Bulletin No. 82 1918

Agricultural Research Institute, Pusa

The Improvement of the Indigenous Methods of *Gur* and Sugar making in the United Provinces

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1918

Agents for the Sale of Books Published by the Superintendent of Government Printing, India, Calcutta.

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The Improvement of the Indigenous Methods of *Gur* and Sugar making in the United Provinces.*

THE improvement of the indigenous methods of *gur* and sugar making in the United Provinces has been under consideration for some years. The rapid increase in the imports of sugar before the war, caused some anxiety to those in authority, and steps were taken with the view of improving the sugar industry in India.

In the United Provinces a large quantity of sugarcane is grown; *gur* and sugar are made, some of which is sent to the Punjab and other parts of India. Consequently investigations were commenced in the Bareilly District. A small experimental factory was erected in 1914-15. The site chosen was the Government farm at Nawabganj between Bareilly and Pilibhit.

On this farm experiments are made in sugarcane growing and all the varieties grown have been analysed and tested as to milling properties, at the experimental factory, to find out the best varieties for local adoption.

So much depends on the nature of the soil, the manures used, the season, and the methods of cultivation, that nothing positive has as yet been found out as to which of the varieties are the best. For a sugar factory varieties ripening early and late are essential. Experiments point out that if *Saretha*, a tall thin cane, is sown a little earlier, it will perhaps be ready for crushing about the third week of November, though it may not obtain its full maturity. *Chin* also has a tendency to ripen early. *J. 33*, which is perhaps the best variety yet grown on this farm, would ripen in February, and *Dhour*, *Kagzi*, etc., in March. *Uba* and *Agoul* are two very good tall thick varieties, but they contain so much wax and gummy matter that it makes them very difficult to handle. A good deal of trouble was experienced with these varieties this year, the filters choking in half the usual time. The settling in clarifiers also was extraordinarily slow.

In 1915-16 it was intended to test the efficiency of the newly erected plant, but the late arrival of some of the machinery and the difficulty of obtaining a sufficient supply of cane were factors that spoiled the chance of a full season's work. However, the factory was worked whenever

* A note submitted to the Tenth Meeting of the Board of Agriculture, held at Poona in December, 1917.

cane could be obtained, and altogether it was worked for 54 days, sometimes for a few hours per day and at other times for 24 hours. During these spells of working, useful information was gained. The crushing and extracting capacity of the cane mill when working with six rollers, nine rollers, and eleven rollers, was tested. Numerous experiments were made in the clarification of juice. No doubt best and most upto-date scientific clarification methods are in vogue in big modern sugar factories, but the difficulty lay in the fact that the writers wanted to make the method as simple as possible. Simple lime clarification method was quite good, but, with the class of canes available, it did not produce white sugar. Sulphitation was therefore adopted. Sulphurous acid can only exercise bleaching effect in acid medium. In fact any acid will give light coloured juices, but then, in the first place, the inversion, though nominal up to the filters, was very high in the film evaporator with acid juices, though the product was quite white, and, in the second place, if calcium bisulphite was formed it went in solution and was reprecipitated in the evaporator. On the other hand juices slightly pink to phenol-phthalein gave better results as the danger of inversion was reduced and the voluminous precipitate of insoluble calcium sulphite carried down with it other coagulated impurities. This method was adopted in the latter part of the season this year, but it could not be fully tested. Next time it is expected to be given a full trial. To have the full advantage of sulphitation, the modern scientific world uses double sulphitation method, *i.e.*, they sulphite the syrup as it leaves the triples. This, though surely causing some inversion, cannot do any harm in vacuum pans where the temperature remains low, but here, where the temperature gets to about 98° or 99°, the danger of inversion is very great, therefore, it is yet to be seen what grade of product is obtainable without a second sulphitation and without leaving the juices slightly acid as till now. Filtration and concentration of the juice was tried in several ways, and the experiments led up to certain modifications of the plant and a few additional parts are being made at the Canal Foundry, Roorkee, and delivery has been promised by the middle of August 1917. If delivered in August they will be erected in readiness for the season 1917-18, when it is hoped that the factory will receive sufficient sugarcane for a full season's work. If the present monsoons are favourable a sufficient supply of sugarcane is assured.

In the season 1916-17 the sugarcane crop in the Bareilly and Pilibhit districts was a complete failure. Owing to the excessive rain, rust and smut destroyed much cane, and only a comparatively small quantity of a very inferior sugarcane was available.

