removal of gases from the calendria is quite essential, as it affects the co-efficient of heat transmission.

*Steam distribution.*—Steam is admitted into the calendria either at one or two places, depending upon the size of the evaporator. In order to have a good distribution, baffles or perforated partitions are provided inside the calendria, which defines the passage for the steam.

*Removal of condensate.*—This is very important. In the first body, the steam being under pressure, condensed steam can flow by gravity. This water is usually separated from condensate from other cells, as it is not contaminated with any sugar solution, and is principally used for boiler feed water. Some times, when enough water is not available through this source as well as from the pans condensate from the 2nd cell is used to supplement the boiler feed water, in which case, the condensate from the 2nd cell is separated

from other cells. The condensate, from the other cells also called 'sweet waters', is usually allowed to gravitate by means of a fall pipe to a sealing tank, from which it is pumped and used as maceration water, or as wash water for the presses or any other use in the factory. Sometimes, a separate pump is provided for each cell to remove the condensate. This system increases the expense. A system of inverted siphons is also used in some factories to remove the condensate. In this case condensate passes from cell to cell automatically on account of the pressure in the previous cell.

Taking the above points into consideration, and the average conditions in the factory, the standard verticle evaporator is the most suitable in cane sugar factories. It is very simple both in construction and operation, is easily cleaned and gives the least trouble. In average efficiency it is equally good. That seems to be the reason, why modern installations have exclusively put up the standard verticle evaporators, in preference to Lily or Kestner, even though the latter operate at a higher efficiency.

The Lily is a horizontal film evaporator, in which, the juice is continually kept in circulation by means of circulating pumps. In each cell is provided a well, from which the juice is pumped to a perforated box placed above the tubes, from which, juice falls in the form of a shower on the tubes below. The steam is inside the tubes, while the juice is outside. The principle of the Lily evaporator is no doubt sound. It has the best mechanism for circulation, and consequently evaporation efficiency is higher than that of the standard verticle. Against this should be considered the higher cost for upkeep on account of the circulation pumps. Besides, it demands more skill for operation, and cannot be successfully operated by the average man, who operates the standard verticle. In actual practice it gives more trouble, which takes more time for adjustment. The cleaning is not so easy, as is found with the standard verticle evaporator. On the whole, this type has not given satisfaction to sugar manufacturers, even though it has satisfied the sugar refiners. In actual practice the advantages claimed are seldom obtained. There is one disadvantage with this evaporator, which I noticed, when it is worked in white sugar factories. On account of the tubes not being submerged, there is a local over-heating, which causes caramel. Consequently the sirup turned out is slightly dark coloured. This is a serious disadvantage, when white

sugar is to be made. On account of these considerations, sugar manufacturers have not taken up the Lily evaporator. During my visit to various cane sugar countries, I saw only 7 Lily evaporators, one in Louisiana, 2 in Cuba, 2 in Porto Rico and 2 in Hawaii. Not a single central, installed during the last 5 years, has put up a Lily evaporator.

Kestner is another type of film evaporator. It is vertical and differs from the Lily in another respect, that in the former, the juice is in the tubes and not outside, as is the case with the latter, and that it climbs in thin film along the whole length of the tubes. The tubes are 22'-6" long, 1½" in diameter in the first cell and 2" in the later cells. Juice enters at the bottom, climbs in a thin film along the surface of the tubes, and runs out from the outlet to the next cell. Steam enters at the top and condensed water is removed at the bottom. The vapour from the climbing film, is carried from the top to the next body for heating. This evaporator has an ingenious principle, but in actual practice does not work well. On account of greater length of the tubes, it is very difficult to remove the scale. There is one drawback in this evaporator, and that is, the entrainment, which cannot be prevented. I saw this evaporator at central Guanica in Porto Rico.

The heating surface, usually provided in most of the centrals, is 10 sq. ft. per ton of cane per day or 240 sq. ft. per ton cane per hour. In white sugar factories 14-15 sq. feet per ton of cane per day will be desirable, as in this case, on account of heavier liming, the evaporators get scaled soon, which decreases their capacity.

*Entrainment.*—During evaporation some sugar is mechanically carried along with the vapour, which, if not prevented, appears in the condensation waters. For this reason they are called 'sweet waters'. In all standard vertical evaporators, the loss through splashing, which occurs when evaporators are worked to the utmost capacity, is prevented by (1) giving a liberal height to the cells, (2) providing two baffle plates overlapping one above the other. These plates are placed in the body of the evaporator over a calendria. The splashed liquid has to hit the baffle plates, before it goes to the vapour line. The loss, through carrying of small bubbles along with the vapour, is prevented by an entrainment device. I saw three kinds of entrainment devices. In Cuba and Porto Rico, entrainment device consists

of baffle plates placed on the vapour line outside the cell. The condensed liquid is returned by means of a pipe either to the vapour space of the same cell, or to a separate receptacle. The latter gives very satisfactory results. The other device, which seems to be common in the West Indies as well as in Cuba consists in having baffles in the top-most part of the cells. This is an inside device. The condensed liquid is returned to the same cell either by a separate pipe or by an inside connection. The third device, I saw in the West Indies, is a centrifugal separator. The simplest and best entrainment device was seen by me in Hawaii. This consisted of vertical baffle plates, each carrying 2" horizontal tubes. The tubes are arranged in such a way, that a tube in one plate is placed opposite the blank in the other plate. This device is placed in the vapour line outside the cell. It is simple, very effective and can be made in any sugar factory on the spot.

*Condensers.*—There are two types of condensers, the surface and the injection, out of which the latter are universally used in the cane sugar industry. In the injection type of condenser, the vapour is condensed by direct contact with water. The condensed vapour, together with incondensable gases, and the cooling water, may be removed together by a vacuum pump called a 'wet air pump' or the cooling water and the condensed vapour may be removed separately by gravity alone, while the incondensable gases, together with the accompanying vapour, is removed by a separate vacuum pump. This is called a 'dry air vacuum pump'.

The wet air condenser and pump is only used in old plants. The disadvantage of this system is that, on account of the air and water being pumped together, a slow speed pump is necessary. Consequently pumps of large dimensions are required to do the work. This becomes expensive on account of the upkeep. In large factories, pumps will have to be of enormous size, if wet air system is to be used. All modern installations have abandoned this system altogether.

The type of the condenser—commonly used is the fall pipe counter current jet condenser. In this the cooling water enters at the upper part of the condenser, in which it is broken into a shower by means of a perforated plate so as to present large surface for better condensation of the incoming vapour, and meets the vapour in its downward flow,

which consequently gets condensed. The condensed vapour together with the cooling water flows down the fall pipe, which is usually more than 33 feet long into a central well, from which it runs out by gravity against atmospheric pressure due to the height of water. The air pipe is usually placed at the top of the condenser, so that, incondensable gases from the condensed vapour will have to pass through the incoming cooling water, which consequently get cooled. This is not possible with parallel current jet condensers, as the incondensable gases will be in contact with the hot injection water, before they pass on to the air pipe of the vacuum pump. The air pipe is provided with a separator, directly connected to the fall pipe of the condenser so as to drain off any water that may be carried by air pipe on its way to the vacuum pump. This type of condenser is the best of all, because a cooler air goes to the vacuum pump, which fact decreases its volume as well as its vapour content, thus aiding the vacuum pump.

The water to the condenser is usually supplied from a supply tank, placed above the condenser, so that water may flow by gravity. Water is supplied to the supply tank by means of separate pumps. This is the best system, because the vacuum can be effectively controlled by means of injection water, which is required in the case of vacuum pans. In some factories, the cooling water is supplied to the condenser by means of suction from a supply tank placed on a lower level. In this case, the amount of water entering the condenser depends upon the vacuum, and *vice versa*. This system does not work so satisfactorily in factories, which have a common air line and a common vacuum pump to operate all the evaporators and the vacuum pans. As the vacuum and the amount of injection water is interdependent, control of vacuum is very defective.

There is one type of condenser, which I saw in use at central Violetta of Cuba Cane Corporation in Cuba, which dispenses with the vacuum pump altogether. It is the ejector condenser, which removes the incondensable gases and water together, by means of the momentum of the flowing water, which ejects the discharge without the aid of a circulating pump. This is possible, where sufficient head of water is available. This has been found to give excellent service, maintaining a vacuum of 27". The vacuum pumps, ordinarily used, wear out in course of time, and hence this type



of condenser, which dispenses with the vacuum pump, will be most suitable. This condenser was tried for the first time at the said factory, and further results will be awaited with great interest.

*Central condensation.*—In all modern factories, the use of a separate condenser to each evaporator and pan is common. A few factories have one common condenser for all evaporators and pans, instead of a separate condenser for each. This system reduces first cost, but the greatest disadvantage is the irregularity caused, when any pan has to be disconnected, either on account of the dropping of the strike or a cut to another pan. In actual practice, this upsets the vacuum in other pans, unless great care is taken. From the point of maintaining a constant vacuum and introducing no disturbance in the working of the pan, the central condensing system is not desirable. In all recent installations, central condensing system has been abandoned in favour of separate condensers so as to meet all the irregularities met with in the factories.

*Central vacuum pump.*—The old practice was to provide a separate vacuum pump for each evaporator and each pan, when separate condensers were provided for each. In some modern installations, I noticed, that, in addition to separate condensers for each evaporator and pan, a central condenser was provided, through which the air, drawn from the other condensers, was made to pass, before it went to the vacuum pump. This, in my opinion, is the best system, because, not only it enables one vacuum pump being used for the whole system, but it also cuts down the work of the pump due to the cooling of the air on its course to the pump, thus permitting the use of a smaller pump. The cooling of the air decreases its volume as well as vapour content, and consequently, a pump with a smaller displacement will do the work. With this system, however, an extra vacuum pump is provided, which is used, when starting a pan, until the necessary vacuum is attained, after which the pan is connected to the central vacuum pump. This is desirable so as to cause no disturbance in the vacuum.

*Vacuum pump.*—There are two types of vacuum pumps used in cane sugar factories, the wet air and the dry air pumps. The wet air pumps are to be seen in old factories, where wet air condensers are used. The pumps used are of

reciprocating piston type. The condensed water and incondensable gases enter the pump through a pipe, from which it is discharged through rubber discs. These pumps usually run very slow, and are of huge dimensions for bigger units. Consequently, they consume large amount of steam, which increases the expense.

The dry air pumps commonly used are either the Edwards or slide valve reciprocating pumps. The former are single acting, and hence installed as double or triple barrelled units. They may be directly driven by an engine or by a motor through gearing. The slide valve reciprocating pumps work as slide valve engines. In these pumps, the clearance is of importance as it affects the capacity.

Centrifugal pumps, driven by motors, are coming into general use in factories, in which the accessories are electrified. These pumps run at greater speed, and consequently pumps of smaller dimensions do the necessary work. In factories, having all the accessories electrified, centrifugal pumps are the most suitable.

*Cooling of water.*—A great quantity of water is required for condensation purposes in sugar factories. When plenty of water is available, the question of cooling of water does not arise. In the Bombay Deccan in sugarcane districts, there will not be much difficulty in getting water either from the canals or from underground sources. The water level in the canal area is so high, that a good supply of water will be available within a depth of 20-30 feet. Where water has to be paid for, it has to be used sparingly over and over again. In most of the countries I visited, there is generally a scarcity of water, except in Louisiana and British Guiana. A few factories, which are located along the coast in Cuba or Porto Rico, generally use salt water for condensation purposes. In order that water should be used over and over again, when it is scarce, it must be cooled, as it is warmed by the condensing vapours from the evaporators and pans. There are two systems used for cooling water. They are the tower cooling and spray cooling. In the former, water from the condensers, either flows by gravity or is pumped to the cooling tower, where it is divided into thin stream, before it goes to the storage cistern below. The division of water into thin stream exposes more surface to the air, which hastens cooling. In spray system, water is finely divided into a fine

shower by means of sprays before it goes to the storage cistern. The modern practice is to use a spray cooling system. It cools the water much faster on account of the division of water into fine spray, is much swifter, and is found to be cheaper in the end. There is only one disadvantage, and that is the frequent choking of the spray nozzles. This difficulty is solved by keeping spare nozzles.

*Scale in the evaporators.*—As the juice is concentrated, some of the impurities in solution, which become insoluble on concentration, are deposited on the heating surface of the evaporators. These are known as scales. Obviously the least soluble will be deposited in the first cell, where, the concentration is low and the most readily soluble will be deposited in the last cell. The suspended matter, carried along with the clarified juice, is likely to be deposited in the first cell. Usually the first cell contains little scale as compared to other cells. The scale in the last cell is the thickest, and presents great difficulties for removal. No matter what care is taken in clarification, scaling is unavoidable as a part of the dissolved impurities is bound to be deposited when the juice gets concentrated. In factories, using sulphitation process, as is the case in Louisiana, evaporators get scaled much quicker. In Java, where a low initial acidity is carried, consequently having a low amount of  $\text{CaSO}_3$  in solution in the juice, scaling is very little, and I noticed there, that evaporators could be operated without cleaning for nearly two months.

The scale in the first two cells of the evaporator consists mostly of phosphate of lime. When the sulphitation process is followed,  $\text{CaSO}_3$  is likely to be precipitated and deposited along with the phosphate of lime. The scale in the last two cells consists mostly of silica and some oxalate of lime. Boiling with  $\text{HCl}$  will remove the phosphate and sulphite of lime, while, for removal of silica, caustic soda is used.

The scale, that is formed in the evaporators, must be removed, as it affects heat transmission. In factories, making white sugar by the sulphitation process, evaporators get scaled quickly and are required to be cleaned every week. In actual practice, I saw two methods in use for the removal of the scale. One is the mechanical treatment, and the other is the chemical treatment. In the mechanical treatment, the tubes are scraped off by means of wire brushes operated.

either by hand or motors. In the British West Indies, scraping by hand is usually followed, as labour is cheap. In countries, where labour is expensive, motor driven brushes can be successfully used. This method seems to be the most effective.

The other method is used in Louisiana and Cuba. For this purpose, 1 or 2 per cent. solution of either caustic soda or hydrochloric acid is used, and the cells are boiled under atmospheric pressure for at least four hours. This operation is usually repeated every week. Sometimes the cells are boiled both with caustic soda and hydrochloric acid alternately. The chemical treatment is expensive, and for conditions in India, where labour is cheap, the mechanical treatment will be the best. Similar treatment is required to be given for juice heaters.

*Treatment of the sirup.*—In the multiple effect the juice is concentrated to a sirup of about 60°-65° Brix in raw sugar factories. From the point of fuel economy, it should be boiled to as high concentration as possible. It is, however, limited by the fact, that a higher concentration than 65° causes trouble in maintaining an even grain in the pan. When white sugar is to be made, a concentration above 50°-55° Brix Be. 28 is rarely exceeded. This helps subsidence, and gives a better control on the graining as well as the boiling of sugar in the pan.

The further treatment of the sirup varies in different countries. In Louisiana, where usually a high acidity of juice (about 1c. c. of N/10 NaOH) is maintained, no more sulphitation of sirup is practised. The sirup, as it comes out of the evaporators, is sent to the brush pan, where it is heated, and the scum brushed off, after which, it is sent to the storage tanks, where it is allowed to settle. A few factories at this stage, pass it through excelsior filters. On allowing it to stand, a precipitate is formed, which settles slowly at the bottom. This precipitate, is formed out of colloidal matter in sirup, which flocculates on standing. Dr. Brewster has analysed this precipitate from a sirup made in the laboratory by the sulphur lime clarification, which consists of 87.32 per cent. of ash. Ash is mainly composed of 23.23 per cent.  $\text{SiO}_2$ , 32.02 per cent.  $\text{CaO}$  and 42.00 per cent.  $\text{SO}_3$ . The removal of this matter is only feasible by settling. Filtration will remove this precipitate, but is very expensive

and troublesome. The sirup is then drawn to charging tanks while the sirup bottoms, consisting mainly of this precipitate are washed off, diluted, brought to boil and allowed to settle. The clear juice is drawn off, and sent along with the press juice for reclarification, while the mud is sent to the mud tanks for filter pressing. The acidity of the sirup is usually about 2 c. c. of N/10 NaOH. Sulphiting of the sirup is done, only when the acidity is low.

In Mauritius and Java, where the juice is sulphited to a slight acidity (0.3-0.4 c. c.), a sulphitation of the sirup is quite necessary. In the boiling of sirup into white sugar, it is quite necessary to keep it distinctly acid so as to obtain a bright coloured sirup, which gives white sugar. The sirup is first heated to boiling, the impurities appearing on the floating scum are skimmed off, and then it is either filtered or allowed to settle. The filtration of a sulphitation sirup is very troublesome and very expensive. So settling is usually followed. The clear sirup, after it is cooled to 65° C or below is then sulphited to an acidity of 1500 mgrms. of SO<sub>2</sub> per litre of sirup (=4.7 c. c. of N/10 NaOH) in Java, or to 1-1.2 grams of SO<sub>2</sub> per litre in Mauritius, which comes to 3.1 c. c. of N/10 NaOH to 10 c.c. of sirup. This acidity is much higher than that followed in Louisiana. In Java in acid thin juice process, the sirup is sulphited to 800 mgrm. of SO<sub>2</sub> per litre of sirup, *i.e.*, 2.5 c.c. of N/10 NaOH, which is practically the same, as is the case in Louisiana with the sulphitation process. The only difference is that, in Louisiana, the thin juice is maintained at a relatively higher acidity than is the case in Java or Mauritius.

Java manufacturers think, that the acidity of thin juice carried in Louisiana, is too high and would cause more inversion. Actual results show that Louisiana factories do not obtain the undetermined loss in any way higher than what the Java factories obtain. The undetermined represents the inversion loss. As said previously, the high acidity of juice, maintained by Louisiana factories, does not result in any more inversion due to the presence of CaSO<sub>3</sub>, which acts as a buffer against the dissociation of acids present in the juice. It should be noted, that the acidity, determined as above, is with reference to phenolphthalein as an indicator, and has no relation to pH value, which is the only rational and correct way of expressing an acidity or alkalinity.

#### XIV.—Sugar boiling.

The sirup is then boiled to grain in vacuum pans. All the boiling has to be done at low temperature in order to avoid the danger of the destruction of sugar, that occurs at high temperature as well as to minimize inversion. In order to do boiling at low temperature, vacuum has necessarily to be maintained. The complete equipment consists of a pan, an entrainment device, a condenser and a vacuum pump. There is practically no difference in the equipment of an evaporator and a vacuum pan, the only difference being in the pan itself. All that has been written with regard to entrainment device, condenser and vacuum pump in the case of the evaporators, is equally applicable in the case of vacuum pans also. Only one point needs emphasis. It is a usual practice to return the entrained liquid to the same pan by means of a separate pipe. This system is objectionable when white sugar is to be made, because the entrained liquid on account of its contact with the iron surface in the baffles or vapour pipe, is dark coloured, which imparts some colour to the masecuite. The best system is to have an entrainment device outside the pan in the vapour line, and conduct the entrained liquid to a separate sealed tank, and to use it later on for maceration or press cake washing. The inside entrainment device does not permit the separation of the entrained liquid, for which reason, it is not desirable.

The vacuum pans are of two kinds, the coil and the calendria, out of which the calendria pans are of recent date, and are coming into more general use. In the coil pans, the heating surface is formed by the heating coils  $3\frac{1}{2}$ -4" in diameter usually made of copper. Each coil has a separate steam connection both for live and exhaust steam, and a separate outlet for the condensed steam, for which, steam traps are generally used. These pans are generally worked with live steam of about 40 lbs. pressure. Exhaust steam can be used with coil pans, but the boiling is so slow, that the boiling capacity is considerably decreased, which results in blocking the house. For this reason, the use of exhaust steam with coil pans has not been found to be practicable. With coil pans, the heating surface is not so efficient, because specially with long coils, a great part of the steam already gets condensed, before it passes over half the distance of the coils. Consequently only half the heating surface is working very efficiently. Besides the prompt removal of the condensate

offers certain difficulties in actual practice on account of the traps, which go out of order. In any case for efficient working of the coil pan, live steam of about 40 lbs. is desirable.