The Agricultural Adviser to the Government of India, accompanied by the Director of Land Records and Agriculture, United Provinces, visited the factory on the 8th December, 1916, and was shown the hopeless condition of the crop.

Later on in the season an interesting experiment was carried on; a bundle of cane containing about 200 to 400 sticks was weighed each day successively for a week with the result that the average stick of cane weighed only 2·21 *chhataks* or about 4½ oz. as compared with 1½lb., the average weight of cane in the Peshawar District, where the senior author was invited by the Government of North-West Frontier Province to consider the possibilities of sugar manufacture in that province. Though the writers have no figures to show the weight of an average cane in countries like Java and Mauritius, yet they are sure that it is much more than at Peshawar.

Sugar and *gur* were made, analyses were made daily and further experiments were made in the factory, and the results recorded. (*See* the table of analyses in the Appendix.*) But with such a small quantity of inferior sugarcane the factory could not be tested as to efficiency or as to whether or not it could be made a commercial success.

After briefly describing the indigenous methods of *gur* and sugar making in these provinces, a description of the new experimental factory at Bareilly will be given.

Indigenous Methods.

A very large proportion of the sugarcane grown in these provinces is crushed by the small country-made mills, which have two or three rollers 8″ in diameter and are wonderfully cheap. They are, however, of a type which has been discarded by the modern scientific world on account of wastefulness; the rollers being arranged vertically, some of the expressed juice falling down by gravitation is picked up and carried away by the lower crushed canes passing from the mill and so is lost.

The mills are designed to be rotated by a pair of bullocks, such as are found locally, and give an extraction of about 50 per cent. when crushing good cane, which compared with the modern MULTIPLE MILL shows a loss of 25 per cent. at least.

From a broad economic point of view, the low extraction given by these mills is a national calamity, but from the cultivators' point of view, it is "Hobson's choice." He would like very much to get more

* *See* page 14.

juice, but he cannot afford to buy or hire a better mill and stronger bullocks, which would be necessary to get higher extraction, whilst, on the other hand, the *khandsari* (the native sugar manufacturer), to whom he sells the juice, does not like too much sucrose being taken out of the cane because it reduces the calorific value of the crushed cane as fuel, which he uses for boiling and concentrating the juice.

The Nahan Foundry THREE ROLLER MILL, which is an improvement on the type most commonly in use, has hardly found any favour with the ordinary cultivators, because it is more costly than the ordinary mill and the bullocks required to drive it need to be more powerful and consequently more costly than they can afford to keep.

Gur making indigenous method.

In *gur* making the juice after being expressed by the country mill is put into a shallow iron pan, about three feet six inches in diameter, under which is a furnace (a hole in the ground); the fuel used is dried leaves and the crushed cane dried in the sun. The juice is boiled and concentrated to about 44° "Beaume", specific gravity 1·438. The attendant, when the mass in the pan becomes very thick, takes out a little, dips it into cold water, and rolls it into a small ball, and by this means he can tell when it is ready. When ready it is ladled on to flat, circular, flanged plates, about 3 feet in diameter, made of clay and straw, on which a little quantity of *reh* or alkali earth has been sprinkled. The object of this *reh* is to improve the colour as well as to keep the stuff from adhering to the plates. A layer of the *gur* in a semi-liquid form, about one inch thick, is allowed to cool down to a certain degree which the coolies know by touch, then two coolies vigorously stir it up with wooden tools shod with iron, and when it becomes pliable like baker's dough it is shaped into cakes or balls or lumps to suit the market in which it is to be sold. Some *gur*-makers pass the juice through a cotton cloth to take out bits of cane and other impurities; others do not. In the Bareilly District a recovery of eight to nine maunds of *gur* per one hundred maunds of cane is made. This *gur* is inferior to the Meerut *gur* in colour and purity, which is probably due to the inferior cane and the dark coloured juice from it. It is said that in some districts the cane yields 10 per cent. of *gur* or even more.

Sugar making indigenous methods.

The country mills are usually hired by co-operant cultivators and are fixed up adjacent to the *bel**, which is owned by the *khandsari* who

* "Bel" = Indigenous factory.

pays money in advance to the cultivator to insure the supply of juice during the cane crop, for which the *khandsari* pays his own price to the cultivators who are often in debt to him. It is to be noted that the *khandsari* buys the juice ; he does not buy the cane, so that if there is a bad season, or a succession of bad seasons, and the crop is poor, the cultivator suffers and not the *khandsari*. When the climatic conditions cause the canes to be stunted and the fibre content is high, it often happens that the juice is rich, so that the *khandsari*, buying the juice by measure, gains and the cultivator loses.