The calendria pan is meeting with great favour in Cuba. This is worked with exhaust steam of about 5-8 or 10 lbs. pressure, which means a great saving in steam consumption. This kind of a pan was originally introduced in Cuba so as to be able to use all the surplus exhaust steam available in the factory.

A calendria pan is like a standard verticle evaporator in construction, with this difference, that the tubes are somewhat shorter, thicker and larger in diameter. The diameter of these tubes varies from  $3\frac{1}{2}$ "-4" while, in the evaporators it is about 2". In order to promote better circulation, either the tube sheets or the tubes or both may be inclined. The inclination of the tubes has one advantage, in that it defines a passage for the condensate, which increases the heat transmission. The down-take is in the middle. There are two types of calendria pans—the single calendria and the double calendria, latter being also called "express pan". The latter is meeting with great favour in Cuba. There is no question, that the calendria pans are more satisfactory and more economic than the coil pans, because (1) the calendria pans work much faster, a pan being struck in 2 hours. This is due to more heating surface in a calendria pan for the same capacity (2 sq. feet heating surface to 1 cu. ft. capacity, as against 1 to 1 in the coil pan) and secondly, due to better and rapid circulation, and the more efficient removal of the condensate, the latter being partly due to sloping tube sheets and inclined tubes. The quicker boiling is desirable in making white sugar. (2) On account of faster boiling and rapid circulation, a quick granulation is easily effected, which gives a uniform size grain. This is very important in making white sugar. Not only a uniform granulation gives a better grade of sugar, easy for curing and washing, but it reduces the amount of tailings, which are necessarily required to be remelted. With coil pans, a uniform granulation cannot be obtained specially, when dealing with low purity sirups, unless a high pressure steam of 40-50 lbs. is used, which causes quick evaporation and better circulation. With the use of high pressure steam, however, there is a danger of forming caramel. (3) All calendria pans are worked with exhaust or low pressure

steam usually of 8-10 lbs. pressure effecting a great economy in steam consumption. Factories, having no surplus exhaust steam, can instal with advantage, a pre-evaporator to supplement the exhaust. (4) Calendria pans are much easier for cleaning than coil pans. They can be easily cleaned by wire brushes within a comparatively shorter time and at a less expense. It would thus seem, that calendria pans have all the advantages over coil pans. There is only one disadvantage and that is, the graining has necessarily to be done higher in calendria pans, because the calendria must be always covered, before steam is let in. The result is, a smaller grain sugar is obtained, unless the pan is cut. This difficulty is felt, when raw sugar is to be made, because a bigger grain is preferred for refining, but in making white sugar, a smaller grain is required and this disadvantage is of no consequence in white sugar factories. In raw sugar houses, this difficulty can be solved by cutting the pan. In order to obviate this difficulty, calendria pans are provided with one or two coils below the calendria. The best thing is to have one coil pan, and the rest calendria pans. When white sugar is to be made, there is more consumption of steam, and for reasons of economy in steam consumption and ultimately in fuel consumption, calendria pans are the most suitable.

*Boiling sirup to grain.*—There are two or three methods of graining the pan, which are used in different factories. They are as follows:—

(1) *For raw sugar.*—The vacuum pump is first started. When the pan attains a vacuum of about 18", syrup is charged to the amount required. This varies according to whether graining is to be done high or low. When the vacuum goes to 22"-23", steam valve is opened. In coil pans, each coil is opened, as the syrup covers it. In calendria pans, steam valve is opened, when the calendria is covered with syrup. The amount of syrup, that is charged, depends upon, whether graining is to be done high or low. This depends on the grade of massecuite, and also, whether the pan is to be boiled straight or is to be cut for boiling other strikes. For boiling massecuite yielding 96° test sugar, much grain is not required, but when crystallizer massecuite is to be boiled, plenty of grain is necessary. When the pan is to be cut, more grain is necessary. When



syrup is boiled nearer to graining point, there are two or three methods by which graining is obtained. These are:—

(a) The syrup is allowed to grain without any change in vacuum or temperature. When enough grain is obtained, a sufficient charge of syrup is made. This charge must be done carefully. An intermittent charge of syrup is continued, until the sling is broken off, after which a continuous charge is set. This method of graining does not yield uniform granulation, as in order to get sufficient grain, three or four granulations are necessary.

(b) The vacuum is lowered, before the pan is ready for graining. When first granulation appears, vacuum is increased to cool the pan suddenly, and a light charge of syrup is made. This gives a quick granulation. The charging of syrup is then arranged as usual. This gives a quick and uniform granulation.

(c) *Seeding*.—This is a recent method of graining. The pan is boiled as usual until the first granulation appears, when the seed is charged. For seeding, fine sugar or preferably sugar dust is used. The amount of seed used is about one cupful for a pan. This gives a uniform granulation.

(2) *For crystallizer massequite*.—To boil a crystallizer massequite it is usual to take a footing from first massequite or syrup. It is quite essential to take plenty of grain for this massequite, in order to present plenty of surface for the sugar to deposit upon in the crystallizer, so that the purity of final molasses can be brought to the lowest possible limit. Under the usual system of boiling, in order to get plenty of grain, three or four granulations are necessary. This means no uniformity in grain and also more time. The use of sugar dust as seed helps a good deal to get a uniform grain, plentiful and also saves time. As soon as a distinct granulation is noticed in the pan, seed is charged through a funnel specially prepared for the purpose. This gives the grain quick, and, therefore, care should be taken to charge the syrup at the earliest possible moment. Otherwise, there will be too much grain. A light charge of syrup, a few minutes after seeding, helps to get a quick granulation.

(3) *For plantation granulated.*—In this case, it is desirable to have a small grain, which should keep its crystalline structure so as to give a sparkle to the sugar. It is, therefore, essential to have plenty of grain, and graining must be done high in the pan so as to have the required size. Seeding in this case is of special advantage. In order to prevent fouling of the grain, boiling is usually done at a high temperature, so that the mass remains free.

At Usine St. Madeleine, where the "Searby cane shredder" is used and the bagasse reduced to a fine state, difficulty was always met in making a raw sugar of good keeping quality. The bago-cellulose is so fine due to shredder, that it passes in large quantities through a 100 mesh sieve of a Carter automatic juice strainer. Experiments showed, that the sugar obtained from the strained juice, could not be washed to a higher purity than 98, regardless of the amount of water used. Seeding with sugar dust, was tried, and no difficulty was met in washing sugar up to a purity of 99.3. The seed, in this case, caused a shock granulation, and prevented crystallization to start on a nucleus of fine bago-cellulose, which was responsible for the poor quality of sugar.

The use of seed for graining is very desirable to get a uniform granulation. Besides, it gives plenty of grain, before the mass gets too close, which causes fouling. A light charge of liquor, a few minutes after seeding, quickens granulation and gives plenty of grain. A high pressure steam of about 50 lbs. pressure is desirable at the time of graining to quicken granulation.

The two principle systems of boiling are: (1) the pure massecuite system and (2) the mixed massecuite system. In the first system, the first massecuite is formed of pure sirup only. The second massecuite is formed of first molasses, obtained from first strike. This after curing gives second molasses, which is boiled into third massecuite. Usually, the final molasses is obtained from the third massecuite. If the initial purity of the sirup is low, say 80, the final molasses can be obtained in two strikes by this method. The first strike will be of 80 per cent. yielding a molasses of 60 purity, which, when boiled into crystallizer massecuite, will yield final molasses of about 31°-32° purity. The greatest disadvantage of this system is, that all massecuites, after the

first, are grained on an impurer material like the first molasses, and the resulting sugar is dark coloured. This sugar will then have to be remelted, because, no matter how much water is used for washing this sugar, the dark colour cannot be removed, as it is entrained in the body of the crystal, since the time it started. Even double purging will not help to remove this dark colour. The refiners have the greatest objection in buying any sugar containing dark seed. They do not mind, so long the sugar has dark colour on account of the adhering film of molasses, because, the latter can be removed by washing, but the former persists in the melt, which demands greater quantity of bone-char. Secondly, if this sugar is melted as is necessary, it demands a greater boiling capacity, than what will be required, if a mixed massecuite method is followed, because, the sugar, being grained on syrup in the latter case, can be used either as seed in the form of a magma for the first strike or preferably can be double purged. Thirdly, the pure massecuite method does not leave any latitude to change the purity of the final massecuite, as it always will depend on the purity of the molasses. If a higher purity molasses is obtained, the resulting massecuite will yield final molasses of a higher purity. On account of these reasons, the pure massecuite method is not followed in any of the raw sugar factories. The mixed massecuite method consists in boiling the strikes with sirup and molasses, in such proportion as to obtain the desired purity of the massecuite. For instance, a straight strike of 80 purity from pure sirup is boiled, which gives 60 purity molasses. The next strike will then be boiled with sirup, and topped with molasses, so as to bring the purity of the mixed strike to about 70 purity. This gives first molasses of 50 purity, which is boiled on grain formed from pure sirup into a massecuite of 60 purity. This is then kept in a crystallizer and purged later giving final molasses of about 30 purity.

In the mixed massecuite system, the sugar is likely to be coloured, but this is immaterial, so long the colour is due to the enveloping film of molasses. Raw sugars are mostly sold on the basis of polarization, and colour does not count, so long it is not due to dark seed. There is much less chance for a dark seed in mixed massecuite method, than is the case with pure massecuite method. One precaution is necessary, when mixed massecuite method is followed. On account of the continuous circulation of the molasses due to the topping,

of first strike, the non-sugars, in course of time, get concentrated, and the molasses becomes gummy which causes considerable trouble in boiling. It is, therefore, essential to liquidate all the first molasses at least once a week by boiling a straight strike from pure sirup, and using molasses from it for topping in subsequent strikes.

In the mixed massecuite method final molasses can be obtained in two or three massecuites depending upon the initial purity of the sirup. With 80 purity sirup, final molasses is easily obtained in two massecuites. With 84-86 purity sirup, three massecuite method becomes necessary. In both the methods the first sugar is of 96°-97° polarization, which is the standard basis for the purchase of raw sugar. The second sugar, in the case of three massecuite method, is also made of 96 test by a little washing in the centrifugals. The final sugar, in both the methods, is of low polarization and dark coloured, which is disposed of in either of the three ways, (1) by melting and reboiling, (2) by using it as a magma for seed, (3) by double purging.

The first method is followed when the sugar is very dark coloured, or whenever there is an excess of the same remaining, after a part is used as a magma for seed. Many factories remelt the sugar, and mix it with the sirup. The best practice will be to remelt the sugar, send it to raw juice and pass it through the defecation process.

Many factories use the final sugar as a magma for seed for the 1st or 2nd massecuite. In this way a part of the final sugar is disposed of, the rest being melted. It is essential to grain the crystallizer massecuite on pure sirup, if the sugar, from the same, is to be used as seed for the 1st or 2nd strikes. This will give a purer grain, and eliminate to a certain extent the dark seed. The chief object of using this sugar as seed, is to make raw sugar of a bigger grain, which, on account of its large size, carry little molasses. All the molasses present in raw sugar, is in a state of film surrounding the crystal. The bigger the size of the crystal, the less the surface, and consequently less the molasses. Such a sugar polarises much higher without washing. When the final sugar is used as seed, the practice is to make a magma of this sugar either with sirup or 1st molasses, and introduce it in the pan. The use of sirup for making a magma causes difficulties in boiling. As the sirup is richer

in sugar than molasses, the massecuite cannot be boiled at higher supersaturation from the beginning, owing to the danger of the formation of false grain. Before molasses is taken in the pan for boiling the strike, the massecuite has to be concentrated to a higher supersaturation, which, later, results in the formation of either false grain or 'smear'. In one factory, where sirup was used for making a magma, I always noticed smear or false grain, after the molasses was charged in the pan. The use of molasses for making a magma obviates this difficulty, as strike can be boiled at a higher degree of super-saturation from the beginning. When sugar is to be used as a magma, usually smaller size grain is secured in the crystallizer massecuite.

Double purging of the final sugar is followed in some factories. For this purpose, the sugar from the centrifugals is mixed with 1st molasses, and cured along with the 1st or 2nd massecuite. By this method only one grade of sugar is made in the factory. For double curing, the crystallizer massecuite will have to be boiled to a bigger grain so that the size of the crystal will not differ much from the first sugar. This seems to me to be the best method to get rid of the third sugar, as the accompanying molasses will not go back with seed to the first massecuite, as is the case when it is used as seed. This method requires more centrifugal capacity.

When white sugar is to be made, a combination of the two methods is followed. All the first strikes are boiled of pure sirup, but the second and third strikes are started on a footing or grain from sirup, and boiled with 1st and 2nd molasses respectively to a desired purity. The 1st two strikes give white sugar, while the third gives raw sugar and final molasses. This sugar has to be remelted. It cannot be used either as seed or for double purging. The remelt is sent to the raw juice for receiving the usual treatment of defecation and sulphitation.

Another difference, in white sugar manufacture, is the separation of 'run off' from wash, specially when double purging is not done. The sugar has necessarily to be washed in the centrifugals with comparatively much more water, than what is used in raw sugar manufacture. The wash is very bright coloured, and is, therefore, separated from the run off. It is ultimately used for boiling a mixed strike, which gives white sugar. The disadvantages of this practice

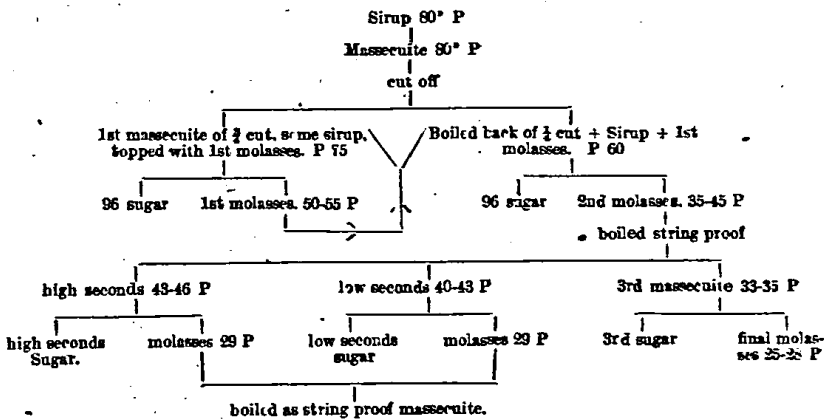
are: (1) a great quantity of water is required to be used, which has to be evaporated, (2) during washing, some of the crystals are dissolved, (3) it is difficult to secure uniform washing unless a great quantity of water is used.

The best system is to double-purge the sugar as is done in Java. The sugar is first cured in the centrifugals without washing, is then thoroughly mixed with sirup, and the magma is then cured in separate centrifugals. In this method, the dark molasses is completely replaced by a light coloured sirup, which, being not so viscous, is easily washed with little water. The sugar is then washed in the centrifugals, and the wash mixed with the purging sirup, which is reused for making a magma, until it gets too dark coloured to be used, when it is mixed with juice. This method requires more centrifugal capacity, but is most effective in removing all the colouring film of molasses adhering the sugar crystals, with a minimum amount of water, and giving the best white sugar.

The method of boiling sugar depends upon (1) the grade of sugar to be made, whether plantation white or raw, (2) the initial purity of the sirup, and (3) the equipment of the house. It is, therefore, impossible to lay out any standard method, but a few methods, practised in some of the sugar factories, are given below to give some idea:—

(1) For raw sugar:

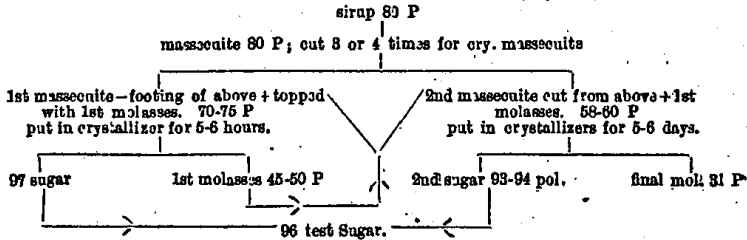
(a) Purity of sirup 80; equipment: 4 coil pans, no crystallizers but hot rooms.



On account of no crystallizers such a complicated system is followed to get a low purity final molasses.

(b) the same purity sirup. Equipment: 2 coil pans and crystallizers.

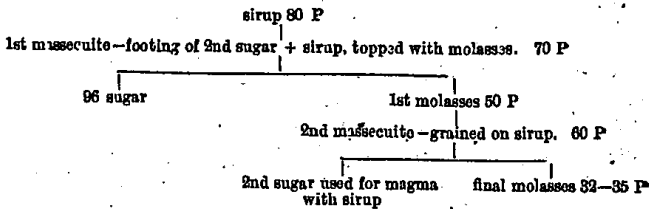
2—Massequite method.



In this method the 2nd sugar is mixed with the first which is not a good practice.

(c) Purity of sirup 80; equipment: 3 coil pans and crystallizers.

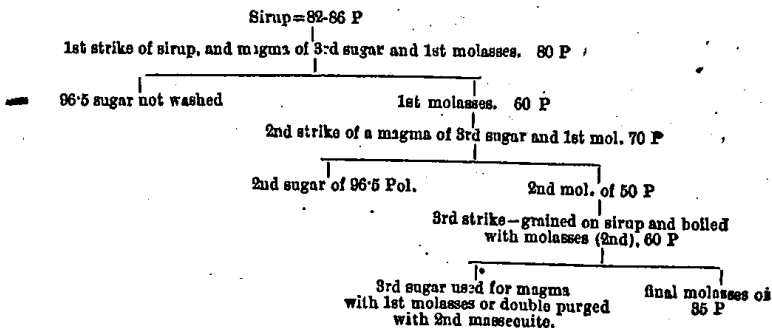
2—Massequite method.



Occasionally, a straight strike is boiled to liquidate the classes, which is in continuous circulation.

(d) P of sirup 82-86; equipment: calandria and coil pans and crystallizers.

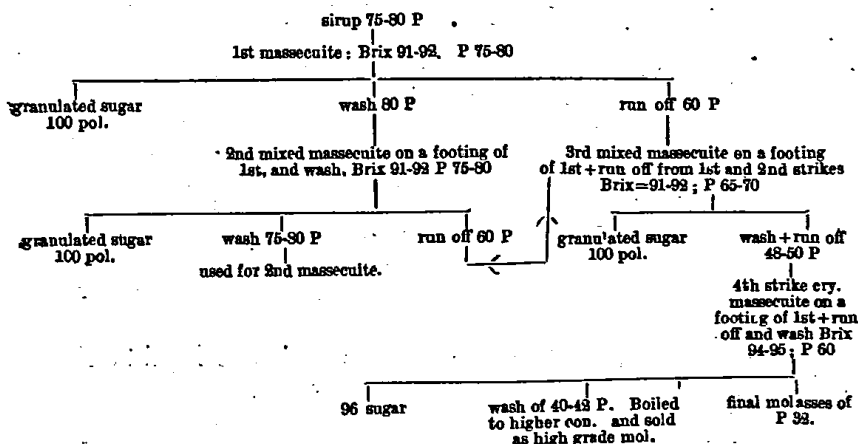
3—Massequite method.



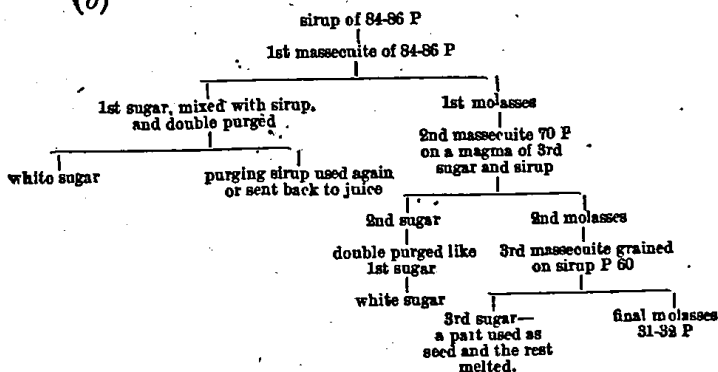
It may be seen, that, with a low initial purity of sirup, the molasses can be exhausted easily in 2 massecuites to about 30 purity. This system is quite general in British Guiana and Louisiana. When the initial purity is high, as is the case in Cuba, 3 massecuite method is required to exhaust the molasses. When factories are not equipped with crystallizers, a large hot room capacity is needed to keep string proof massecuites. This system is very laborious and wasteful and all modern factories have abandoned this system altogether in favour of the crystallizers.

(2) For white sugar :

(a) purity of sirup 75-80; equipment: coil and calendria pan and crystallizers.



(b)





*Crystallizers.*—Formerly before the crystallizers came into general use in the cane sugar industry, the usual practice to exhaust the molasses, was to boil the final massecuite string proof, and allow it to crystallize in open tanks. A few houses, not equipped with crystallizers, still follow this system, notwithstanding the fact, that this process is considered to be insanitary and more wasteful. The greatest objection to this system is, that it takes much longer time to get a sufficient crystallization. Consequently, the massecuite has to be left for days and months together. Therefore, not only does it require a much greater storage capacity, but there is a greater loss in inversion and fermentation. It does not exhaust the molasses to the same extent, as a crystallizer massecuite does, on account of certain inherent defects in the method. On account of a lack of circulation due to viscosity, the crystallization is never complete. Consequently the final molasses are of a higher purity for the same purity massecuite. On account of lack of circulation, and lack of temperature control in rooms, the massecuite is suddenly cooled, on account of which, the sugar separates into a number of small crystals. Some houses in Louisiana have put up hot rooms provided with thermostats, but this increases the expense. On account of the lack of circulation, the crystal has no chance to grow. Consequently, string proof sugar has always small grain, which, on account of its specific surface, retains a greater quantity of molasses. The sugar is consequently dark coloured. This sugar cannot be washed in the centrifugals for fear of dissolving the crystal. The use of this sugar as seed is very objectionable not only, because it gives dark seed, but it brings back a greater part of the final molasses in the house. On account of small size of the crystals, and on account of its viscosity, the string proof massecuite presents great difficulties in curing. On account of all these reasons, as well as on grounds of economy, crystallizers have come into general use.

The crystallizers are horizontal tanks either open or closed, provided with stirrers. These rotate at a very low speed, usually at one revolution per 4 minutes. The massecuite is boiled to grain, and dropped at a Brix of 95-96 into the crystallizers, in which the sugar crystals are allowed to grow. This is possible on account of the circulation. In order to have a gradual cooling, crystallizers are provided

with water jackets in cold countries like Louisiana. In the tropics, they are not required. As the crystallization proceeds, and the massecuite gets cooled in 4 or 5 days, a little water is added to reduce the viscosity which causes not only better circulation promoting better exhaustion of the molasses, but it aids considerably the curing. In about 5 or 6 days, depending upon the temperature conditions of the locality, the massecuite gets sufficiently cooled, after which it is cured in the centrifugals.

The purity, to which the crystallizer massecuite be brought before striking, depends on certain considerations. Every factory aims to exhaust the molasses to the lowest possible limit. The purity of the final molasses depends to a great extent on the initial purity of the crystallizer massecuite. The lower the purity of the massecuite, the lower the purity of the molasses obtained therefrom. But there is a limit, beyond which it is not advantageous to go. First of all, the maximum drop of 30 in purity from massecuite to molasses, is obtained, when the crystallizer massecuite is of 60 purity. As this purity drops, the drop in purity from massecuite to molasses also drops. For instance, a massecuite of 60 purity gives a drop of 30 purity yielding 30 purity final molasses. If the purity of the massecuite be reduced to 50, it may give a drop of 20 only giving final molasses of 30 purity. This does not give any advantage. On the contrary, it gives more trouble in actual practice. As the purity is reduced below 60, the massecuite becomes so viscous, that the boiling becomes very defective on account of bad circulation, resulting in the formation of false grain. This gives many troubles in curing, on account of the viscosity of the massecuite, reducing the capacity of the centrifugal machines and requiring water for washing. It may be inferred from this, that the purity of the final molasses cannot go below 30, and it may be asked, how certain factories obtain a purity of the final molasses down to 27-28. The only place I saw so far, where molasses is exhausted to this purity, is Louisiana. There, the juices are of low purity and massecuites can be boiled to a lower purity without any trouble of viscosity, which yields final molasses of a lower purity than 30, though the maximum drop in purity is not obtained. In the Tropics, the only places, where final molasses is exhausted to 27-28 purity, are central Meroidita in Porto Rico, and Kahuku sugar mill in

the Hawaiian islands. The crystallizer massecuites at the two places, are boiled to 53-54 purity which yields final molasses of 27-28 purity. This means a drop of 26-27, which is lower than the maximum drop of 30. The chief cause, which has made it possible for these two factories to boil the crystallizer massecuite to such a low purity as 53-54, is the elimination of the bago-cellulose from the juice by means of strainers, which seems to have eliminated, to some extent, the gums from the molasses. The chief reason, why crystallizer massecuites cannot be boiled below 60 purity in actual practice, is the viscosity due to gums. The presence of gums in molasses may be traced to the circulation of molasses in the house, resulting in the concentration of non-sugars as well as to the formation of gum from bago-cellulose. It is known, that lime acts partially on bago-cellulose, resulting in the formation of dextran, which is gummy. This shows how advantageous it is to remove the bago-cellulose from the process in its early stage.

*Mixers.*—The massecuite, after it is dropped from the pan, is conveyed through open gutters or closed pipes to mixers. The closed pipes require careful attention in steaming the same after the massecuite is passed, to prevent choking. The former is simpler, and easier for supervision. Mixers are troughs usually U shaped, narrower at the bottom with stirrers inside, which keep the mass in continuous circulation. Some factories use the crystallizers as mixers, keeping the massecuite in them for a few hours from 4-8 hours, depending on the available capacity. For raw sugar this practice is very good, as it gives a greater drop in purity of the molasses obtained therefrom. For white sugar immediate curing is necessary, as the massecuite, when cooled, does not cure so readily. In order to prevent rapid cooling, covered mixers will be better.

#### XV. The separation of the crystals.

The next operation is to separate the sugar crystals from the adhering molasses. This is done by means of centrifugal machines. The most commonly used are 40" x 24" machines, all top-driven. It has been found that 40" are the most economical in modern sugar houses. With smaller machines, not only greater speed is required in order to produce the same centrifugal force, but more units of labour are required, as the capacity decreases with the size of the machines.

Four makers are in use.—Watson Laidlow and Co., American Tool Co., Mackintosh, and Pott Cassels and Williamson, of which the Watson's machines are in greater use. The massecuite is fed directly from the mixer to the machine by means of a spout.

*Drive for the centrifugals.*—Three methods of driving the centrifugals are in use. They are the belt, the water and the electric drive. The latter is coming into general use and has been exclusively put by mills installed recently. Opinion is as yet divided as to which is economic in the end. Belt drive is the old method of driving the centrifugals. In this, power is generated in a steam engine, which drives a countershaft, which, in turn, drives another shaft, on which are mounted clutches, one for each machine, the power being transmitted from the clutch to the machine by a belt and pulley. This is the simplest and the cheapest drive. In case of overload, the utmost that may happen is either a belt slip or the giving way of the belt, which can be easily repaired in the house. In this drive, the common trouble is the belt slip, which increases the loss in transmission, and reduces the speed of the machine thus affecting the quality of the work. Consequently, belt drive machines require constant attention.

Water drive is very common in the Hawaiian islands. In this case the source of power is the water under pressure. For this purpose, big pumps are provided, which supply water to the centrifugals under a pressure of 125-175 lbs. Where water power is available, this will be the cheapest source of drive for the centrifugals. The water driven machines work very well, and there is nothing to get out of order. The machines work with a steady speed, which is not the case with belt driven machines, on account of the trouble of belt slip. But, in this case as each machine is driven individually and not collectively, as is the case with belt drive, provision has to be made to derive an excess of power during acceleration, which becomes expensive. In Watson's machines, this has been arranged by the provision of two jets, one of which automatically stops as soon as speed is attained. With all that, it demands more power, and so it is rather expensive. Many times, a sufficient water pressure is not maintained, which affects the speed of the machines. This is its only draw-back. The water can be used over and over again in this case.

*Electric drive.*—The electric drive for the centrifugals is getting more and more common. There are two systems of drive in this, the collective and the individual. In the first, there is a common electric motor to all the machines in a battery, from which power is transmitted by means of a belt. It differs from the belt drive in one respect, and that is, the substitution of a motor for an engine for generating power for the machines. Consequently, there is present the same trouble namely the belt slip. That seems to be the reason, why the latter system, though expensive, is adopted by all modern factories. In the individual drive, a separate motor is placed directly on the top of the machine, and connection is made to the rotating spindle by a friction clutch. There is no question, that a separate drive for each machine is much more expensive than a collective drive for all machines in a battery, because individual motor must be of such a size as to be able to develop an excess of power, which is required by the machine over short intervals during acceleration. It is obvious, that with one central motor for driving a battery of centrifugals, there will be a saving in power, as the excess power required by the individual machine during acceleration, can be easily developed by the central motor, which is capable of driving all the machines at a time. In the collective drive all the machines are not running at an acceleration at the same time, and consequently it is not necessary to have a motor of the power capable of producing the sum total of the excess power required by each machine during acceleration. The sum total of the individual motors will always exceed that of the central motor. This consequently becomes expensive. Still, the present practice is to have a separate motor for each machine so as to incur no loss in power through belt slip, as is common with belt drive. With this drive, it is necessary to provide a number of reserve motors as little carelessness on the part of the workmen may result in burning the motor.

The molasses is separated from the sugar crystals by means of centrifugal force. In raw sugar manufacture, no washing of the sugar with water in the centrifugals is necessary, if the massecuite be of a high purity like 80. With lower purity massecuite, little water is used to remove the adhering film of molasses in order to increase the polarization of the sugar to 96° test. It is very important, that the water be used at the proper time. Immediately after the molasses disappears from the surface of the sugar crystals in the centrifugals, water should be used. Water must follow the molasses, so that the latter is, so to say, forced out.

If water is used long after the molasses has been separated, it does not help in removing in any more molasses, but on the contrary, dissolves a part of the sugar crystal, which is not desirable. It is desirable, that the least amount of water should be used. The water, used for washing, dilutes the film of molasses that surrounds the sugar crystal, for which reason, washed sugar is liable to deterioration in storage. In order to regulate the quantity of water, automatic water sprinkler is provided for each machine.

In white sugar manufacture sugar has necessarily to be washed to remove the adhering film of molasses. Sufficient water must be used to make the sugar white.

After the separation of the molasses from the sugar is nearly complete, the machine is stopped. Longer running of the machine than what is necessary results in hardening the sugar, which is very difficult for scraping. When the machine stops, sugar is scraped off either by wooden handles worked by hand or by plough scrapers. The latter are used in countries like Cuba, Louisiana and Porto Rico where labour is expensive. With self discharging machines, no scraping is required. These machines work alright with first sugars. For white sugar, these machines are not desirable, as in case proper washing is not done, the sugar cannot be spun again, which in this case, is automatically discharged to the conveyer as soon as the machine stops. All self discharging machines have to be charged while in motion.

In raw sugar factories the separation of wash from 'run off' is not necessary, but in white sugar factories, it is found necessary, if double purging is not followed. The amount of water used is much more than what is used in raw sugar factories. This wash is of light colour and of high purity. Consequently, it is separated by providing two separate gutters behind the centrifugals.

*Double purging.*—When double purging is done, as is usual in Java in white sugar factories, the masse-cuite is first cured in centrifugals without washing, the sugar is then dropped and mixed with sirup (thick juice), and the magma again purged in separate centrifugals. Water is used for washing the sugar, but wash is not separated, as it mixes in this case with sirup and not with molasses.

*Calculation of pan, crystallizer and centrifugal capacity.*  
—A calculation is made below for conditions in the Bombay Deccan according to the method used by Dr. Geerligs in his book on white sugar manufacture. The system given therein differs from the Louisiana system in this

respect, that all white sugar is obtained by double curing, and a part of the final sugar is used as seed. This system, therefore, requires more centrifugal capacity, but secures better washing of the sugar:—

*Process.*—Sulphitation.

*Products.*—Plantation granulated and final molasses.

*Data.*—Grinding capacity 1,000 tons of cane a day of 24 hours Fibre in cane 11 per cent., sucrose in cane 14 per cent. Brix of normal juice 18, purity of juice 84, purity of sirup 86.

Normal juice extraction 80 per cent.

Purity of 1st, 2nd, and 3rd massecuites 86, 70 and 60, respectively.

Purity of 1st, 2nd, and 3rd molasses 66, 50 and 30, respectively.

Brix of 1st, 2nd, and 3rd massecuites 94, 94 and 94, respectively.

Purity of 1st sugar to be 97.5; sugars from 1st and 2nd massecuites to be double purged.

*Calculation:* on a basis of dry solids. One thousand tons of cane yield 800 tons of juice containing 144 tons of dry solids, which amount is present in sirup and primary massecuite.

(1) 1st massecuite yields

$$\text{sugar per cent.} = \frac{86 - 66 \times 100}{97.5 - 66} = 63.5 \text{ and 1st molasses per cent.} = 36.5 \text{ of } 66^{\circ}\text{P.}$$

(2) 2nd massecuite yields

$$\text{sugar per cent.} = \frac{70 - 50 \times 100}{97.5 - 50} = 42.0 \text{ and 2nd molasses per cent.} = 58 \text{ of } 50^{\circ}\text{P.}$$

1st massecuite consists of solids from sirup.

2nd massecuite consists of

$$\begin{array}{r} 86 \\ \diagdown \quad \diagup \\ 70 \\ \diagup \quad \diagdown \\ 66 \end{array} \quad \begin{array}{l} 4 = 1 \text{ sirup or } 20 \text{ per cent. sirup.} \\ \\ \\ 16 = 4 \text{ 1st molasses or } 80 \text{ per cent. of } 66 \text{ P.} \end{array}$$

3rd massecuite of 60 purity consists of

$$\begin{array}{r} 86 \\ \diagdown \quad \diagup \\ 60 \\ \diagup \quad \diagdown \\ 50 \end{array} \quad \begin{array}{l} 10 = 1 \text{ or } 28 \text{ per cent. sirup.} \\ \\ \\ 26 = 2.6 \text{ or } 72 \text{ per cent. of } 2\text{nd molasses of } 50 \text{ P.} \end{array}$$

$$\begin{array}{r} 86 \\ \diagdown \quad \diagup \\ 60 \\ \diagup \quad \diagdown \\ 50 \end{array} \quad \begin{array}{l} 10 = 1 \text{ or } 28 \text{ per cent. sirup.} \\ \\ \\ 26 = 2.6 \text{ or } 72 \text{ per cent. of } 2\text{nd molasses of } 50 \text{ P.} \end{array}$$

Molasses, for final massecuite of 60 purity, is obtained from 2nd massecuite, so, for 100 parts of final massecuite,  $\frac{72 \times 100}{58}$  parts of 2nd massecuite of 70-purity, are necessary. to give 72 parts of 2nd molasses of 50° P. This is equal to 124.1 parts of 2nd massecuite of 70 P. This in turn requires  $\frac{124.1 \times 80}{100}$  first molasses, which is obtained from  $\frac{24.1 \times 80}{36}$  parts of 1st massecuite. This is equal to 272 parts of primary massecuite of 86 P.

*Summary --*

100	parts of final massecuite of 60 P containing 28	parts of	Primary massecuite.
124.1	„ „ 2nd „ „ 70 P „	24.8	„ „ „
272.0	„ „ 1st „ „ 86 P „	272.0	„ „ „
496	parts of mixed massecuite containing	324.8	parts of „

so 144 parts of dry solids in sirup yields  $\frac{496 \times 144}{324.8} = 220$  tons of dry massecuite. Taking the Brix of the massecuite to be 94.0, this is equal to  $\frac{220 \times 100}{94} = 234$  tons of mixed massecuites of 94 Brix every day. Taking 8 hours, as the average time for one pan, the total vacuum pan capacity should be  $\frac{234}{8} = 80$  tons or 1,700 cu. ft., 3 pans of 30 ton capacity each, would be most suitable.

*Crystallizer capacity.*—234 tons of mixed massecuite consist of 128 tons of 1st massecuite, 58 tons of 2nd massecuite, and 48 tons of final massecuite. The latter at 94 Brix is equal to  $\frac{48 \times 2000}{94.4} = 1,017$  cub. ft. As this massecuite swells considerably, and water has to be added from time to time, an allowance of 25 per cent. is made. So it comes to about 1,250 cub. ft. Taking 4 days as the usual time required to cool the massecuite, it means a capacity of 5,000 cub. ft. To this should be added a spare capacity of two crystallizers one to receive the massecuite and the other to discharge it to the centrifugals. Taking the size of the pan to be 600 cub. ft. each, each crystallizer should have a capacity of 600 cub. ft. + 25 per cent. or 600 + 150 or 750 cub. ft. The number of crystallizers will then be  $\frac{5000}{750} = 7 + 2$  for allowance or 10 in all.

*Centrifugal Capacity.*—Taking 2 per cent. moisture in sugar, 128 tons of 1st massecuite of 86° purity yield



$\frac{128 \times 94 \times 63.5}{100 \times 98} = 78$  tons of sugar. 58 tons of 2nd masse-  
 cuite of 70 P yields  $\frac{58 \times 94 \times 42}{100 \times 98} = 23.3$  tons of sugar.

128 tons of 1st massecuite giving 78 tons of sugar.  
 58 " " 2nd " " 23.3 " " "  
 48 " " final " of 60 P " "  
 23.3 " 2nd sugar returned for purging.

257.3 tons for 1st purging.

For double purging.

78 tons of sugar from 1st massecuite.

23.3 " " " " 2nd " returned to  
 1st massecuite.

101.3 tons + sirup used, which comes to about 150  
 tons in all.

The total centrifugal capacity will be  $257.3 + 150 = 407.3$   
 tons of massecuite per day of 24 hours.

For double purging.—40" machine will purge 2 tons an  
 hour. So 4-40" machines will be necessary for 150 tons of  
 massecuite for double purging.

1st and 2nd massecuites are equal to 209.3 tons. They  
 will require 6-40" machines.

3rd massecuite is 48 tons. Taking 2/3rds of a ton per  
 machine per hour, it will require about 4 or better 6-40"  
 machines for 3rd sugar.

Thus 4-40" machines for double purging, 6-40" machines  
 for 1st and 2nd massecuite and 6-40" machines for 3rd mas-  
 secuite, in all 16-40" machines will be required.

*Sugar conveyers.*—After the sugar is dropped from the  
 centrifugals, it is carried by conveyers and elevators to the  
 sugar bin. I saw three kinds of conveyers in use. They are  
 (1) the screw conveyer, (2) the grasshopper conveyer, (3)  
 the belt or slat conveyer. In Louisiana, the first is common.  
 The disadvantage with this conveyer is that, it cannot be  
 kept clean. The grasshopper conveyer is common in Cuba,  
 West Indies, Hawaii and Java. It works very well and  
 can be kept clean. With final sugar, the grasshopper conveyer  
 does not work well on account of the sticky nature of the  
 sugar, for which purpose, either the screw conveyer or the  
 slat conveyer is preferred.