The *bel* usually contains five iron pans of the cheapest possible kind, which are built up on a furnace made of mud, in a mud house roofed with grass. One cannot conceive anything that would be less costly. The pans vary in size ; the juice is put into the largest pan and boiled and evaporated until it is reduced in volume by 50 per cent., it is then ladled into the next pan and further evaporated and concentrated and so on until it reaches the fifth pan where it is highly concentrated and made ready for crystallizing out. It is then placed in large earthenware vessels about two feet high and one and a half feet in diameter. After partial crystallization the stopper is taken from a small hole in the bottom of the vessel and the molasses is allowed to drain off. A river grass called *sewar* (*Vallisneria spiralis*) is placed on the top of the sugar to a thickness of two or three inches, which has the effect of removing the molasses on account of moisture and its power to retain heat, bleaching the sugar to a depth of half an inch or more.

The *sewar* is changed daily until the whole contents of the vessel have been treated. The sugar taken off each day is taken to the *pata*, a level floor surrounded by a low wall. The sugar is here dried in the sun and crushed by coolies walking on it and twisting their feet as they walk. This is called *swadeshi* sugar for which orthodox Indians will pay higher price than can be obtained for the high class modern factory sugar.

There is another indigenous process in which the *rab** is put into gunny bags, placed one upon another six or seven high ; a cooly stands upon the top bag supported by a pole and sways backwards and forwards, and by this means most of the molasses is separated from the sugar. The bags are then emptied into wooden bins and the sugar is treated with *sewar* grass as mentioned before, then sun-dried, and ground by coolies walking on it with the twisting movement of feet. By these indigenous processes the recovery of sugar from 100

* "Rab" = Mixed crystallized sugar and molasses.

maunds of cane is 3 maunds as against 10 maunds by the modern process in tropical countries.

There is another process in which after concentration in the five pans the massecuite *rab* is put into *kalsis*, earthenware vessels holding about forty pounds, and when it has crystallized out it is centrifuged ; the molasses then taken off is again boiled and concentrated and a second sugar is made and the molasses is again spun off in the centrifugal machine, and although it is still rich in sucrose it is sold for mixing with tobacco and cattle feeding. The produce by this process is about 4%.

Any improvement of a permanent character would probably cost a hundred times the amount or more than what is spent on the temporary mud-house and arrangement of pans. The cultivators have no money to spend, and the *khandsaris* who are rich do not desire any change.

Some of the more prosperous cultivators have adopted, and others are inclined to adopt, power-driven mills, and the kind of power most favoured seems to be the oil-engine.

It is an ideal scheme to have some kind of motive power, other than bullocks, on a farm, but if it were assumed that oil-engines could be worked successfully by the cultivators, and that they could be used for driving sugarcane crushing mills, the question arises as to whether their use could be made a commercial success. Would the general adoption of oil-engines in sugar production be likely to check or reduce the rapid increase in the importation of sugar recorded previous to the war ? The senior author ventures to say that it would not.

In a modern factory crushing, say, 1,000 tons of cane per day (which is a moderate quantity), little or no fuel is required other than megasse. In the case of the oil-engine-driven mill the cost of the oil would be a serious handicap.

The extraction of juice by the THREE ROLLER MILL, no matter how powerful, must be less than that obtained by a FOURTEEN ROLLER MILL or a TWENTY ROLLER MILL with maceration or imbibition such as are now used in modern factories ; and in any improved factory it is essential that a MULTIPLE MILL be used to ensure high extraction.

The climate of the United Provinces is not as favourable to the growth of sugarcane as is the climate of the tropical sugar-growing countries. In Bareilly District very cold weather, and sometimes frost, occurs in December and January just at the time when the cane is ripening ; growth is stopped and glucose keeps high as will be seen on reference to the Appendix. It has been found that the cane, especially the thicker and softer varieties, are not ripe until February,

so that the cane crushed previously is high in glucose, low in sucrose, and the density of the juice low, which is a considerable disadvantage when compared with countries where there is neither frost nor cold weather.