The conveyer carries the sugar to a pit, from which it is  
 elevated by bucket elevators to the sugar bin. In raw sugar.

factories, the sugar is then weighed, and filled in bags, after which, the latter are stitched, and either shipped or sent to the warehouse. Before bagging sugar, it is desirable to cool it so as to prevent caking. In the Hawaiian islands, sugar driers, similar to granulators, are used for cooling sugar before it is bagged. The driers were originally installed to dry the sugar so as to reduce the amount moisture in the sugar. This was subsequently abandoned but the same machines are now used for cooling the sugar.

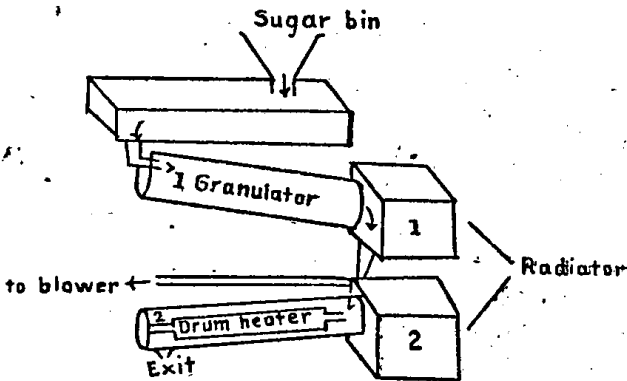
In white sugar manufacture, the sugar has to be thoroughly dried, before it is bagged. A little amount of moisture will affect the keeping quality considerably. There are two methods in use, drying the sugar by steam and by the granulator.

*Drying the sugar by Steam.*—In Java, the use of steam is common. In this case, the sugar, after it is free from molasses in the second set of centrifugals, is dried by injecting steam. The basket is covered, and steam is injected directly on the sugar. Generally saturated steam is used, but a moderately superheated steam is advantageous, as it can remove the last traces of moisture. This system may not dry the sugar so well as a granulator does because in this system steam cannot come into contact with all the particles of sugar. Java manufacturers prefer this system, because they object to the use of the granulators on account of the rubbing of the crystals in the granulators, which is considered to make the sugar crystals dull. Experience shows, that crystals do not become dull to the extent, the Java manufacturers believe. In fact all the refined granulated sugars, which are generally very bright, are dried by means of the granulators.

*Drying the sugar by granulators.*—In Louisiana, white sugar is dried by means of a granulator. It consists of either one of two drums slightly inclined to the horizontal towards the discharge end, and revolving on trunnions. When two drums are used, the one, which is usually placed at the top, is used for drying sugar and the other, which is placed below the other, is used for cooling the sugar. The best practice is to provide two drums, so that both the operations of drying and cooling the sugar can be effectively done. When only one drum is used, cooling of sugar cannot be done in the machine, which is essential before bagging, to prevent caking.

In the granulator, sugar is dried by means of hot air, which enters the drum on account of induced draft usually

provided. At one end of the drum is placed a radiator, which heats the air, as it enters the granulator. The sugar which enters at the other end, travels on account of the rotation of the drum and on its way, meets the incoming hot air, which removes the moisture from the sugar. A temperature of about  $170^{\circ}\text{F}$  is usually maintained in this drum. The dried sugar, then, enters the second drum, in which, it gets cooled on its way to the other end of the drum. In this drum, is provided a steel drum centrally located, which is kept hot by means of steam. Usually a low pressure steam of about 10-15 lbs. is used for this purpose in order to prevent charring, which occurs, if a high pressure steam is used. For the radiator live steam of 40-60 lbs. pressure is used. The temperature in the 2nd drum is maintained at  $100^{\circ}\text{-}125^{\circ}\text{F}$ . The following rough sketch shows the working of a granulator:—

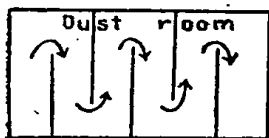


The only precaution that is required to be taken, is to keep a constant temperature so as to secure good drying and cooling. In no case, the central drum in the second granulator be made hotter by using a high pressure steam, as it will burn a part of the sugar. At the end of the inclined drum is placed a wire screen, which separates the coarse lumps, which are melted. The sugar comes out at about  $112^{\circ}\text{-}114^{\circ}\text{F}$  temp.

*Dust separator.*—As hot air blows through the granulator under induced draft, it carries along with it fine dust, containing finer particles of sugar. I saw three or four devices to separate the sugar dust. They are (1) water separation, (2) dust room separation, (3) steam separation.

*Water separation.*—I saw two systems in use. One was the blowing of the dust through a tank filled with water. This is a simple device. Particles get dissolved, as the dust blows through the water. This, however, is not efficient, and lot of sugar dust passes out. The second system which I saw in the refineries is to inject hot water in the form of a spray, which on coming in contact with the dust, dissolves the sugar. This operates like the jet condensers. This works good, & most of the sugar, that is likely to pass through the dust can be recovered in this way.

*Dust room separation.*—This is the simplest device. It consists of a dust room, provided with wooden baffles, in order to change the direction of the dust as well as to slow the velocity. On account of these reasons, a great part of the sugar dust is retained on the floor as well as on the walls of the room. Rough sketch is given below:—



In this device, a part of the sugar is blown to the air along with the dust, and separation is not efficient, but this device is very simple and cheap.

*Steam separation.*—This works in the same way as a water jet separation. Only instead of water jet, steam jet is used. A saturated wet steam is used for this purpose. This works very well, but is expensive on account of the steam, that is required to be used.

The dust, thus recovered, is used for the purpose of 'shock' seeding, the excess remaining being remelted.

*Sugar screening.*—The sugar from the granulators is then sifted through screens, in order to get a uniform size grain. The sugar is usually separated in Louisiana into 3 grades, the fine granulated, coarse granulated and the lumps. The latter are remelted, while the others are bagged and sold. For this purpose, a rotating screen separator, having different mesh screens, is used. For fine granulated, a 16 mesh screen, and for coarse granulated, 10 mesh screen are used. The lumps are retained by the 10 mesh screen. This is a simple and cheap device.

In the refineries, a vibrating separator is used. It consists of an inclined frame, having 2 or 3 different mesh screens placed one above the other, the coarse being placed at the top and the finer being placed at the bottom. As the sugar enters the top screen, on account of the inclination, as well as the vibrations of the separator, the fine sugar passes through the upper screen, while the coarse pieces travel to the other end of the screen, and are separately collected. This separator is all closed, and consequently, is much cleaner.

After the sugar is separated into different sorts, it is filled in bags. Usually granulated sugar is filled in 100 lbs. bags in Louisiana. Always double bags are used. The inside bag is made of coarse linen or cloth, which holds the sugar, while the outside bag consists of jute, called the gunny bag, which supports the inside bag. The object of a double bag is to keep the white sugar, free from moisture absorption during storage and transportation. The use of paper for the inside bags is said to be more efficient and cheaper.

#### **XVI. Accessories—Pumps and self recording instruments.**

The equipment of a sugar factory involves the use of a number of pumps at different stations in the house. They are feed water pumps, raw juice pumps, clarified juice pumps, mud pumps, syrup pumps, molasses pumps, magma pumps, injection water pumps, &c. Before the electrification of the accessories in a sugar mill came into use, the most common type of pumps were the Duplex piston pumps, all driven directly by steam. The efficiency of these pumps is generally low. They consume much steam, and in actual practice always leak and hence are wasteful. With the electrification of accessories, the use of centrifugal pumps is getting more and more common. Centrifugal pumps are run at high speed, and hence are very suitable for electric drive by means of motors. The centrifugal pumps are much cheaper in first cost, easy for operation, require much less attention and little floor space. There is no doubt, that electric drive for pumps is more economic. In all modern houses centrifugal pumps are used except for molasses and magma, for which special piston pumps, driven by electric motor, are used. On account of the peculiar nature of the molasses and magma, centrifugal pumps cannot be used for this purpose.

This practice has resulted in the reduction of floor space, compactness of the plant, and general cleanliness of the house. The electrification of the accessories is fully justified by the use of the centrifugal pumps.

In all modern factories, it is a practice to provide self-recording instruments. This secures a better control on all operations in the factory. In one factory in Louisiana, the following self-recording instruments were provided:—

1. For temperature of fuel oil.
2. For live steam pressure.
3. „ „ temperature.
4. For temperature of chimney gases.
5. For draft of the chimney.
6. For maceration water.
7. For steam flow meter.
8. For temperature of juice heaters.
9. For temperature in a quadruple. Two thermometers, one for temperature of steam in the calandria, and the other for the temperature of the juice.
10. For recording vacuum in each body of the quadruple.
11. For recording temperature in the pan.
12. „ steam pressure in the pan.
13. „ exhaust steam pressure.

These instruments record the actual work that is being done in the factory during 24 hours. Every 24 hours, a new graph paper is replaced. On account of the self-recording instruments, the Superintendent is able to detect any fault either in the operation or any man, even though he may not be present in the factory for all the time. This enables the engineer to check the efficiency of the furnace and mills from time to time. The importance of self-recording instruments cannot be too much stressed. Their advantages are so obvious, and the cost involved is so little, that every modern factory cannot do without them, specially when the best efficiency is desired.

## XVII. Generation of Steam.

The steam, required for power as well as for heating and evaporation in the factory, is generated in the boilers. In the cane sugar factories, the two types of boilers, commonly used, are the horizontal return tubular (fire tube) and the water tube. All new installations in Cuba have put water tube boilers.

The horizontal return tubular boilers are suited for smaller plants. They are much cheaper than water tube boilers, and for this reason smaller plants find them economic. They are not considered safe for pressure above 200 lbs. per sq. inch, but in cane sugar factories, the pressure commonly used is not above 125 lbs., and never has so far exceeded 150 lbs. This point is, therefore, not of so much consequence. For large plants, water tube boilers are preferred, chiefly on account of their higher efficiency, safety and reliability as quick steamers. Fire tube boilers are not quick steamers on account of their greater water holding capacity, and defective circulation of water. In spite of this fact, in countries where labour is not so well trained, fire tube boilers are considered satisfactory and economical for small plants, requiring steam not above 200 lbs. pressure.

The type of multi-tubular boiler commonly used, is the horizontal return tubular. In this, the hot gases go underneath the boiler to the other end of the furnace, and return through the tubes, after which they pass through the chimney. In Java, the hot gases are again made to go back on the outside of the water drum, before they are allowed to go through the chimney. The latter method gives more efficiency. These boilers are easy for cleaning by mechanical means such as the brush.

The water tube boilers, most commonly met with, are the Babcock and Wilcox, and the Stirling. The water is in the tubes and consequently there is a better circulation of water. In the Stirling boiler, there is a mud drum, provided at the bottom, through which the precipitated impurities from the water are removed. The Stirling boiler is expensive but its efficiency is very high. For this reason, these boilers are used in large plants, specially when higher efficiency is desired, on account of the shortage of fuel.

The steam pressure usually used in cane sugar factories is about 125 lbs. A few factories generate steam of about 140—150 lbs., but reduce its pressure by a reducing valve to about 110 lbs., when it is to be used for driving the engines. A pressure below 90 lbs. is not good. It not only affects the engine efficiency and the mill work, but the exhaust steam pressure is too low for use. When steam is to be used for heating or evaporation purposes, a pressure of 120 lbs. is considered to be too high. The steam pressure is reduced to about 40 lbs. or less before it is used. In order to avoid this trouble, it is a practice to instal two sets of boilers in a factory—one called the high pressure boiler; the steam from which is used for power purposes, and the other, the low pressure boiler, the steam from which is used for heating purposes. The two steam lines are connected to a common steam line so as to transfer some of the high pressure steam to the low pressure steam line, when there is a shortage. This system has been found to work well.

The quality of steam, commonly used, is the saturated steam. This is also called wet steam, as it contains some partially condensed steam. Superheated steam is coming into general use in places, where the mills are electrified. In such houses, the electric power is produced by means of a turbine directly connected to a dynamo. A saturated steam is injurious to turbines on account of the condensed vapour it contains, which wears out the blades in the turbine. Superheated steam has been found to be more economic in turbines. The degree of superheat, usually used is 100° F. There is one great advantage in using superheated steam, and that is, the exhaust steam is nearly free from oil and condensed vapour. In factories, where the live or exhaust steam has to travel a long distance, there is a greater loss of heat through condensation of some steam along the pipe lines. An exhaust, from superheated steam, has sufficient excess heat to prevent this condensation. It should be noted, that a greater part of the useful heat in steam is due to latent heat, which is totally lost during condensation. 1 lb. of steam, at atmospheric pressure, contains 1,150·4 B. T. U. of heat, of which the latent heat is 970·4 B. T. U. This is nearly 84 per cent. of the total heat, which is lost through condensation. Secondly, in engines, when saturated steam is used, the greater loss is due to cylinder condensation, which is prevented by the use of superheated steam. For this reason, for power purposes, a moderately superheated steam will be decidedly advantageous.



The use of superheated steam for power purposes secures greater efficiency as the following figures show:—

Type of engine.	Saturated steam, lbs. per hour.	100° superheat, lbs. per hour.
Simple non-condensing ...	29-45	20-38
Do. do. Corliss.	26-35	18-30
Do. Duplex steam pumps.	120-200	80-160
Turbine non-condensing ...	28-60	24-54

So far superheated steam is not used for driving the mill engines in cane sugar factories, except in one factory in Java, though its use is known to secure greater efficiency. It is expected, that, in future, greater attention will be paid towards economy in steam consumption in cane sugar factories, when, the use of at least a moderate superheat for driving the mill engines will be decided upon.

For purposes of heating and evaporation, superheated steam offers no advantage. On the contrary, it is not considered desirable as superheated steam parts with its heat with difficulty due to the fact, that it acts more or less like a perfect gas. For this reason, saturated steam is exclusively used for evaporation purposes. Prof. Kerr's experiments, with regard to the use of superheated steam for evaporation, have shown no benefit.

The power, required for the factory, varies a good deal. It depends upon the equipment of the factory, the kind of cane, the amount of maceration water used, and the grade of sugar to be made. Prof. Kerr, who conducted actual tests in some factories in Louisiana, found that, for raw sugar factories, the power required to run the factory was  $1\frac{1}{2}$  B. H. P., for every short ton of cane ground. For white sugar factory,  $1\frac{3}{4}$  B. H. P., for every ton of cane ground was required. Taking into consideration the conditions in the Bombay Deccan, it comes to about 1.70 B. H. P. per short ton of cane ground (for calculations, *see* page 190). This can be reduced as more attention is paid to economy in steam consumption in cane sugar factories. The above figures indicate the capacity of the boilers, that should be installed in the factory. In actual practice I found the B.H.P., provided for raw sugar factories in Cuba, was from 1.25 to 1.85 per ton of cane.

The heating surface usually provided is 10-12 sq. feet per B. H. P., depending upon the kind of the boiler. For water tube boiler 10 sq. feet and for fire tube 12 sq. feet are provided. It is of the utmost importance, that, the heating surface should be cleaned from time to time, as it affects heat transmission.

*Furnaces.*—In cane sugar factories, the fuel exclusively used is bagasse. When it is not sufficient, it is supplemented by cane trash, wood, molasses, or fuel oil. The different fuels demand different conditions in the furnace. For bagasse, a voluminous combustion chamber is necessary, on account of the bulky nature of the fuel. Secondly, sufficient time must be allowed to secure complete combustion before the gases impinge on the heating surface. The kind of furnace, usually used for burning bagasse, is the usual Dutch oven, which is an extension of the ordinary furnace. The Dutch oven is very spacious, and is provided with step grates. The bagasse falls through the hopper on the step grates, through which air is supplied to the furnace. The Dutch oven provides a voluminous combustion chamber, and secures better combustion. The distance between the furnace and the boiler, is sufficient to keep the hot gases in contact for sufficient time to cause complete combustion, before they impinge on the cooler heating surface of the boiler. Babcock and Wilcox boilers are provided with a slightly different furnace. In this, in addition to the step grates and a long extended combustion chamber, a reversed check wall is provided, which causes complete combustion of the gases, before the latter impinge on the heating surface. In Java, the step grate furnace is provided with a supplementary furnace, in front of the step grate near the hopper. In this, wood is burnt, the hot gases from which partially dry the bagasse before it falls on the step grates.

Cane trash and wood can be burnt in this furnace. In Java, cane trash is cut into small pieces by means of cutters, and is then carried near the furnace by means of a blower. In Hawaii, molasses is burnt in the same furnace. For this purpose, molasses is thoroughly mixed with bagasse, as it comes out of the last-mill before the mixture is fed to the furnace. When molasses has to be burnt alone, a different type of furnace is necessary. In Hawaii, some factories have installed separate boilers and furnaces for burning molasses only, because not only it secures greater efficiency, but it makes it possible to operate the boiler when

the mill is not running. I saw two systems in use for burning molasses. In one system, molasses is burnt in an ordinary bagasse furnace modified to suit molasses burning. In the other, molasses is atomized and then burnt along with steam in a way similar to fuel oil. Further details are given in chapter on the disposal of by-products.

*Burning oil.*—When fuel oil is to be used, a different kind of furnace is necessary. It is not a good practice to burn oil and bagasse together in the same furnace, as it considerably affects the efficiency. In Louisiana, where fuel oil is used to supplement the bagasse as fuel, it is found that, when oil and bagasse is burnt together, the efficiency is about 45-50 per cent., while bagasse alone gives 60-65 per cent., and fuel oil alone 70-75 per cent. In the case of oil, no Dutch oven is required, but fuel oil is burnt in the furnace very close to the boiler. In order, that oil should burn properly, it has to be atomised, for which special burners are used. The points in using fuel oil are :—

(1) *Pre-heating the oil.*—The oil is heated by steam jacket to 160°-180° F; depending upon the density of the oil, before it is charged to the burner.

(2) *Atomizing the oil.*—Atomizing is secured by using live steam along with the oil, which is fed under pressure to the furnace. This is done in special burners. About 14 lbs. of steam is required for every lb. of oil. Care should be taken to prevent over-heating of the oil, otherwise it will form gas in the burner, leaving unvaporised portion, which clogs the burner.

(3) *Distance between the burner and the heating surface.*—The burner is situated on the grate surface of the furnace below the boiler. It should not be kept too close, otherwise the smoky flame of the oil would directly hit the heating surface, which gets scaled, considerably affecting the efficiency. The distance between the burner and the heating surface, should never be less than 36" and should preferably be 48-60". This gives the best efficiency.

(4) *Control of air.*—This is quite necessary. In Louisiana, trouble is traced mostly to excess air. The best draft is considered to be 0.09". It should not exceed 0.12".

The present practice is either to have separate boilers for burning oil or to provide a supplementary furnace right under the heating surface of the boiler for burning oil. The bagasse is burnt in the Dutch oven, while oil is burnt in the supplementary furnace. The former practice is common in Louisiana probably on account of the fact, that considerable oil has to be used due to low fibre content. The latter practice is followed in many factories in the tropics, where oil has to be used occasionally, whenever there is a shortage of fuel due to lack of cane or other causes. The latter system is less expensive, and is suitable, where fuel oil has to be used occasionally.

*Grates.*—In the bagasse furnaces, step grates are commonly used. Bagasse automatically moves over the grates on account of the steps, while ash falls through the grates. In Louisiana, I noticed, flat shaking grates being used by a few factories. Shaking grates have one advantage over all others, and that is, they can be cleaned without opening the furnace doors, preventing the rush of cold air during cleaning which cools the furnace.

*Air supply.*—In almost all the factories I visited, a system of natural draft is in use, air supply being controlled by the dampers. This system is working very well, and does not cause any difficulty. When artificial draft is used, air is supplied either under induced or forced draft. In the former, the furnace pressure is below the atmospheric pressure, as a result, air is sucked through the grates in the furnace, which gives a better furnace efficiency. In the latter the furnace pressure is always higher than the atmospheric pressure due to forced air, and care has to be taken to prevent the leaking of hot gases through the doors. For this reason, an induced draft is preferred. In both the cases, a fan driven either by an electric motor or steam turbine or steam engine is necessary to create the draft. For this reason, this system is expensive, and unless some advantages are obtained to balance the extra expense, the installation of an artificial draft will be uneconomic. There seem to be two conditions, under which an artificial draft will be advantageous. Firstly, when boilers are required to be overworked in order to generate more steam, larger amount of fuel has necessarily to be used, which cannot be done efficiently, unless ample air is provided. This is possible only, when forced draft is used. Secondly, when it is desired to use the heat of the waste

gases, either for heating the boiler feed water by means of economizers, which, however, is not so necessary in cane sugar factories, as ample hot water from evaporators and pans is available, or for generating superheated steam, or for drying bagasse, a forced draft will be economic. In my opinion, it will not be economic to use a forced draft, so long the heat of the waste gases is not used for the purposes mentioned above, to increase the furnace efficiency. With smaller plants, forced draft will be expensive.

*Feeding of the bagasse.*—The bagasse, as it comes out of the last mill, is carried by means of carriers near the furnace, and is then delivered through chute to a hopper from which, it is fed to the furnace. In the hopper, is placed a rotating wheel, which feeds the bagasse, and prevents the inrush of cold air by keeping the mouth open and closed alternately. In the Hawaiian islands, a mechanism whereby, the mouth of the hopper opens at particular times only, so that inrush of air is prevented, is working very efficiently. In bagasse furnaces this is an important point, as the inrush of cold air cools the furnace and reduces its efficiency.

*Feed water.*—In cane sugar factories, plenty of hot condensed water is available. The condensed water, from the first body of the evaporator, and from the pans supplies usually enough water for the boilers. When this is not enough, condensed water from the 2nd body of the evaporator is used as a supplement. Water from other cells of the evaporators is not used, as it is likely to contain some sugar carried through entrainment, which causes foaming and priming in the boilers. The water obtained through these sources is very hot, the temperature being 160°-180° F., which is pre-heated to about 212° F by means of exhaust steam, before it is fed to the boilers. Pre-heating of feed water secures greater efficiency.

Water is fed to the boilers by means of pumps. The usual type is the Duplex piston pump. In electrified mills, special centrifugal pumps for boiler feed water are used. It is necessary to have extra feed pumps.

*Boiler and furnace efficiency.*—Very few factories have been equipped to test the efficiency of the boilers from time to time. In order to test the efficiency, it is necessary to know the amount of steam generated by the boilers, and the amount of fuel burnt. The amount of steam generated,

is known from the amount of feed water delivered to the boiler or by means of steam flow meters, which are getting common in modern installations. Besides, automatic records for registering boiler feed water, steam, temperature, and pressure of steam, &c., are used in modern factories. In many old centrals, the work of the boilers is judged solely by the stack temperature, and the testing of CO<sub>2</sub> content of the flue gases occasionally. This is not enough for, though it gives an indication as to the draft, it does not give any idea as to the efficiency. What is really required, is the amount of CO and oxygen. The presence of CO indicates the supply of insufficient air, while that of oxygen indicates excess air. Hence an indication of CO<sub>2</sub> content alone is not sufficient to indicate the proper combustion of the bagasse.

In one central, I had an occasion to test the boiler efficiency. In the beginning of the campaign, a surplus bagasse was left, but, as the season advanced, not only all the surplus bagasse was used, but some fuel oil had to be used, and this happened, even though cane showed a higher fibre content. On a rough test being made, the efficiency was found to be 35 per cent., which was decidedly low. The efficiency of bagasse furnace under good working conditions is about 60 per cent. It is desirable to test the boiler efficiency from time to time.

### **XVIII. Steam consumption in cane sugar factories.**

The importance of steam consumption in cane sugar factories is obvious when one takes into consideration the question of fuel. So long cheaper sources of fuel were available, and the competition amongst the sugar manufacturers not so keen, this point did not receive any attention. Besides so far no economical method of the disposal of the excess bagasse is found out, which would have encouraged the sugar manufacturers to go in for an economical use of steam to save bagasse, thus adding to the profit. With scarcity and rise in prices of fuel, and also keen competition amongst the sugar manufacturers, the question of saving of fuel expense has come into prominence. How is this to be done, unless the steam consumption at different stations in the sugar house is known? So far regarding white sugar factories, I have come across actual tests taken by Prof. Kerr of Louisiana State University in Adeleine Sugar Factory. The tests show the actual steam consumption at different stations in

the house. Prof. Kerr's results show, that, of the total steam used in that factory, about 45 per cent. was used for evaporation and sugar boiling, about 20 per cent. for juice heating, only 3 per cent. for mechanical work (*i.e.*, for mill engines), about 3 per cent. for cane handling machinery, and about 20 per cent. for radiation and unaccounted for. In this factory, a great part of juice heating and sugar boiling was done by live steam. It will be seen, that the greatest chance for saving steam will be in heating, evaporation, and sugar boiling, which consumed about 65 per cent. of the total steam. The loss, through radiation and unaccounted for, is unavoidable, still it can be reduced. The working of steam balance in a sugar house, therefore; may show the direction, in which economy in steam consumption can be effected.

In actual practice, very few factories are running on bagasse alone. Only in St. Kitts, Antigua and Java, a great majority of the factories are operated on bagasse alone. This is mostly due to the high fibre content of the cane. In St. Kitts and Antigua it is 15 per cent., while, in Java it is 13 per cent. In Java, sometimes a shortage of fuel is felt, which is then supplemented with dried leaves. In Hawaii, bagasse is supplemented with final molasses. In Cuba, Porto Rico and the West Indies, factories have to use extra fuel, either wood or fuel oil. There is, however, no justification for these factories to use any extra fuel, when it is taken into consideration, that, the fibre content is 11.5-13 per cent., that the maceration practised is not so heavy, as is the case in the Hawaiian islands, and that only raw sugar is made. In Java, I saw one factory making white sugar by the acid thin juice process, operated on bagasse alone. The fibre content of the cane was only 11.5 per cent., and the maceration was about 17 per cent. This was made possible by using economical engines for driving mills—valve engines which are high speed engines (120 R. P. M. as against 55 R. P. M. with other engines), by using superheated steam for driving the engines and using a quintuple. In order, that all the heating, evaporation and boiling be done on exhaust steam alone, exhaust steam of a higher pressure of  $1\frac{1}{2}$  atmospheres was produced. The 2nd body of the evaporator was robbed of a part of its steam to do the juice heating. All the accessories except the vacuum pump were electrified. With this system a part of the bagasse was saved. This is the only instance amongst white sugar factories, that I came across, which was operating the factory on bagasse alone,

even when cane contained 11·5 per cent. fibre. In Cuba and Porto Rico, attention is being directed in recent years to the economic utilization of steam. The following are some of the devices, that are being adopted to economize steam;—

(1) The substitution of more efficient engines for driving mills and other machines. The American manufacturers use Corliss valve engines instead of slide valve engines, which consume much less steam.

(2) The substitution of collective drive for mills instead of the individual drive. In the old system, every mill was driven by a separate engine. Consequently steam consumption was high and the exhaust steam was far in excess of the requirements of the factory.

(3) The installation of quadruples or quintuples with pre-evaporators. With the improvements referred to in nos. 1 and 2, the exhaust steam available is not enough to do all the heating and evaporation, so a pre-evaporator is necessary to generate sufficient low pressure steam to do all the heating; evaporation and boiling. The changing of triple into quadruple or quintuple saves a great deal of steam.

(4) The use of calandria type vacuum pans. This makes it possible to use a low pressure steam which was not economically possible with coil pans.

It may be observed, that all the above improvements save steam required to do the heating, evaporation and boiling. In the Bombay Deccan, cane contains a low amount of fibre from 10·5-11 per cent., and factories have to make white sugar, which demands more steam. With the usual equipment, it will not be possible to operate the factory on bagasse alone and dried leaves will have to be used as a supplementary fuel. The following calculation of steam consumption in white sugar factories for the prevailing conditions in the Deccan will show the necessity of economizing steam. The calculations are made according to Prof. Kerr's method used in his bulletin, and his data is taken wherever necessary:—

*Data:* grinding capacity 1,000 tons of cane a day.  
 Product: plantation white and final molasses;  
 saturation on cane 15 per cent; fibre in cane  
 10·5 per cent.; composition of bagasse; moisture  
 49 per cent.; fibre 46 per cent.; Brix of normal  
 juice 18·0.



*Calculation :*

There will be 105 tons of fibre from 1,000 tons of cane.

Bagasse will be  $\frac{105 \times 100}{46} = \frac{10500}{46} = 228$  tons per day. Therefore, juice will be  $(1,000 + 150) - 228 = 922$  tons.

- (1) Raw juice heaters: temp. of raw juice  $82^{\circ}\text{F}$ ;  
temp. of heated juice  $220^{\circ}\text{F}$ . Brix of N. J. =  $18^{\circ}$ ;  
Brix of D. J. =  $15.6$ ; amount of juice 922 tons.

$$\begin{aligned} \text{Heat added} &= (220 - 82) \times 0.9 \times 922 \times 2,000 = 229,024,800 \\ &\text{B. T. U.} \\ &\text{per day.} \\ &= 9,542,700 \\ &\text{per hour.} \end{aligned}$$

(0.9 is assumed to be the specific heat of the juice);  
equivalent water lbs. F and A  $212^{\circ}\text{F} = \frac{9,542,700}{970.4} = 9,834$ .

Thermal efficiency according to Prof. Kerr, is 98%.  
Steam F and A  $212^{\circ}\text{F}$  actual =  $\frac{9,834}{98} = 10,352$  lbs.

Steam F and A  $212^{\circ}$  actual % cane =  $\frac{10,352 \times 100}{41.7 \times 2,000} = 12.4$ ;

equivalent steam at boiler pressure of 100 lbs., feed  
water temperature  $200^{\circ}\text{F}$  and quality of steam  
 $96\% = \frac{1,188.5 - (200 - 82)}{970.4} = \frac{1,020.5}{970.4} = 1.05$ , which is the  
factor of evaporation.

Therefore, equivalent steam at boiler conditions%  
cane is  $\frac{12.4}{1.05} = 11.8$ .

- (2) *Thin juice heaters.*—This is done after bag filtering.  
Brix of D. J. is  $15.6$ ; Brix of thin juice is  $16.6$ .

Mud removed is 22 lbs. per ton of cane (Prof.  
Kerr's figure).

Total mud removed per day = 22,000 lbs. or 11 tons.

Mixed juice less mud =  $922 - 11 = 911$  tons.

Water lost % mixed juice (without mud) =  
 $\frac{16.6 - 15.6}{16.6} \times 100 = \frac{100}{16.6} = 6.0\%$ .

Water lost tons =  $911 \times 6\% = 54.66$ .

Thin juice per day =  $911 - 54.7 = 856.3$  tons.

Thin juice % cane =  $\frac{856.3 \times 100}{1,000} = 85.63$ .

Specific heat of thin juice =  $0.9$ .

Temp. of thin juice before,  $180^{\circ}\text{F}$ , and after,  $205^{\circ}\text{F}$ .

Heat added per 24 hours =  $(205-180) \times 9 \times 856.3 \times 2,000$   
 $= 38,533,500$  B.T.U. per day  
 $= 1,605,562$  „ per hour.

Equivalent steam F and A  $212^\circ$  F =  $\frac{1,605,562}{970.4} = 1,655$   
 lbs. per hour.

Efficiency of thin juice heaters = 95.

Therefore, steam F and A actual =  $\frac{1,655}{0.95} = 1,742$  lbs.  
 per hour.

Equivalent steam F and A actually required %  
 cane =  $\frac{1,742}{834} = 2.09$ .

Equivalent steam boiler conditions % cane =  $\frac{2.09}{1.05} = 2.00$ .

(3) Heating mud; Prof. Kerr gives the figure to be  
 about 0.67% steam on cane.

(4) Quadruple effect: amount of thin juice = 856.3  
 tons per day.

Brix of thin juice = 16.6; Brix of sirup = 54.0; pres-  
 sure of exhaust steam = 4 lbs.

Water lost % mixed juice =  $\frac{54.0 - 16.6}{54.0} = 69.3$ .

Water lost tons =  $856.3 \times 69.3\% = 593.4$ .

Water evaporated per lb. of steam in the quadru-  
 ple = 3.5 lbs. (according to Prof. Kerr's figures).

Steam per day lbs. =  $\frac{593.4 \times 2,000}{8.5} = 339,086$ .

Steam per day in tons =  $\frac{339,086}{2,000} = 169.5$ .

Steam % cane =  $\frac{69.5}{1.0} = 16.95$ .

Steam F and A  $212^\circ$  F % cane =  $\frac{16.95 \times 962}{970.4} = 16.78$ .

Equivalent steam boiler conditions =  $\frac{16.78}{1.05} = 16.00$ .

(5) Sirup blow ups and molasses: according to Prof.  
 Kerr's figures this comes to 1.08 % cane.

(6) Vacuum pans: Brix of sirup = 54.0.

(a) Sirup—

% decrease in water content =  $\frac{54.0 - 15.6}{54.0} = 71.1$ .

„ „ „ „ =  $922.0 \times .711 =$   
 $655.5$  tons.

Sirup tons per day = 266.5.

„ % cane =  $\frac{266.5 \times 100}{1,000} = 26.65$ .

## (b) Molasses—

$$\text{From 1st massecuite} = \frac{94 \times 128 \times 36.6 \times 100}{100 \times 100 \times 80} = 54.9 \text{ tons.}$$

$$\text{From 2nd massecuite} = \frac{94 \times 58 \times 58 \times 100}{100 \times 100 \times 80} = 39.5 \text{ tons.}$$

Wash at 0.1 per ton of cane (according to Prof. Kerr's figures) =  $0.1 \times 1,000 = 10$  tons.

Brix of massecuite 94.0, Brix of sirup 54.0,  
Brix of molasses 80.

According to previous calculations,

1st massecuite per day tons 128

2nd " " " 58

3rd " " " 48

Total " " " 234

$$\text{" " \% cane} = \frac{234 \times 100}{1,000} = 23.4.$$

Total sirup, molasses, and wash per day tons  
 $266.5 + 94.4 + 10 = 370.9$ .

Tons of water evaporated =  $370.9 - 234.0 = 136.9$ .

Pan efficiency (according to Prof. Kerr) = 0.85.

Steam per day tons  $\frac{136.9}{.85} = 161.1$ .

Steam % cane =  $\frac{161.1 \times 100}{1,000} = 16.11$ .

Equivalent steam F and A 212° F, of 30 lbs.  
pressure =  $\frac{16.11 \times 927}{970.4} = 15.4$ .

Equivalent steam boiler conditions =  $\frac{15.4}{1.05} = 14.5$

- |   |   |
|---|---|
| (7) granulators : steam %<br>cane = 0.48.                     | } according to Prof.<br>Kerr's figures. |
| (8) feed water heater :<br>steam % cane = 2.58                |   |
| (9) cane handling machinery :<br>steam % cane = 2.16.         | "                                       |
| (10) mechanical work : steam %<br>cane = 2.02.                | "                                       |
| (11) radiation and unaccounted<br>for : steam % cane = 13.67. | "                                       |

## Summary:—

	Steam % cane.	Steam % total.
(1) raw juice heaters ...	11·80	17·70
(2) thin juice heaters ...	2·0	3·0
(3) quadruple effect ...	16·00	24·00
(4) vacuum pans ...	14·50	21·75
(5) syrup blow ups, mud } defecators, molasses } melters.	1·75	2·62
(6) granulators ...	0·48	0·72
(7) cane handling machinery.	2·16	3·24
(8) feed water heaters ...	2·58	3·87
(9) mechanical work ...	2·02	3·03
(10) radiation and unaccounted for.	13·67	20·07
	66·96	100·00

$$\text{B. H. P. per ton of cane} = \frac{66.96 \times 1.05 \times 2,000}{24 \times 34.5} = 1.70.$$

*Amount of exhaust steam available in cane sugar factories:*—According to Prof. Kerr, the total indicated horse power for steam engines and pumps required for 1,383 tons of cane was 907·26. According to Koppeschaar the amount of steam per B. H. P. is 44 lbs. The amount of steam for 1,383 tons of cane will be  $907.26 \times 44 = 39,919.44$  lbs. The loss by condensation and radiation is about 10%. The exhaust steam available will, therefore, be  $39,919.44 - 3,991.944 = 35,927.496$  lbs. per hour. Cane ground per hour is  $\frac{1,383}{24} = 57.62$  tons.

$$\% \text{ exhaust steam on cane} = \frac{35,927.496 \times 100}{57.62 \times 2,000} = 31.2.$$

In factories using Corliss engines, the steam consumption per B. H. P. is 35 lbs. The steam consumption per hour will, therefore, be  $907.26 \times 35 = 31,754.1$  lbs. With 10% loss by condensation and radiation, the amount of exhaust steam available per hour comes to  $31,754.1 - 3,175.41 = 28,578.69$  lbs. Therefore, exhaust steam per cent. =  $\frac{28,578.69 \times 100}{57.62 \times 2,000} = 24.80$ .

*Amount of live steam obtainable from bagasse alone.*—According to previous calculation, the amount of bagasse per 1,000 ton of cane is  $\frac{105 \times 100}{46} = 228$  tons per day (bagasse contains

46 per cent. fibre and 49 per cent moisture). 1 lb. of bagasse gives an equivalent steam F and A  $212^{\circ}$  F of 2.5 lbs. Therefore, 228 tons of bagasse will give steam as below:  $228 \times 2,000 \times 2.5 = 1,140,000$  lbs. For 1,000 tons of cane, amount of steam required is  $1,000 \times 1.70 \times 34.5 \times 24 = 1,407,600$ . Deficit comes to about 267,600 lbs. per 1,000 tons of cane or 13.5 per cent. cane.

The steam, required for heating, evaporation and boiling, is about 45 per cent. on cane. In this case, live steam is used for juice heating and boiling. If this can be done by exhaust steam, supplemented by pre-evaporators, in which case, steam can be used multifold times by directing the vapours from the evaporators for juice heating and boiling, a considerable saving in steam can be effected.

It is thus evident, how essential it is to have pre-evaporators in addition to quadruples so as to generate sufficient low pressure steam to do all the heating, evaporation and boiling. There is no justification for using extra fuel in modern factories. It seems that cane sugar factories, on account of the scarcity of fuel and the keen competition in the sugar world, will in future look more to economic utilization of steam.

### XIX. Chemical Control.

Under this is included the account of sucrose, from the time it enters the factory in the form of cane, till it leaves the factory in the form of sugar and other by-products. For this purpose, a system involving the weights and routine analysis of the material at various stages in process of manufacture is followed. The practical benefit, to be derived from a chemical control, is the production of a standard product together with minimum losses in the process. Without a chemical control, it is impossible to detect the various losses, that occur in milling, filter press, inversion, entrainment, molasses, &c., and to judge their extent. From this point of view, chemical control is a necessary requisite in a modern sugar factory.

All factories, whether old or modern, and whether making raw or white sugar, maintain at present a chemical control. However, very few of them have as yet realized the importance of accuracy with regard to weights and analysis of the material in process. If chemical control is to serve any useful purpose, it is quite essential to have correct

weights, correct samples and correct analysis of the material in process at various stages. Many factories maintain a laboratory, a chemist and a so-called chemical control, because it is considered to be a modern requirement. Very little use is made of the facts shown by the chemical report. Only a few factories seem to have understood the importance of a chemical control, and it is such factories, which are working most efficiently.