The following amazing figures which are quite reliable will serve to show the best and the worst sugar production that the writers know of:—

Sugarcane produced per acre.

	Maunds
Java	1,100
Bareilly District	250

Sugar produced per acre.

Java	110
Bareilly District (indigenous methods)	7½
	Tons
100 acres of cane in Java yield	404
100 acres of cane in Bareilly yield	27¾

In the Bareilly District it is impossible to get an out-turn equal to Java, but improved cultivation and modern factories would very much improve matters as the following figures will show.

On the Government Farm, Bareilly District, a sugarcane, *J. 33*, was produced at the rate of 600 maunds per acre, and at an adjacent sugar factory, Pilibhit, 7½ per cent. is the recovery of sugar from indigenous cane. This works out at 45 maunds of sugar per acre, which is a considerable improvement on 7½ maunds by the indigenous methods.

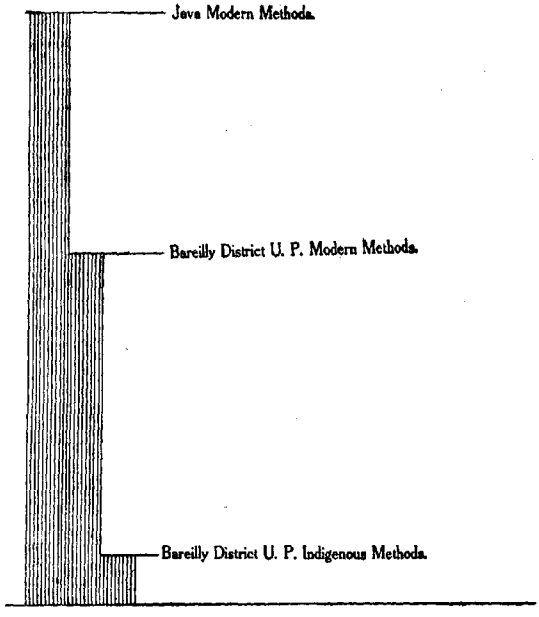
By means of intensive cultivation it is possible to produce on this farm 800 maunds of cane per acre, and it is likely that with the better cane the recovery of sugar at the factory (Pilibhit) would be brought up to 8 per cent. This would give a recovery of sugar per acre of 64 maunds.

Sugar produced per acre.

	Maunds
Java (modern methods)	110
Bareilly District (modern methods)	64
Bareilly District (indigenous methods)	7½

(*vide* Diagram below).

Diagram of Sugar Produced per acre.



Sugar imported into the United Provinces from Java has to bear considerable charges, which go far, no doubt, to level up the prices.

Import duty 10 per cent., shipping freight, railway freight, handling in Java at the docks and at Calcutta, warehousing, agents' fees, etc., amount to a considerable item, which must be debited against Java's production.

The writers have had no opportunity of obtaining reliable figures of the cost of production of sugar per acre in each case, which would have been very interesting for the purpose of comparison.

At least we see by the above comparative figures that the very best cultivation is necessary and factories of the highest efficiency are essential, if India is to compete in her own sugar markets.

Experimental Factory, Bareilly.

The factory (Plate I, fig. 1) was erected in 1914-15, and the plant was designed by the senior author with the view of improving the indigenous methods and, in his opinion, it is the smallest plant that could be worked on a commercial basis. Care has been taken to make the machinery and process as simple as possible, so that the superskilled management and highly technical supervision, so essential in large modern factories, would not be necessary.

In the initial stages the plant is being worked under expert technical control, with a view to find out whether a plant like this could be confidently placed before the public as the first step towards improvement of the methods of indigenous sugar manufacture, which small capitalists, such as zemindars or ordinary *khandsaris*, would be able to go in for. An attempt is being made to produce white sugar without the aid of a vacuum pan, and all its appurtenances which are so costly, requiring expensive highly trained men to control.

The experimental work was proceeded with during the seasons 1915-16 and 1916-17, but it was found to be impossible to obtain sufficient sugarcane to run the factory for a complete season, especially as the sugarcane crop in 1916-17 was a complete failure in the Bareilly District, only a small quantity of very inferior cane being available.

The local cultivators were found to be so much in debt to the *khandsaris*, who freely give advances to ensure a supply of juice during the season, that they could not sell their cane to the factory even when offered higher prices than the *khandsaris* gave.

The cane grown in the locality by the ordinary cultivators is of a very poor quality, as will be seen by a reference to the Appendix.