The importance of a chemical control cannot be emphasized. Specially it is of great consequence in white sugar factories, because the product, to be turned out, must be of a standard quality, the juices and sirup are necessarily kept acid, which causes some inversion, and the massecuite, run off, and wash have to be classified on account of the varying purities. From the point of a maximum production of a product of a standard quality a minimum acidity has to be maintained. Secondly, run off and wash of different purities have to be separated in order to boil massecuites of certain purities. All this cannot be done, unless the acidity and purity of the material are determined from time to time. An account of sucrose and glucose, that enter the house in the form of juice, has to be maintained to find out the losses in inversion and destruction of glucose, which usually come under the item 'undetermined or unaccounted for.' The boiling efficiency of the house can be judged from the undetermined. For making white sugar a strict chemical control is, therefore, absolutely essential.

The best chemical control from the point of correct weights, correct sampling and correct analysis, that I noticed during my visit to various factories, was maintained by the factories of the Cuban American in Cuba and by a number of factories in Java. These seem to me to be the only factories, in which great care is exercised in obtaining correct weights of cane, maceration water, juice, sugar, molasses, &c. A great majority of the factories do not weigh maceration water, few of them care to weigh molasses, some measure juice, which involves a number of corrections. The result is a calculation of figures, which are more approximate than real. The various stages, at which a chemical control in a modern white sugar factory is required, are:—

(1) *Milling*.— At this stage it is necessary to know, whether a satisfactory extraction of sucrose is obtained,

and whether the moisture and sucrose contents of the bagasse are within the required limits. For this purpose, in addition to analysis of bagasse and juice, it is necessary to know the weight of cane, juice and maceration water.

(2) *Clarification*.—During this stage, juice has to be maintained at a certain acidity. The correct amounts of lime and sulphur are judged by the acidity, which is determined by means of a titration with standard alkali or soda solutions, and a suitable indicator. The determination of purity and glucose ratio gives an indication of the elimination non-sugars and inversion.

Control of the filter press work in order to reduce the loss of sugar to a minimum is secured by determining the sucrose in the cake.

(3) *Evaporation*.—The analysis of sirup gives an indication as to inversion and destruction of glucose. The latter is responsible for darkening of the sirup.

(4) *Sugar boiling*.—The determination of purity of run offs and wash in order to make it possible to boil a massecuite of desired purity, the polarization of the sugar, and the analysis of final molasses are required.

As said previously, the three necessary requisites, of a reliable chemical control, are correct weights, correct samples, and correct analysis.

*Correct weights*.—In a sugar house, the material that must be weighed, if reliability is to be secured, is cane, maceration water, dilute juice, sugar and the molasses. To this list, may be added the filter press cake, though in actual practice, it is not weighed on account of the nature of the material. The usual practice is to weigh the cake from a few plates, from which weight is calculated for the whole press. This gives only an approximate figure, but it does not vitiate the chemical control. Cane is usually weighed on the platform balance, before it is used for milling, the maceration water and the juice are weighed either by Richardson automatic scales or the Howe scales. The former automatically dump, as soon as the necessary weight of juice or water is reached. They work alright, so long they are kept clean, and for this reason are not preferred. The Howe are beam scales, and are very reliable. Molasses is weighed on a similar scale or on a platform balance in tank cars in factories, when molasses is

shipped. It is a usual practice to have the balances checked by the chemist and the superintendent of fabrication every 3 or 6 hours. This is the most essential thing to maintain accuracy, without which the results will not be reliable.

*Correct sampling.*—The system of sampling should be made as representative as possible. Factories, which do not weigh cane, calculate its weight from the direct determination of fibre in cane and bagasse. This method has one defect, and that is the impossibility of obtaining a representative sample of cane. The samples, that are required to be taken are: bagasse, crusher juice, residual juice, mixed juice, clarified juice, press juice, press cake, sirup, massecuites, run offs, wash, sugar, final molasses, condensation water, boiler feed water, &c. :—

(1) *Crusher juice.*—For this purpose a system of continuous sampling is followed. A pump is inserted to the chute, over which the crusher juice flows. The pump is driven by the crusher roller. The sample is collected in a receiver.

(2) *Residual juice.*—An intermittent sample every half an hour from the last roller, is taken.

(3) *Mixed juice.*—Sample is drawn from each weighing tank, and is collected in a sample container. This is an intermittent sample, though for practical purposes, it may be considered as continuous.

(4) *Clarified juice.*—Intermittent sample every half an hour. A continuous sample is desirable.

(5) *Press cake.*—A composite sample from every press every 6 hours.

(6) *Syrup.*—Continuous sample from the evaporator or sample from each tank.

(7) *Bagasse.*—Sample every half an hour, and preserved with Ammonia and chloroform to be analysed every 6 hours. If this is not possible, a sample at least every three hours should be taken and analysed. It is better to take as many samples as possible so as to have a representative analysis.

(8) *Massecuites.*—A sample from each strike.

(9) Run off from each strike.

(10) Wash from each strike.



(11) *Final molasses*.—A sample from each crystallizer massecuite.

(12) *Sugar*.—A composite sample from each bag of sugar every 12 hours.

(13) *Condensation and boiler feed water*.—Intermittent samples as often as necessary.

From the above samples are prepared composite samples to be analysed as stated later on. One important thing about sampling is the steaming of sample cans, after each sample is brought to the laboratory.

*Correct analysis*.—As soon as samples are obtained, they should be analysed immediately, so that the results can be used in rectifying any error in process. It is no use analysing a product, if its analysis cannot be used in rectifying the errors in the process. On this account rapid methods in control work are necessary. Dr. Spencer, the technical and chemical expert of the Cuban American Co., has standardized methods of sugar analysis both from the point of rapidity and accuracy. The methods are so rapid that any error in process found on the basis of analysis can be rectified.

*Number of analysis*.—The day is divided into 4 watches of 6 hours each, during which composite samples are analysed as below:—

Every 3 hours: bagasse from each tandem for moisture and sucrose.

Every 6 hours: bagasse for moisture and sucrose if a composite sample is obtained. Otherwise every 3 hours as said above.

Crusher juice for Brix, polarization and purity.

Residual	„	„	„	„	„
Mixed	„	„	„	„	acidity.
Clarified	„	„	„	„	„
Press	„	„	„	„	„
„ cake			„		
Sirap	„	„	„	„	„
Raw sugar			„		

Every 12 hours: composite sample of mixed juice for glucose and ash.

Every 12 hours : composite sample of clarified juice for glucose.  
 " " sirup for glucose.  
 " " sugar " " ash and  
 moisture.

Every 24 hours : Molasses (final) for sucrose, glucose and ash.

Besides every massecuite for Brix, polarization and purity.

" run off " " " " "  
 " wash " " " " "  
 " final molasses " " " " " from every  
 crystallizer massecuite.

Condensation water from evaporators and pans, and boiler feed water for alfa-naphthol test, as often as necessary.

All figures of analysis are maintained in a laboratory book. The records maintained by the chemist are as below:—

(1) Record of daily analysis of all sugar house products.

(2) Control record containing weight of cane, maceration water, juice, sugar, molasses, &c., their analysis and the sucrose account. The figures are filled in daily and averages made at the end of each run.

(3) Record containing the daily and run reports of the factory.

(4) Record containing tank capacities.

A daily report is made by the chief chemist, in which all the manufacturing data, as regards cane ground, sugar made and in process, molasses made and in process, &c., together with the analytical data, is given. A form is appended herewith (*see page 222*).

Every week or every fortnight, when the factory is stopped for general cleaning, a run report is made. It is quite essential to have at least a fortnightly run report, so as to give an idea as to the efficiency of the factory. For this purpose, stock is taken by the chief chemist. The run report furnishes full data, from which the efficiency of the factory may be judged. A copy of this report is supplied to the superintendent of fabrication, engineer and the manager. A form of a run report, which seems to me to be the most suitable, is appended herewith (*see page 223*).

The best system of administration from the point of efficiency of the factory, was seen by me in the Cuban American factories in Cuba and a short description will be of use.

The estate is divided into two departments, the plantation and the mill. The administrator or the manager looks to the plantation and office management. He arranges for the cane supply as well as the marketing of sugar and molasses. The administration of the mill consists of

(1) Supervising chemist and technologist. He looks to all the factories of the Cuban American Co. in Cuba. He lays down definite instructions as regards the daily routine work in the laboratory, standard methods of analysis, and the process of manufacture to be followed in the house.

(2) Superintendent of fabrication, aided by assistant superintendents who work alternately in each shift. He is responsible for the manufacture of sugar from crushing of cane to bagging of sugar.

(3) Chief chemist, aided by 2 or 4 assistant chemists, depending upon the size of the factory. They work alternately in each shift of 12 hours. The chief chemist prepares the daily reports, fills all the laboratory and control records, and prepares the run report. He may be taken as the chief accountant of every lb. of sucrose, that enters the house.

(4) Chief engineer assisted by 2 assistant engineers. He is responsible for the proper working of the machinery only. He has nothing to do with fabrication.

(5) Electrician: He looks to all the electric machinery.

It is evident from above, that the factory is divided into fabrication and engineering departments. The fabrication department is managed by chemists, who are better qualified on account of the chemical and technical knowledge they possess. After all, the manufacture of sugar is a chemical process, involving a number of chemical reactions, which necessarily demands a sound knowledge of chemistry. The superintendents and assistant superintendents are recruited from the chemistry department of the factory. In order to secure an efficient working of the factory, it is quite essential

to have a close co operation between the superintendent, the chief chemist and the engineer, which is not difficult of accomplishment, if the function of each department is clearly indicated.

In order to obtain some idea as to the working of modern factories, I give below control figures of some factories in Louisiana, Cuba, Hawaii and Java:—

	Raw sugar factories.					White sugar factories.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Polarization of cane ...	10.62	13.51	14.08	13.74	13.05	9.72	12.26	13.50
Fibre in cane ...	9.10	10.60	10.37	11.67	12.51	9.75	11.74	11.38
Sucrose extraction ...	90.80	94.99	94.02	97.89	97.55	90.07	92.40	92.30
Saturation per cent. cane ...	15.20	17.42	4.81	24.67	35.00	13.90	...	16.50
S lost per cent. fibre in bagasse.	...	6.37	8.27	...	...	9.93	8.3	...
Tons of cane to a ton of sugar.	11.1	8.03	7.78	7.82	8.26	14.3	10.2	8.9
Sugar 100 pol. per cent. cane...	...	...	...	...	...	6.70	9.80	11.2
Molasses per cent. cane ...	3.0	2.43	2.61	2.82	2.91	5.06	3.2	...
P of final molasses ...	27.3	33.42	32.79	31.97	32.0	34.43	33.0	36.7
Fuel oil gals per ton of cane...	6.0	0.80	1.92	none	...	7.73	none	none
S per cent. in press cake	4.56	5.13	6.79	1.33	1.00	6.06	6.8	5.6

N.B.—S = sucrose ; P = purity.

Factory I has a crusher and 3 mills.

„ II „ a double crusher and 6 mills.

„ III „ „ „ „ 5 „

„ IV „ a single „ „ 4 „ and a 'Searby shredder'.

„ V „ „ „ „ 4 „

„ VI „ „ „ „ 3 „

„ VII „ „ „ „ 4 „

„ VIII „ „ „ „ 4 „

*Sucrose balance.*—(a) Raw sugar factories:—

	I.		II.		III.		IV.		V.	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Sucrose in cane per cent.	100	...	100	...	100	...	100	...	100	...
S in juice per cent. ...	80.8	100	84.99	100	84.68	100	87.89	100	97.55	100
S in sugar .. ...	81.2	89.43	88.48	98.14	87.6	93.11	91.68	98.69	98.99	92.03
S in molasses per cent.	5.66	6.24	5.82	5.61	5.76	0.12	5.89	5.51	7.29	7.49
S in press cake ..	1.51	1.67	0.74	0.73	0.58	0.62	0.81	0.81	0.19	0.20
S in unknown ..	2.43	2.67	0.45	0.47	0.14	0.15	0.51	0.50	0.06	0.28

*N.B.*—S=sucrose; A=sucrose in cane; B=sucrose in juice.

Roman figures refer to factory numbers as detailed on the last page.

(b) White sugar factories:—

	VI.		VII.		VIII.		
	A.	B.	A.	B.	A.	B.	
Sucrose in cane per cent.	...	100.0	...	100.0	...	100.0	...
.. in juice ..	...	80.07	100.0	92.40	100.0	92.8	100.0
.. in sugar ..	...	69.90	77.69	79.80	86.80	88.40	90.80
.. in molasses per cent.	...	16.09	17.83	9.05	9.90	6.0	6.5
.. in unknown ..	...	3.35	3.72	1.80	2.0	0.07	0.2
.. in press cake ..	...	0.68	0.76	1.75	1.9	2.13	2.8

Roman figures refer to factory numbers as detailed on the last page.

Capital letters A and B refer to sucrose in cane and sucrose in juice respectively.

**XX. Disposal of the by-products.**

(1) *Final molasses.*—Final molasses is a by-product in the sugar industry, the composition of which serves as an indication of the efficiency of the manufacturing process. It contains, in addition to non-sugars, sucrose, which cannot be economically separated. The amount of sucrose lost in molasses varies a good deal, depending on the quality of juice and the efficiency of the mills. In Louisiana, where the juices are of low purity and contain a high amount of reducing sugars as much as 2 per cent and over, the final molasses purity can be brought down to as low as 25, but in the tropics, where juices are usually of high purity containing a low amount of reducing sugars, the final molasses

rarely runs under 30. In the Hawaiian islands, where the juices are of high purity containing a very low amount of reducing sugars (0.5 per cent. or under), and a great amount of ash, it has been found difficult to reduce the purity of final molasses below 35, though the efficiency of the factories in the Hawaiian islands is usually high. There is one more factor, which affects the purity of the final molasses, and that is the sucrose extraction. The very high extractions, usually obtained in the Hawaiian islands, are attended with more impurities in the juice, which ultimately hold more sucrose in solution, causing a high purity of final molasses. The following represents analysis of some typical samples of molasses:—

	Louisiana.	Hawaii.	Cuba.	Java.
Brix	81.80	89.03	90.67	92.33
Polarization	19.80	28.46	29.25	29.50
Sucrose	27.99	32.09	36.56	32.94
Invert sugar	27.25	13.73	20.33	27.40
Apparent purity	24.20	31.97	35.03	32.00
Gravity purity	34.22	36.04	44.16	35.70
Ash	7.71	15.19	12.40	9.68
Purity of juice	75.80	84.85	84	84

Figures, showing the composition of final molasses in India, are not available, but there is no doubt, that the exhaustion of molasses in India is not carried to the same extent, as is carried in other countries. According to the report of the Indian Sugar Committee, the Indian factories recover on an average of 6.85 per cent. sugar on cane against an average of 9.75 per cent. sugar in Java from cane of practically the same sucrose content.

The average amount of molasses obtained in the various countries is about 3 per cent. on cane. It is a little over 3 per cent. in Hawaii, about 3 per cent. in Porto Rico, and about 5 per cent. in Louisiana. Factories in India turn out a much higher proportion of molasses, varying from 4.5 per cent. or even more on cane. It shows the poor boiling house work of the factories in India.

The average amount of molasses obtained per ton of cane ground is about 5 gallons. This comes to about 40 gallons of molasses per ton of sugar. The profitable disposal of the molasses in the sugar industry is quite a problem at the present time. There is no market for all the molasses turned out by the factories. In Louisiana, it is used for stock feeding, and for the manufacture of industrial alcohol. In Cuba, most of it is run to waste. In the British West Indies, a great part was utilized for the manufacture of rum, but this has now stopped on account of the lack of market for it. A small part is used for making molascuit. In all those countries, however, the factories mainly depend for their profits on the sugar. Consequently, every attempt is made to exhaust the molasses to the lowest purity. Only in Jamaica, I noticed, the factories mostly depended for their profits on the rum market. Consequently, the purity of molasses, used for making rum, was high.

In India, we have similar conditions, where the economical disposal of the molasses makes all the difference between profit and loss to the sugar factory. There is a general belief in India (which seems to have been based on this fact), that the excise policy of the Government, as regards the manufacture of rum, is the chief cause, which acts to the detriment of the Indian sugar industry. Nothing is more erroneous than this belief, as can be seen from the experience of other countries, where sugar industry is in a prosperous condition, even when molasses is practically run to waste. It seems, that in India, as in Jamaica, the factories depend for their profit on rum, which is the weakest point of the sugar industry. This dependence, on the rum market, has resulted in a low recovery of sugar, as more sucrose is being utilized for the manufacture of rum. In Jamaica, the sucrose recovered per cent. sucrose in juice is between 87-88 against 90-92 in Cuba, which is its neighbour, while sucrose lost in molasses for making rum is 10-11 per cent. on sucrose in juice as against 7-8 per cent. in other countries. It is no wonder, that factories, which depended for their profits on rum could not make any profit, when the market for rum went low. This tendency of utilizing more sucrose for making rum, instead of utilizing it for recovering more sugar, which is a more profitable commodity, and of ultimately depending for profits on the rum market is greatly to be regretted. The best thing is to extract as much sugar

out of molasses, as is economically possible, before final molasses is disposed of, either for making rum or other purposes. This will greatly help the Indian sugar industry.

The recovery of sugar from final molasses in the case sugar industry is not commercially successful. In the beet sugar industry, on the other hand, where final molasses is of a high purity (55°-60°) due to the absence of glucose and presence of a high amount of ash, sugar is recovered from molasses. The following figures will show the difference between cane and beet molasses :--

	Cane.	Beet.
Brix	80.0	80.0
Sucrose	30	50
Raffinose	0	present
Invert sugar	3.2	trace
*Ash	6	10
†Organic non-sugar	12	20
Sugar ash ratio	5.1	5.1
Gravity purity	37.5	62.5

\* Contains a high amount of potash varying from 2.6 per cent.

† Contains gums, organic acids, nitrogenous substances, caramel and other products of decomposition.

The sugar from beet molasses is recovered by precipitating it from the same as an insoluble compound. For this purpose, it is usual to use either Barium, or Strontium or Calcium oxides. These oxides combine with sucrose to form saccharates, which are insoluble. They are separated by filtration, after which they are decomposed into Ba, Sr or Ca carbonates and sucrose. The Barium process is used at Wallaceberg, Ontario, lime process by the Great Western Sugar Co., in U. S. A., also called the "Steffen's process" and the Strontium process is used in Germany. Out of this, lime process is the least expensive, but gives a low recovery. This process is not economically successful in the cane sugar industry.



It may be asked, as to why the same process is not economically successful for recovering sugar from cane molasses. First of all, beet molasses contains no glucose, which fact facilitates the extraction of sucrose in the form of saccharates. Cane molasses, on the contrary, contains a high amount of glucose, which makes it difficult to separate calcium saccharate from glucose.

Secondly, the process requires a large amount of lime, which increases the expense. In the beet sugar manufacture, the process, used for making white sugar, is the carbonatation process, which demands a great quantity of lime stone. Not only lime stone is required for supplying  $\text{CO}_2$  gas, to neutralize the excess of lime used in the process, but a great quantity of lime is required for clarification. Such is not the case in cane sugar manufacture. All the lime, that is used for the recovery of sucrose from molasses by the calcium saccharate process, is reused in beet sugar manufacture. Thus there is practically no more expense for lime for recovering this sugar, as is ordinarily required in the carbonatation process. Besides a kiln is quite necessary to generate carbonic acid gas in beet sugar manufacture, which increases complications and expense.

Thirdly, the calcium saccharate process is required to be run at low temperature (below  $15^\circ \text{C}$ ), which is usually obtained by refrigerating apparatus, except when conducted in winter in cold countries. This becomes too expensive in the tropics. The beet factories are all situated in the torrid zone, where temperature is very favourable to this process. The low temperature is quite necessary, because calcium saccharate, which is formed by the addition of calcium oxide to molasses, forms a granular precipitate in the cold easy of filtration. In the tropics, a low temperature will have to be maintained by refrigerating plants, which makes the cost prohibitive.

At present, the final molasses in the cane sugar industry is utilized for the following purposes, though a great part is run to waste. They are: (1) cattle feed, (2) supplementary fuel, (3) fertilizer, (4) the manufacture of alcohol.