The most favoured varieties of cane are *Chin*, *Padaria*, and *Dhour*. The *Chin* is a cane with a hard rind and a fibre content of 17 per cent. to 19 per cent. *Dhour* and *Padaria* have a fibre content of about 15 per cent. The cultivators plant the hardest varieties of cane which will have the least chance of being damaged by wild pigs and other animals which abound in this district.

On the Government Farm, Bareilly District, softer varieties have been grown, but it has been necessary to use wire fencing to keep out

the pigs. This could not be done by ordinary cultivators owing to the high cost of the fencing.

Experiments at the Farm with new varieties of cane were made in 1915-16, but last season the excessive rain spoilt the crop.

In consequence of the insufficient supply of cane to the factory it worked only 54 days in 1915-16 and 44 days in 1916-17, consequently the cost of labour and fuel was much higher than it would have been, had the factory worked continuously for a season of four months, which is the average duration of a season in the United Provinces.

To return to the plant, it was found that the evaporating power of the plant was not equal to the crushing power of the mill, therefore it has been necessary to increase the plant by the addition of another film evaporator, which will bring the evaporating capacity equal to the crushing capacity of the cane-mill, and three crystallizers to do away with the earthenware vessels used for crystallizing, which proved to be inefficient. The new additions are expected to be erected in time for the season 1917-18.

Description of the Plant.

The cane-crushing mill (Plates II and III) is a compact arrangement of eleven rollers, and is capable of crushing one ton per hour (27·2 maunds). There are no intermediate carriers as is usually the case in multiple mills. These have especially been avoided to keep the price of the mill as low as possible. The cane in process of crushing passes by gravitation from roller to roller and is finally delivered on to the firing platform in front of the steam boiler, from whence it is thrown into a specially constructed megass furnace attached to the boiler. The dimensions of the rollers are :—The Krajewski rollers 9″ dia., top three $9\frac{3}{4}$″ dia. 15″ long ; middle three 10″ dia. 15″ long ; and bottom three $10\frac{1}{4}$″ dia. 15″ long. When crushing at the rate of 30 maunds per hour the extraction of juice from the inferior cane supplied averaged, in 1915-16, 62·5 per cent. for the whole period of the trials when out of 54 days the factory was worked 9 days with six rollers only (*see* Appendix), and in 1916-17 the extraction was 64·98 per cent. The sucrose extracted in juice from 100 in cane averaged 85·34 for the season 1916-17.

The juice on leaving the mill is strained through a sieve and passes into a tank from whence it is pumped to the top of a wooden chamber. In falling through this chamber the juice is broken up into minute streams by means of specially constructed obstacles fixed in the chamber.

Sulphur fumes, generated in a small furnace by burning sulphur, are made to travel upwards by means of a steam jet which induces a current of the sulphur fumes to mix with the juice. The object of this is to bleach the vegetable-colouring matter present in the juice, and have a heavier precipitate of lime salts in the clarifiers, which would effectively envelope the coagulated gums and pectines and settle with them at the bottom. The juice then falls into a tank where it is weighed and mixed with milk-of-lime to neutralize the acids present. The attendant uses litmus paper to guide him in neutralizing the juice. It is then pumped into the clarifiers, which are tanks, two in number, fitted with copper steam coils. In these the temperature of the juice is raised until a scum has formed, which is carefully removed and afterwards pressed to recover the juice it contains. After the scum has been removed flocculent particles of lime sulphite, sulphate, and other impurities in suspension gradually settle to the bottom. The clear juice is then decanted off by means of a pipe supported by a float, and run into a filter composed of specially woven cotton bags.

The juice coming from the filter is bright and clear and ready for concentration. This is done by means of a film evaporator (Plate IV), a vessel of copper in which revolves a cylinder made of copper pipes, which are heated by the exhaust steam from the engine that drives the cane-mill, etc., supplemented by a small quantity of steam direct from the boiler.

When the juice is concentrated to a given density (40° Beaume), specific gravity 1·383, it is ready for making sugar and is put into the crystallizers (Plate V) to grain out; or if it is intended to make *gur* it is further concentrated to about 44° Beaume, specific gravity 1·438, then poured into earthenware vessels, and is ready for sale in a few days.

After graining the sugar is separated from the molasses in a centrifugal machine (Plate VI), and after drying is ready for the market.

The molasses is boiled again and put into masonry tanks, where it remains until it crystallizes out and is again centrifuged. The sugar taken from this is called second sugar, and is darker in colour than the first sugar. The molasses from this is again boiled and again allowed to crystallize to get out as much sugar as possible. The sugar from this is called third sugar.

The scum and settlings from the clarifiers are put into a tank in which there is a steam coil. They are limed to alkalinity and boiled violently, and the clear alkaline juice is pressed out, leaving a solid cake

which is useful as manure. The juice from this residuum is mixed with the raw juice in the liming tank after it has been weighed. The filter press, however, proved to be too small to cope effectually with the scums when the factory worked day and night, and so the scums had to be run in filter bags. An experiment to find out the loss in filter bags mud, which analysed comparatively high, was carried on this season, and weights of mud were taken successively for several days. The average figures are :—

	Mds.	Seers.
Average weight of filter bags mud per day . . .	5	10
Weight of mud on the weight of cane	1·6	per cent
Loss of sucrose in mud on cane	0·2	„

The crushed cane—megass— is used for generating steam in a multi-tubular boiler. When the cane mill is working no other fuel is required, but when it is stopped wood fuel is necessary to keep up steam to drive the film evaporator and centrifugal.

Below are given figures to compare good and ripe canes with unripe and bad canes :—

	Good quality unripe	Good quality ripe	Ordinary quality unripe	Ordinary quality ripe
Variety of cane . .	J·33	J·33	Dhour	Dhour
Date of analysis . .	22nd Nov., 1915.	16th March, 1916.	18th Nov., 1915.	24th Feb., 1916.
Juice analysis—				
Sucrose . . .	13·79	20·40	10·44	15·40
Invert sugar . . .	1·69	0·32	2·32	0·89
Purity	81·85	91·48	75·22	87·00
Brix degrees . . .	16·86	22·3	13·88	17·7

There is promise of a sufficient supply of cane to keep the factory working during the season 1917-18, and, if the cane is supplied, the factory will be tested as to the possibilities of success as a commercial concern, and a report showing the result of the season's work will be issued in due course.

At the time the foregoing Note was written, there was some doubt as to whether the new machinery then being made by the Canal Foundry and Engineering Works, Roorkee, would be ready and erected by the beginning of the sugarcane crushing season. This point has now been cleared up ; the three new crystallizers and the film evaporator are now erected at the Nawabganj Experimental Factory, and the steam connections will be completed in time for the new crop.

The cane has turned out to be very good compared with other seasons. The larger varieties grown on the Government farm are excellent, *Assami White*, *J. 33*, and *Ashy Mauritius* are particularly good in size and healthy. A small quantity of *Uba* has been destroyed by rust. It is possible that the above-mentioned varieties may be still further improved by deeper trenching and perhaps by using other manures than have been used on this farm previously, if so, there might be a chance of increasing the height of the middle figure in the diagram (p. 8), which if accomplished would be worth any number of experiments.

Now that it has been demonstrated that good cane can be grown in this district, the senior author ventures to suggest that it might be advantageous to continue the experiments both on the farm and in the factory, to find out the results that could be obtained by means of a FOURTEEN ROLLER MILL such as is used in other sugar-producing countries. The FOURTEEN ROLLER MILL has become very popular and may be said to be a standard type in other countries.

It is to be noted that (as far as the senior author knows) there are no fourteen roller mills in the United Provinces or Bihar ; the sugar factory proprietors have not ventured beyond eight rollers except in one case, nine rollers, and another eleven rollers.

The cane mill at the experimental factory at Nawabganj has eleven rollers, and it is suggested that a three roller unit be added and attached, which would make it into a fourteen roller mill, and that vacuum evaporation be adopted.

Most of the additional plant necessary for this experiment could be obtained in India, the whole of which, including housing, would cost about Rs. 20,000.

APPENDIX.

I. Statement showing Weekly Averages, 1915-16.

Factory started work on 6th December, 1915.