(1) *Cattle feeding*.—Cane sugar molasses has a pleasant flavour, while beet molasses has bad odour. Hence, it is used as a cattle food. Molasses is not a complete food in itself,

since it contains only 0.15 per cent. nitrogen, but the salts present have a stimulating effect on the appetite and digestion.

Molasses is either given by mixing with concentrated food previous to feeding or in the form of cattle food specially prepared for the purpose. At present, it appears on the market under three different trade names, "molascuit" "molassine meal" and "extravim". Molascuit is formed of molasses and pith of sugarcane, molassine meal of cane and beet molasses and sphagnum moss, while extravim contains cane molasses only. The preparation of molascuit is generally common. In Demerara, some factories prepare molascuit. For this purpose fine powdery bagasse, screened through a mosquito curtain, is used. About 120-125 gallons of molasses are required to make a ton of molascuit. This works at about 4 lbs. of bagasse per gallon of molasses. It analyses as below :—

Sucrose	28-30	} 50-52 per cent. sugar.
Invert sugar	20-24	
Moisture	12-14	

The composition of other meals is as below :—

	Protein.	Fat.	Fibre.
Extravim	5.24	0.50	4.95
Molasses meal	8.82	0.63	6.25

In India, where cattle food is scarce and dear, it will be best to utilize molasses for cattle feeding. If molasses is to be used directly with cattle food, the difficulty is of storage and transportation. It is difficult to transport liquid molasses unless there are special railroad cars for the purpose. In Java, the molasses is concentrated in special pans, until it solidifies on cooling. This is then filled in mats and is transported.

The preparation of molascuit will solve the problem of transportation and storage. In Northern India, where cane contains a high amount of fibre, it will be possible to obtain bagasse pith to make this mixture, but in the Bombay Deccan, cane contains a low fibre, and consequently bagasse alone may not be enough as a fuel. It will, therefore, not be possible to get bagasse pith to make molascuit, unless cheaper sources of fuel are available to supplement the bagasse. The amount of bagasse required to make molascuit is 4 lbs. per gallon of molasses. From each ton of cane are obtained about 5 gallons of molasses. So for every ton of

cane 20 lbs. of bagasse will have to be used for making molascuit. This means, that about 4-5 per cent. of the bagasse will be required to prepare molascuit (taking 23 per cent. as the bagasse obtainable on cane). Under the circumstances, some other substitutes such as wheat bran or rice bran will have to be used. At any rate there is a good market for molasses as cattle food or as a material for curing tobacco in India.

(2) *Supplementary fuel.*—In the Hawaiian islands, where a heavy maceration is usually practised to the extent of 40-45 per cent., the amount of bagasse obtained is not sufficient to run the factory. The amount of fibre in cane is 12 per cent. or more, which, under the usual amount of maceration, should supply more than enough fuel. It is a usual practice to supplement this fuel with molasses, which, under the usual conditions, goes to waste. For this purpose a perforated pipe is put on the bagasse carrier after the last mill, through which, a stream of molasses is fed to the bagasse, as it passes over the carrier to the furnace. In using molasses as fuel, it is very important, that it be mixed well with the bagasse so as to eliminate the trouble in the furnace. The usual trouble is to get clinkers, which break and throw off sparks. In order to get a proper mixture, the bagasse mixed with molasses is carried over two separate carriers so as to give a turn over to the bagasse, which effects proper mixing of the molasses.

In places, where bagasse is not sufficient to run the whole factory, and, where other fuels are costly or where molasses cannot be disposed of in any other way, it is better to use it as a supplementary fuel. According to Messrs. McCleary and Agee, molasses of 80 per cent. total solids has a thermal value of 4,950 B. T. U. per lb. After making correction for vaporizing the moisture, it comes to about 4,700 B. T. U. per lb. The calorific value of molasses and other fuels is as below :—

Fuel.	B. T. U. per lb.
(1) Molasses	... 4,700
(2) Air dried wood	... 4,500-5,000
(3) Bagasse (45 per cent. moisture).	4,500
(4) Petroleum	... 16,000-17,000
(5) Anthracite coal	... 15,000-16,000
(6) Fuel oil	... 18,800

This shows, that molasses has practically the same calorific value as either bagasse of 45 per cent. moisture or air dried wood, and in using it, as fuel; one has to consider the price of the other fuels obtainable with the market price for molasses. In the Bombay Deccan, molasses can be profitably disposed as cattle food or for curing tobacco, and, though bagasse alone may not supply enough fuel, it can be supplemented with trash. If this is not enough, other fuels such as groundnut or safflower husk can be obtained. It may, however, be possible to obtain safflower and groundnut hulls in large quantities at a cheaper price, in which case it is best to use them and utilize molasses for cattle feeding.

It is also a practice to burn molasses in special furnaces with ample combustion volume by atomizing the same with steam. Molasses is pre-heated to about 180° F, and is fed to the furnace through special burners at 60 lb. pressure. The flame is similar in appearance to oil fire. No auxiliary fuel is required to maintain the furnace temperature. Under these conditions, there is a loss of some potash. The efficiency is higher in this case, but the process is expensive.

In one place, molasses alone was burnt in an ordinary bagasse furnace modified to suit molasses burning. The Dutch oven is provided with a slow rotating cast iron drum (similar to a stoker), on which molasses drops in continuous thick jet. The speed of this drum is one revolution per 4 minutes. Molasses gets caramelized, and assumes a lumpy form, before it is ready to fall on the flat shaking grates below the drum. The lumps complete their combustion on these grates. Shaking grates are found to be very good, as they prevent the inrush of cold air during shaking, which is required to promote good combustion. The inrush of cold air cools the furnace, and reduces the boiler efficiency considerably. Pre-heating of molasses in this case is not good, because the molasses runs too fast on the drum, and falls on the shaking grates, before it is caramelized, and thus goes to waste.

The burning of molasses in separate furnaces increases its efficiency. Ordinarily molasses, when burnt with bagasse, evaporates 1.7 to 2 lbs. of water. When burned separately with an injector burner, it evaporates 2 to 2.2 lbs. of water. With the furnace provided with a rotating drum, there is no necessity of using any steam with molasses.

(3) *Molasses as a fertilizer.*—Molasses as a fertilizer has been experimented upon in Mauritius and Java with good results. 20 tiers, *i. e.*, 3,800 litres of molasses per acre (=28 lbs. of nitrogen, 14 lbs. of phosphoric acid, and 110 lbs. of potash) gave an increase of 11·85 tons of plant cane and 8·80 tons of 1st ratoon per acre. In Java, it gave an increase of 12 tons of cane to an acre. The composition of molasses, so far as the fertilizer ingredients are concerned, is as below :—

	Mauritius per cent.	Hawaii. per cent.
Nitrogen	... 0·50	0·83
Potash	... 1·96	5·81
Phosphoric acid	... 0·25	0·16

In the Hawaiian islands, it was found, that the use of molasses as a fertilizer, in addition to the usual dressing, caused harm on account of its effect on nitrate nitrogen as well as ammonia nitrogen. In the former case, nitrate nitrogen is converted into unavailable form, while in the latter, the nitrification of sulphate of ammonia is checked. Even with organic fertilizers, the ammoniafication and nitrification are retarded.

During my travel I found, only one factory in the Hawaiian islands (Pauhau) was recovering potash by burning molasses. For this purpose, a specially constructed furnace 18 ft. long, 6 ft. wide, and 5' 6" high was used, the molasses being fed in the form of a thick jet. The fire in the furnace is first started with wood. Afterwards no more fuel is required. Molasses burns along with steam jet. There are no grate bars in the furnace, and the air is supplied through the openings of the feeding mouth. The molasses is allowed to form clinkers, which are then well spread and allowed to burn in the furnace. The ash is then cooled, sifted through a screen, the clinkers returned to the furnace for reburning, while, the sifted stuff is filled in bags. The process is very simple and costs \$ 30 a ton. By this method about 75 per cent. of the potash in the molasses is recovered.

Mr. Elliott, the chemist of the Pauhau sugar company, has found, that the recovery depends upon the draft and

heat of the furnace, the best recovery being obtained at a low draft not exceeding 0·10", and at a low temperature just sufficient to effect the combustion of the molasses. At high temperature, the chloride of potassium, which forms the bulk of the potash salts in the molasses, is volatilized, thus directly affecting the recovery of potash. With higher draft, there is also a loss of potash due to the ashes going through the chimney.

This practice is possible, where there is no market for molasses, and where there is a demand for potash as a fertilizer. In India, where the necessity of potash and phosphoric acid to sugarcane has yet to be demonstrated, this practice has no immediate future. It should be remembered, however, that this practice involves the burning of nitrogenous substances, which is a loss.

When molasses is used as fuel along with bagasse, almost all the potash and phosphoric acid will appear in the ashes from the furnace. This, when applied to the fields, will supply the potash that may be required by the cane crop.

The following analysis of the ash at the Pauhau plantation shows the value of this fertilizer as a potash supplier:—

	Per cent.
Potash water soluble . . .	27·66
„ acid „ . . .	28·33
Lime . . .	17·67
Phosphoric acid soluble in acid . . .	2·00
„ water soluble . . .	trace.

(4) *The manufacture of alcohol.*—The question of manufacture of rum, as a beverage from molasses, is attended with peculiar difficulties in India, where the drink question has become acute at the present time. From a moral as well as patriotic point of view, no self respecting Indian would like to go in for making rum from molasses. In India, at the present time, legislation is being passed to restrict the consumption of liquor, and time may not be far distant, when there will be practically no demand for such highly intoxicating liquors as rum. In India, there is a good market for molasses as cattle food, and as a material for

curing tobacco. Fortunately, on account of the prohibition laws in the United States, rum market is in a depressing condition. In the West Indies, where a great part of the molasses was used for making rum, conditions have gone so far that most of the distilleries are closed at present. There is not so much demand as to utilize all the molasses for making molascuit, and consequently, a great part of the molasses is going to waste. It is on account of this pressing problem that the question of alcohol, as fuel for internal combustion engines, is receiving a good deal of attention.

This feature of the question has a special interest in India, where the cost of gasolene is very high. With the more extended use of motor cycles, cars and trucks year by year, the consumption of gasolene, which is used exclusively by these vehicles, is increasing by leaps and bounds. Experiments in the Hawaiian islands have conclusively proved, that in countries, where the cost of gasolene is high—anywhere above 35 cents (=Rs. 1-1-0) a gallon, the manufacture of motor fuel from final molasses will be a paying proposition. Of course, when the question of selling motor fuel to public is considered, one has to think of the competition with gasolene, which is delivered under well organized marketing conditions. This is specially true in the United States, and hence, in Hawaii, attempts are being made to make and utilize all the motor fuel on the plantations.

The substitution of alcohol for gasolene, as fuel in internal combustion engines, was originally attended with certain difficulties due to its character. It does not vaporize so quickly, as gasolene does and, consequently great difficulties are encountered in starting and operating an engine, until it gets sufficiently hot. In order to improve vaporization, a mixture of alcohol and ether (the latter can be prepared from alcohol by treatment with sulphuric acid) was prepared. This did improve the vaporizing quality of the mixture, but it caused other troubles, such as corrosion of cylinders by the acid products of combustion from ether and alcohol. In order to neutralize the effects of acids, a base such as pyridine or aniline was used in the mixture. There are at present two or three formulae for this mixture, which is as below:—

	Hawaiian Mixture.	Natalite.
Alcohol	... 55.55	54.0
Ether	... 42.78	45.0

	Hawaiian Mixture.	Natalite.
Kerosene ...	1.11	...
Pyridine ...	0.56	...
Trimethyl Aniline ...	...	1.0

Mr. Foster, of the Maui Agricultural Company in the Hawaiian islands, has developed another formula which is as below:—

	By Volume.	Per cent. by Volume.
92 per cent. alcohol ...	100	75.2
95 per cent. ether ...	30	22.6
Kerosene ...	2	1.5
Pyridine or Aniline ...	1	0.7

This formula is patented, and the company is now making motor fuel according to this formula, which is used on the plantation. Aniline is a base, and is considered to be better than pyridine, on account of its low cost and absence of disagreeable odour. This mixture contains about 9 per cent. water, which is considered to have beneficial effect on the cylinder.

The use of motor alcohol as a substitute for gasolene has certain advantages. There is far less carbon trouble with alcohol than with gasolene. Consequently, engines can be operated for a longer time without cleaning. Secondly, motor alcohol does not cause a dilution of lubricating oil in the same way as gasolene does.

When motor alcohol is to be used in engines using gasolene, adjustment of the carburetter is necessary. Some carburetters have cork floats coated with shellac, which is dissolved by alcohol, and consequently they fail to function. Carburetters with metal floats, are, therefore, necessary. A higher compression in the cylinder is also necessary.

*Thermal value of motor fuel.*—According to the report of the Hawaiian Sugar Planters' Association, the thermal value of motor fuel of Foster formula is as follows:—

	Motor spirit.	Gasolene.
B. T. U. per lb. ...	12,600*	20,700
B. T. U. per gallon ...	83,000	130,400
Thermal value ...	1.57	1.00

\* Based on alcohol 11,100; ether 16,200; and kerosene 20,800 B. T. U. per lb.



On actual experiments with regard to mileage or power production, it is found, that 1 gallon of gasolene is equal to 1.4 gallons of motor alcohol. It should be remembered, that to produce good combustion, about half the amount of air is necessary in the case of motor alcohol, and consequently, the fuel mixture entering the cylinder is about 25 per cent. higher in fuel value than is the case with gasolene mixture, which increases the efficiency.

*Cost of manufacture.*—The following figures are obtained from the Hawaiian Sugar Planters' Associations' Report:—

A ton of sugar yields approximately 42 gallons of molasses, which should yield about 15 gallons of industrial alcohol. The detailed cost of manufacturing is given below:—

Based on capacity of 1,000 gals. distillery per day.

	\$ per gallon.
Supervision and labour ...	0.020
Fuel ...	0.020
Pyridine ...	0.015
Kerosene ...	0.004
Acid and lime ...	0.002
Interest and depreciation...	0.0245 based on 12 per cent. on \$ 61,200.
Royalty ...	0.010
Incidentals ...	0.005
<hr/>	
Cost of manufacture exclusive of value of molasses ...	\$ 0.1005
<hr/>	

This shows the cost of manufacture is very little. In order to find, whether it is profitable to make motor fuel, one has to consider the value of molasses. With different prices

for molasses, the following statement is prepared by the Hawaiian Planters' Association:—

Value of molasses per ton.	Value of molasses entering into each gallon of alcohol.	Cost of production of motor alcohol, per gallon.	Value of motor alcohol equivalent to one gal. of gasolene; factor 1.4.
\$.	Cts.	Cts.	Cts.
1.00	1.67	11.67	16.34
2.00	3.33	13.33	18.66
3.00	5.00	15.00	21.00
4.00	6.67	16.67	23.34
5.00	8.33	18.33	25.66
6.00	10.00	20.00	28.00

The above figures show, that even with higher price for molasses, the cost of one gallon of motor alcohol does not go above 30 cents. (about a rupee), which is obviously much lower, than the cost of gasolene in India. One has to consider, however, how far the public are prepared to use motor alcohol, instead of gasolene. In the Hawaiian islands, it has been found, that it is mighty hard to compete against highly organized marketing facilities offered by the oil-companies. Consequently, the plantations manufacture alcohol for their own use on the estates, as they already consume great quantities of gasolene and kerosene, and thus become independent of outside supply. In India, there will be a limited consumption on the estates, and manufacturers will have to solely depend on the public for the disposal of motor alcohol. In India, there is already a good market for molasses as cattle food, and for curing tobacco, and the demand for it seems to be so large, that for some years to come, there will be no difficulty for the disposal of molasses at a profit. The question of the manufacture of motor alcohol, therefore, is a remote possibility.

*Process of manufacturing motor alcohol*—I saw this process on Paia estate of the Maui Agricultural Company, which is manufacturing this motor spirit for the past two years. The process was designed by Mr. Foster of the same company and is protected by a patent.

Final molasses is diluted to about 20° Brix and is then pumped to fermentation tanks, made of wood, to which

sufficient quantity of yeast is added. A pure culture of yeast is obtained from the experiment station of the Hawaiian Planters' Association, and is used. Fermentation begins at once, and is complete within 20 hours. No nutrient, such as ammonium sulphate, is added.

The beer is then pumped to the alcohol still of Foster-Misner type. This still is made entirely of red-wood, instead of copper, which thus decreases the first cost. The cost of erection is also small, as plantation carpenters can do all the work. It is economical in work, since wood acts as a good insulating material in preventing radiation losses. No scale is formed on wood, which is also an advantage. As alcohol is to be prepared not for beverage purposes but for making motor alcohol, no attempt is made to secure quality.

The condensation of alcohol is carried in three stages. The condensers consist of copper coils inside wooden tanks, through which vapours flow. First of all, the vapour from the beer on its passage to the condenser gets partially condensed by the wooden still. In the first condenser, water is used for condensing the vapour, in the 2nd, the incoming beer from the fermenting house, and in the 3rd, cold water which completes the condensation. The condensed vapour from condensers 1 and 2, which consists of water and alcohol is returned to the still, while condensed vapour from condenser 3 is withdrawn as 92 per cent. alcohol. The beer is pre-heated, before it enters the still, by the lees after the latter leave the still pot. The lees are then run to sewer and mixed with irrigation water as they have a fertilizing value.

*Preparation of ether.*—The ether generator is of Foster design. This consists of a lead lined receptacle containing sulphuric acid, heated with lead steam coils. 92 per cent. alcohol is continually fed to the still, containing sulphuric acid, by gravity, and the mixture heated by steam of 20 lbs. pressure. The ether vapour passes through a save all, and then through a scrubber, where lime cream is continually sprayed to dissolve any vapour of sulphuric acid, that may pass along with ether. The vapour, freed of sulphuric acid vapour, is then passed through two condensers. The first condenser condenses the alcohol, which is sent back to the ether still, while the second condenses ether of 95 per cent. purity. 1.4 gals. of 92 per cent. alcohol gives 1 gallon of 95 per cent. ether.

The ether is then mixed with alcohol, kerosene and pyridine or aniline according to the formula already given.

The yield of alcohol depends upon the quality of molasses. At Paia, 1 gallon of 90-92 per cent. alcohol was obtained from 2.55 gallons of molasses of the following composition:—

Brix = 84.85; total sugars = 53.54; unfermentable sugars 2 per cent. The above yield is 84 per cent. of the theoretical amount.

*Summary.*—In the above discussion are given the various ways, in which the final molasses is disposed off in various cane sugar countries. At one time, the production of rum from molasses was on a great scale, but since the market for rum went low, other means are investigated, of which, the production of motor alcohol seems to have received a good deal of attention. In India, the disposal of molasses does not present great difficulties. Under present conditions, the best way is to dispose the molasses as cattle food or as a material for curing tobacco. In factories, where the fuel problem is very acute due either to insufficiency of bagasse as fuel or to difficulty of obtaining cheaper sources of fuel or to both, the question of using molasses as fuel should be decided on its own merit. Time is yet distant, when sugar manufacturers in India may begin to feel difficulty in disposing the molasses in the above ways, when the manufacture of motor alcohol, as a fuel for internal combustion engines, will probably afford profitable means for disposing the molasses.