Week ending	Total cane crushed during the week		Total juice extracted during the week		Percentage of extraction	Average analysis of juice				Sucrose in bagasse	No. of working days in the week	Remarks
						Sucrose	Glucose	Purity	Total solids (Brix's)			
	Mds.	Srs.	Mds.	Srs.								
11th December, 1915	209	11	170	0	56·80	12·68	1·72	77·03	16·42°	5·34	3	With nine rollers.
	367	23	200	10	54·47	12·92	1·57	78·05	16·55°	6·71	3	With six rollers. One of the pinions of megass rollers broke down on the 8th on account of a piece of iron coming between the rollers.
18th December, 1915 .	1,163	15	645	10	55·46	13·17	1·81	76·52	17·25°	6·49	6	With six rollers.
25th December, 1915 .	342	24	188	35	55·12	12·40	1·82	75·91	16·30°	6·79	2	Closed for Christmas holidays as the cane was unripe.
1st January, 1916 . .	Holidays											
8th January, 1916 . .	1,078	9	688	15	63·84	13·78	1·38	78·29	17·53°	5·32	6	With eleven rollers for 4 days and nine rollers for two days.
15th January, 1916 .	1,708	22	1,105	10	64·68	15·19	1·33	79·23	19·16°	5·40	6	With nine rollers. Night and day work started from 12th January, 1916.
22nd January, 1916 .	1,974	15	1,277	25	64·70	13·60	1·72	78·65	17·28°	5·45	6	Farm cane unripe and so the analysis rather tends to go down.
29th January, 1916 .	1,967	12	1,271	20	64·63	13·97	1·50	79·83	17·49°	5·52	6	
5th February, 1916 .	773	35	496	20	64·15	13·80	1·38	80·07	17·23°	5·03	3	Worked night and day till 31st and then one day in the day only.
12th February, 1916. .	Closed											
19th February, 1916. .	680	5	431	10	63·40	14·40	1·43	79·04	18·21°	5·41	4	
26th February, 1916. .	1,120	9	705	20	62·97	15·20	1·58	77·45	19·62°	5·63	5	Worked day and night on the 23rd.
4th March, 1916 . .	424	9	260	0	61·28	14·39	1·76	70·00	18·78°	4·56	3	Crushing finished on the 2nd March, 1916.
26th March, 1916 . .	149	14	95	20	64·27	19·40	1·09	86·41	22·45°	6·37	1	J. 33 and other big canes specially supplied by the Government farm. With 11 rollers.
Total .	12,049	3	7,535	35	62·54	14·02	1·57	78·5	17·87°	*5·66	54	*Moisture 50·3. Out of 54 days the factory worked night and day for 18 days.

SUGARS			GURS					RABS					
Quality	Sucrose	Remarks	Quality	Sucrose	Invert sugar	Co-efficient of purity*	Total solids (Brix's)	Remarks	Quality	Sucrose	Invert sugar	Purity	Total solids (Brix's)	REMARKS.
Refined sugar	99·7	Dry	First gur	69·6	10·10	77·77	89·49°	Those juices which were found to contain high glucose were boiled into gur. Experiments were tried to make gur out of molasses first and second both.	Rab in first masonry tank	46·7	18·42	57·05	81·00°	Mixture of the boilings of 1st and 2nd molasses.
J. 33 (cane) sugar	99·4	Nearly dry												
First sugar, first quality	99·2	Dry	First molasses J. 33 gur	70·9	10·58	80·79	87·75°		Rab in second masonry tank	48·1	18·86	58·69	81·95°	Do.
First sugar, second quality	98·6	Do.							First molasses rab (reboiled) in *kalsis*	54·4	19·55	61·15	88·95°	The first time boiling was not thick enough, so it was reboiled. In *kalsis*.
First sugar, third quality	96·7	Half dried	First molasses gur	57·2	17·71	64·19	89·10°							
Second sugar	97·6	Do.							Second molasses rab	52·8	19·55	60·34	87·50°	
Bad sugar, Rooric, etc.	91·0	Do.	Second molasses gur	52·2	19·0	57·80	90·30°		Second molasses rab combined with filter press juice	54·2	15·87	63·91	84·80°	Do.

Some of the sugars were sold without being dried and sieved. Some of very dirty sugar was refined.

(ii)

STUFF	Sucrose	Invert sugar	Ash	Water	Organic matters other than sugars	Co-efficient of purity	Rendement†	Total solids (Brix's)	REMARKS
First molasses	51·00	9·82	..	..	..	69·11	..	73·94°	Average analysis.
Second molasses	39·63	19·69	..	..	..	50·52	..	78·48°	Do.
Juice	14·30	1·48	0·28	81·99	1·95	79·35	11·84	18·01°	Average full analysis.
Molasses	43·60	15·38	5·49	23·49	12·04	56·98	9·01	..	Full analysis of a mixture of 1st and 2nd molasses.
Filter bags mud	14·00	..	..	..	..	..	..	..	Taylor's bag filter began to work from 16th February, 1916.
Filter press mud	7·56	..	..	..	..	..	..	..	Filter press began to work from 26th February, 1916.