*Disposal of bagasse.*—Bagasse is exclusively used as fuel in all cane sugar countries all over the world, as it is the cheapest source of fuel. The amount of bagasse obtainable from cane varies according to the fibre content of the cane. Taking 45 per cent. as the average moisture and 50 per cent. as the fibre in bagasse, the amount of bagasse, obtainable from cane with different fibre content, will be as follows:—

Fibre in cane.	Bagasse per cent. cane.	Bagasse per ton of cane.	Amount of Bagasse required per ton of cane for		Surplus or Deficit in bagasse for	
		lbs.	Raw lbs.	White lbs.	Raw lbs.	White lbs.
10	20	400	500	578	— 100	— 178
11	22	440	500	578	— 60	— 138
12	24	480	500	578	— 20	— 98
13	26	520	500	578	+ 20	— 58
14	28	560	500	578	+ 60	— 18
15	30	600	500	578	+ 100	+ 20

According to Prof. Kerr's experiments in Louisiana B. H. P., required per short ton of cane in raw and white sugar factories, is 1.50 and 1.75, respectively. The amount of bagasse, required per ton of cane, is computed as below:

$\frac{1.50 \times 24 \times 34.5}{2.5}$  taking the amount of water evaporated per lb.

of bagasse of 45 per cent. moisture content to be 2.5 lbs. The above figures represent certain conditions, which vary in different factories. I noticed, that very few factories on the whole were operating on bagasse alone. In Louisiana, where the fibre content varies from 8-10 per cent, and where majority of factories make plantation white sugar, extra fuel to the extent of 5-8 gallons of fuel oil per short ton of cane, is used. In Cuba, where the fibre content is little over 11 per cent. and where raw sugar is made, sugar factories are using oil as a supplementary fuel to the extent of 2-3 gallons per short ton of cane, even though the amount of maceration is usually not over 20 per cent. In Porto Rico, where the fibre content is somewhere near 12 per cent., and, where maceration is a little higher than what is in Cuba, fuel oil to the extent of 2 gallons per ton of cane is used. In the Hawaiian islands, where the fibre content of cane is little below 13 per cent., bagasse alone is not sufficient, probably due to heavy maceration (35-40 per cent.), that is usually practised to obtain high extractions unheard of in any other part of the world. In the Hawaiian islands, final molasses is used as a supplementary fuel along with bagasse, or separately in special furnaces, and these two together provide sufficient fuel. Only in Antigua and St. Kitts, where the fibre content is over 15 per cent., factories are able to operate on bagasse alone. The above table agrees with the actual conditions obtained in various cane sugar countries.

The above facts show, that the question of utilization of bagasse for paper making does not arise. During my travel, I found only two places where bagasse was used for making coarse grade paper. One is New Orleans, where the Celotax company buys bagasse from the plantations to make paper board, which, in that case, use fuel oil, which is much cheaper in Louisiana. This paper board is used for the purpose of insulation for steam pipes, for which there is a market in the United States. Obviously, this is possible in Louisiana because there fuel oil is obtained much cheaper to take the place of bagasse in cane sugar factories.

The other place is the Olaa sugar estate on the island of Hawaii, which makes bagasse paper to serve as a mulch in cane fields. For mulch, a very brittle paper is required

which will allow the young cane shoot to come through. This company has special field conditions, which makes it necessary to use paper mulch in cane fields. This is the one estate, which I saw personally, which has the greatest trouble of weeds due to continuous rain, and the nature of the soil does not permit intercultivation by power. The weeds are so numerous, that unless the cane rows are covered immediately after planting, the weeds get the upper hand and kill the young cane shoots. The practice is to cover the cane rows immediately after planting by paper mulch, which smothers the weeds, but allows the cane shoots to bore through easily. When once the cane gets a good start, weeds are smothered by the cane. This system costs about 35-40 dollars per acre (=Rs. 105-120) and is expensive, but the estate has no other choice but to use it to get a good crop of cane. No other estate in Hawaii uses bagasse for making paper mulch.

The paper is made by the lime process. In order to make it water proof, it is passed through a mixture of asphalt and crude oil (70 per cent. asphalt and 30 per cent. crude oil), and later dried partly by heat, and partly by air. The yield is 50 per cent. of paper on bagasse. The paper is very brittle, and deteriorates quickly in the fields. These two properties, however, serve well for mulching purposes.

The utilization of bagasse for paper has so far not been commercially successful. The complete inter-mixture of the two kinds of fibre, the pith and the rind, each possessing different physical properties, presents great difficulties for separation, without which, its use for the manufacture of paper or for making paper pulp is not found practicable. It should be remembered, that the manufacture of paper is altogether a different proposition from sugar making, requiring technique with which, the sugar manufacturer is not equipped. This has been the experience at Oloa. Secondly, the machinery for paper making is expensive, and it does not pay, unless the plant is kept in operation throughout the year. This is not possible with cane sugar factories, as the bagasse will be obtainable only during the grinding season, which lasts for 4-6 months only. On account of the fuel problem and on account of the peculiar difficulties with regard to the bagasse fibre, which are not yet satisfactorily solved, there does not seem to be any immediate prospect for using bagasse for paper making even in Northern India, where it is possible to have surplus bagasse due to high fibre content of the cane.

## APPENDIX.

(A) On page 18, in calculating the losses involved in gur making, sugar was valued at Rs. 280 a ton. At present price of sugar, which is about Rs. 480 a ton, the value of sucrose lost annually in gur making comes to Rs. 1,03,39,680. Deducting Rs. 16,73,280 as the cost of manufacture, the net loss, obtained with present methods of gur manufacture on the Deccan canals and comes to Rs. 86,66,400 or roughly 8½ million rupees annually.

(B) On page 18, in calculating the value of gur obtained, it was valued at Rs. 20 a Palla of 250 lbs. At the beginning of the year the price was nearly Rs. 30 a Palla of 250 lbs. At this rate (roughly 8 lbs. a rupee) the valuation of gur comes to Rs. 27·6, 29·1, and 30·7 for Brix 18, 19, and 20, respectively. The cost, per ton of cane delivered on the field, thus, comes to Rs. 25·3, 26·8, and 28·4, respectively, which is certainly much higher, than what is paid in any other country including the Hawaiian islands.

(C) Foreign weights and coin used in the bulletin—

Weight: short ton = 2,000 lbs.

„ long „ = 2,240 „

„ picul = 136·2 „ Rs. a. p.

Coin: Doller (\$) = 100 cts. = 3 2 0

„ Guider (f) = 100 „ = 1 1 0 approximately.

(D) On page 19, in calculating the valuation of sugar, I assumed the rate of sugar to be Rs. 280 a ton. At present the rate of sugar is about Rs. 480 a ton. At this rate (*i.e.*, 5 lbs. a rupee) the valuation of 229 lbs. of sugar comes to Rs. 45·8. The value of 71 lbs. of molasses is assumed to be Re. 1. Thus, the total value comes to Rs. 46·8. The cost of manufacture is Rs. 8·5, based on Rs. 80 a ton. The net return, after deducting the cost of manufacture comes to about Rs. 38·3. This leaves a margin of Rs. 13·0, 11·5, and 9·9 per ton of cane respectively. This is a good margin and, present market conditions of gur and sugar seem to be favourable for making sugar. It should be remembered, however, that our price for raw material is much higher than what is prevailing in a country like Hawaii, where the expenses of growing cane are much higher. The cost of cane at the mill there is in the neighbourhood of Rs. 21 (*i.e.*, about \$ 7·0). It is quite essential, therefore, to secure good efficiency, if factories in India are to work profitably. In the accompanying statements, I have given (1) the value of gur obtained from each ton (short) of cane with our present method of manufacture, with different rates of gur from Rs. 15 to Rs. 50 a Palla of 250 lbs. and also for juice of Brix 18, 19 and 20; (2) the price per short ton of cane to be paid to farmers, after deducting the cost of gur manufacture, which is assumed to be Rs. 32, 40 and 48 per "Bhar gad" *i.e.*, per 16 boilings of 1,100 lbs. juice each (which comes to Rs. 2·3, 2·9, and 3·5 per short tone of cane) with

juice of Brix 18, 19, and 20; (3) what should be the price of sugar, if sugar is to be made at a profit from cane, purchased from farmers on the Deccan canals on the basis of the prices of gur from Rs. 15 to 50 per Palla of 250 lbs.

I. Value of gur in rupees, obtained from each short ton of cane with present methods of manufacture, with different rates of gur from Rs. 15 to 50 per Palla of 250 lbs. and also for juice of Brix 18, 19 and 20.

Rate of gur per Palla of 250 lbs. in rupees	Value of gur from each short ton of cane in rupees, with Brix of juice		
	18	19	20
15	13.8	14.6	15.3
16	14.7	15.5	16.4
17	15.6	16.5	17.4
18	16.5	17.5	18.4
19	17.5	18.5	19.4
20	18.5	19.5	20.5
21	19.3	20.4	21.5
22	20.2	21.4	22.5
23	21.2	22.4	23.6
24	22.1	23.3	24.6
25	23.0	24.3	25.6
26	23.9	25.3	26.6
27	24.8	26.2	27.6
28	25.7	27.2	28.7
29	26.6	28.2	29.7
30	27.6	29.1	30.7
31	28.5	30.1	31.7
32	29.4	31.1	32.7
33	30.3	32.1	33.8
34	31.2	33.1	34.8
35	32.2	34.0	35.8
36	33.1	35.0	36.8
37	34.0	35.9	37.9
38	34.9	36.9	38.9
39	35.8	37.9	39.9
40	36.8	38.9	40.9
41	37.7	39.9	42.0
42	38.6	40.8	43.0
43	39.6	41.8	44.0
44	40.5	42.8	45.1
45	41.4	43.7	46.1
46	42.3	44.7	47.1
47	43.2	45.7	48.2
48	44.2	46.7	49.2
49	45.1	47.6	50.2
50	46.0	48.6	51.2



II. Price in rupees, per short ton of cane to be paid to farmers after deduction of the cost of gur manufacture, which is assumed to be Rs. 32, 40, 48, per 16 boilings of 1,100 lbs. of juice each (which comes to Rs. 2.3, 2.9 and 3.5 per short ton of cane) with juice of Brix 18, 19 and 20.

Rate of gur per Palla of 250 lbs. in rupees.	Price per short ton of cane after deduction of the cost of gur manufacture, which is per ton of cane								
	Rs. 2.3			Rs. 2.9			Rs. 3.5		
	Brix 18	Brix 19	Brix 20	Brix 18	Brix 19	Brix 20.	Brix 18	Brix 19	Brix 20
15	11.5	12.3	13.0	10.9	11.7	12.5	10.8	11.1	11.8
16	12.4	13.2	14.1	11.3	12.6	13.5	11.2	12.0	12.9
17	13.3	14.2	15.1	12.7	13.6	14.5	12.1	13.0	13.9
18	14.2	15.2	16.1	13.6	14.6	15.5	13.0	14.0	14.9
19	15.4	16.2	17.1	14.6	15.6	16.5	14.0	15.0	15.9
20	16.2	17.2	18.2	15.6	16.6	17.6	15.0	16.0	17.0
21	17.0	18.1	19.2	16.4	17.5	18.6	15.8	16.9	18.0
22	17.9	19.1	20.2	17.3	18.5	19.6	16.7	17.9	19.0
23	18.9	20.1	21.3	18.3	19.5	20.7	17.7	18.9	20.1
24	19.8	21.0	22.3	19.2	20.4	21.7	18.6	19.8	21.1
25	20.7	22.0	23.3	20.1	21.4	22.7	19.5	20.8	22.1
26	21.6	23.0	24.3	21.0	22.4	23.7	20.4	21.8	23.1
27	22.5	23.9	25.3	21.9	23.3	24.7	21.3	22.7	24.1
28	23.4	24.9	26.4	22.8	24.3	25.8	22.2	23.7	25.2
29	24.3	25.9	27.4	23.7	25.3	26.8	23.1	24.7	26.2
30	25.3	26.8	28.4	24.7	26.3	27.8	24.1	25.6	27.2
31	26.2	27.3	29.4	25.6	27.2	28.8	25.0	26.6	28.2
32	27.1	28.3	30.4	26.5	28.2	29.8	26.0	27.6	29.2
33	28.0	29.3	31.5	27.4	29.2	30.9	26.8	28.6	30.3
34	28.9	30.3	32.5	28.3	30.2	31.9	27.7	29.6	31.3
35	29.9	31.7	33.5	29.3	31.1	32.9	28.7	30.5	32.3
36	30.8	32.7	34.5	30.2	32.1	33.9	29.6	31.5	33.3
37	31.7	33.6	35.6	31.1	33.0	35.0	30.5	32.4	34.4
38	32.6	34.6	36.6	32.0	34.0	36.0	31.4	33.4	35.4
39	33.5	35.6	37.6	32.9	35.0	37.0	32.3	34.4	36.4
40	34.5	36.6	38.6	33.9	36.0	38.0	33.3	35.4	37.4
41	35.4	37.6	39.7	34.8	37.0	39.1	34.2	36.4	38.5
42	36.3	38.5	40.7	35.7	37.9	40.1	35.1	37.3	39.5
43	37.3	39.5	41.7	36.7	38.9	41.1	36.1	38.3	40.5
44	38.2	40.5	42.8	37.6	39.9	42.2	37.0	39.3	41.6
45	39.1	41.4	43.8	38.5	40.8	43.2	37.9	40.2	42.6
46	40.0	42.4	44.8	39.4	41.8	44.2	38.8	41.2	43.6
47	40.9	43.4	45.9	40.3	42.8	45.3	39.7	42.2	44.7
48	41.9	44.4	46.9	41.3	43.8	46.3	40.7	43.2	45.7
49	42.8	45.3	47.9	42.2	44.7	47.3	41.6	44.1	46.7
50	43.7	46.3	48.9	43.1	45.7	48.3	42.5	45.1	47.7

III. Price of sugar necessary to make sugar making pay, if cane is to be purchased on the basis of the price of gur from Rs. 15 to 50 per Palla of 250 lbs.

Rate of gur per Palla of 250 lbs. in rupees.	Price of sugar per long ton with cost of gur manufacture to be per short ton of cane.								
	Rs. 2-8			Rs. 2-9			Rs. 3-0		
	Brix of juice.								
	18	19	20	18	19	20	18	19	20
15	295	240	250	280	295	245	225	230	210
16	244	250	260	239	245	255	234	239	248
17	253	260	270	248	255	265	243	248	256
18	262	270	280	257	265	275	252	257	264
19	271	280	290	266	275	285	261	266	272
20	280	290	300	275	285	295	270	275	280
21	299	299	310	284	291	305	279	285	291
22	298	309	320	293	304	315	288	295	302
23	307	318	330	302	313	325	297	305	313
24	316	328	340	311	323	335	306	315	324
25	325	337	350	320	332	345	315	325	335
26	334	347	360	329	342	355	324	335	346
27	343	356	370	338	351	365	333	345	357
28	352	366	380	347	361	375	342	355	368
29	361	375	390	356	370	385	351	365	379
30	370	385	400	365	380	395	360	375	390
31	379	394	410	374	389	405	369	384	400
32	388	404	420	383	399	415	378	394	410
33	397	413	430	392	408	425	387	403	420
34	406	423	440	401	418	435	396	413	430
35	415	432	450	410	427	445	405	422	440
36	424	442	460	419	437	455	414	432	450
37	433	451	470	428	446	465	423	441	460
38	442	461	480	437	456	475	432	451	470
39	451	470	490	446	465	485	441	460	480
40	460	480	500	455	475	495	450	470	490
41	469	489	510	464	484	505	459	479	500
42	478	499	520	473	494	515	468	489	510
43	487	508	530	482	503	525	477	498	520
44	496	518	540	491	513	535	486	508	530
45	505	527	550	500	522	545	495	517	540
46	514	537	560	509	532	555	504	527	550
47	523	546	570	518	541	565	513	536	560
48	532	556	580	527	551	575	522	546	570
49	541	565	590	536	560	585	531	555	580
50	550	575	600	545	570	595	540	565	590

DAILY LABORATORY REPORT.

DILUTE JUICE.							BAGASSE.					
Brix.	Sucrose.	Purity.	Glucose.	Glucose Ratio.	Acidity.	Watch.	Moisture.	Sucrose.	Fibro.	Watch.		
						I				I		
						II				II		
						III				III		
						IV				IV		
						Average.				Average.		
JUICE FROM PRESSES.							COMMERCIAL SYRUP.					
						I	Brix.	Sucrose.	Purity.	Glucose.	Glucose Ratio.	Watch.
						II						I
						III						II
						IV						III
						Average.						Average.
SYRUP FROM NORIT PRESSES.							MASSECUTE (Each Strike).					
						I	Brix.	Sucrose.	Purity.	Paq No.	Time of Boiling.	Kind.
						II						
						III						
						IV						
						Average.						
NORMAL JUICE.			RESIDUAL JUICE.									
Sucrose.	Purity.	Watch.	Brix.	Sucrose.	Purity.							
		I										
		II										
		III										
		IV										
		Average.										
POLARIZATION OF SUGARS.												
Kind of Sugar.	Watch I.	Watch II.	Watch III.	Watch IV.	Average.							
FILTER PRESS CAKE.												
Kind.	Watch I.	Watch II.	Watch III.	Watch IV.	Average.							
of Cake ...												

Initialed { 1st Watch \_\_\_\_\_

              { 2nd Watch \_\_\_\_\_

              { 3rd Watch \_\_\_\_\_

              { 4th Watch \_\_\_\_\_

DAY REPORT.

Date \_\_\_\_\_ Crop day \_\_\_\_\_  
 Tons Cane Ground \_\_\_\_\_ This Day \_\_\_\_\_ To Date \_\_\_\_\_  
 No. 1 Mill Run Hours Min. No. 2 Mill Run Hours Min. Maceration % Cane  
 Time Lost Hours Min. Time Lost Hours Min. Dilution % Cane  
 Cause \_\_\_\_\_ Cause \_\_\_\_\_ Oil Burned—Gals. per ton  
 Juice Extraction % Cane % Fibre  
 Sucrose Extraction % Bagasse: % Fibre % Sucrose % Moist.  
 Pounds Sucrose Extracted per Ton  
 Pounds Sucrose in Bagasse per Ton

	Aidity.	Brix.	Sucrose.	Parity.	Clerget.	True Parity.	Glucose.	Glucose Ratio.	Moist.	
Crusher Juice	...									
Normal Juice (calcu.)	...									
D. lute Juice	...									
Clear Juice	...									
Syrup	...									
Third Mill Juice	...									
Residual Juice	...									
Filter Press Cake	...									
Massecurites	...									
Run Offs and Wash	...									
Sugar—Granulated	...									
Sugar—W. C.	...									
Sugar—Y. C.	...									
Sugar—96°	...									

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	RUS.	TO DATE.	BALANCE	TO RATE.							
				Sucrose=100%.	Sucrose Extracted=100%.	Cane=100%.	Sucrose Extracted=100%.				
Days Grinding			Sucrose in Sugar								
Tons Cane Ground			" " Molasses								
Tons Cane per Hour			" " "								
Time Lost % Total Time			" " Com'l. Products								
Maceration % Cane			Loss by Inversion								
Dilution % Cane			" in Bagasse								
Juice { No. D. J.			" in Press Cake								
Extraction { No. Cane + No. H3O. }			" Not Determined								
Sucrose Extraction			Total Lost								
Pounds Sucrose Extracted			<b>CHEMICAL COMPOSITION OF CANE AND ITS PRODUCTS.</b>								
" " " per ton...				Acidity.	Brix.	Sucro-s.	Parity.	Glucos.	Batto.	Fibre.	Molsture.
" Bagasse per ton			Cane (Calculated) { Run								
" Sucrose in Bagasse per ton			{ To Date								
Gals. Fuel Oil per ton			Bagasse { Run								
Pounds Sugar per ton			{ To Date								
" " " "			Press Cake { Run								
" " " "			{ To Date								
" " " "			Normal { Run								
" " " "			Juice { To Date								
" " " "			Dilute { Run								
" " " "			Juice { To Date								
" " " "			Syrup { Run								
Gals. Com'l. Molasses "			{ To Date								
Lbs. Sulphur per ton of Cane			Molasses { Run								
Lbs. Lime " " " "			{ To Date								
Reagents " " " "			{ Run								
			{ To Date								