* Co-efficient of purity = Percentage of sucrose on the total solids.
† Rendement = Available sugar.

III. Statement showing the Analysis of Farm Experimental Cane, 1915-1916.

Month and Date	Variety of cane	Field number	Weight of cane crushed	Weight of juice expressed	Percentage of mill extraction	Total sucrose in cane	Percentage of sucrose extracted in juice from 100 in cane	Analysis of juice. Sucrose	Glucose	Co-efficient of purity	Total solids (Brix s)	Specific gravity of juice at 24° C.	Sucrose in bagasse	Remarks
			Mds. Srs.	Mds. Srs.										
January 1916 4	Kinar .	D. $\frac{1}{7}$	74 7	48 25	65·55	11·57	83·84	14·80	1·15	80·87	18·30°	..	5·42	
,, ,, 6	J. 33 .	C. $\frac{1}{6}$	37 14	25 20	68·27	12·24	86·27	15·47	1·88	81·76	18·92°	1·074	5·31	Sown on the flat (eaten by pigs and jackals fallen dry cane).
,, ,, 13	Saretha .	C. $\frac{1}{3}$	126 8	72 5	57·15	10·64	79·88	14·88	1·62	77·90	19·0°	1·074	4·99	
,, ,, 13	Do. .	C. $\frac{1}{2}$	114 23	77 0	67·20	The analysis was not done on account of the pressure of work.								
,, ,, 13	Do. .	C. $\frac{1}{4}$	101 22	65 35	64·87	11·71	84·60	15·20	1·48	77·45	19·74°	1·080	5·10	
,, ,, 14	Do. .	C. $\frac{1}{5}$	125 14	82 10	65·61	12·88	83·77	16·46	1·07	82·63	19·92°	1·081	6·05	Comparatively unripe. A few sticks of this on 25th February, 1916, gave analysis of juice :— Sucrose Glucose Purity 16·80 0·88 87·03 Brix degrees. 21·6.
,, ,, 17	Kagzi .	C. $\frac{1}{8}$	150 18	102 15	68·04	10·17	83·35	12·46	2·11	77·58	16·06°	1·061	5·31	Quite unripe. *Rab* made from it was very slow to crystallize out. Analysis of *rab* is— Sucrose Glucose 61·4 8·86.

,,	,,	18	Dhour	.	C. ½	143 33	97 15	67·70	11·16	83·16	13·71	1·65	80·65	17·00°	1·065	5·84	Unripe.
,,	,,	20	Kagzi	.	C. ½	143 28	94 0	65·41	8·91	81·03	11·05	2·32	72·12	15·32°	1·059	4·89	Quite unripe.
,,	,,	21	Saretha	.	C. ½	106 6	68 5	64·18	12·57	85·76	16·80	0·75	85·45	19·66°	1·078	4·99	
,,	,,	22	Dhour	.	C. ½	120 34	83 5	68·79	10·44	83·52	12·08	1·79	78·32	16·19°	1·063	5·52	Quite unripe.
,,	,,	24	Neora	.	C. ½	131 32	84 20	64·11	11·32	81·53	14·40	1·93	77·41	18·60°	1·076	5·84	Unripe.
,,	,,	25	Dhour	.	C. ½	139 0	91 25	65·91	11·05	82·96	13·91	1·79	79·44	17·54°	1·070	5·52	Do.
,,	,,	26	Kuswar	.	C. ½	53 32	37 10	69·23	..	..	12·10	1·70	77·91	15·53°	..	..	
,,	,,	27	Dhour.	.	C. ½	122 21	79 35	65·19	11·72	82·34	14·81	1·19	84·67	17·49°	1·070	5·95	Unripe.
,,	,,	28	Kagzi	.	C. ½	49 14	31 10	63·32	10·86	82·09	14·08	1·55	81·38	17·30°	1·068	5·31	Do.
,,	,,	29	Khari	.	C. ½	52 13	34 10	65·45	11·07	85·07	14·39	1·86	81·76	17·00°	1·070	4·78	Do.
,,	,,	30	Kagzi	.	C. ½	28 37	19 0	65·68	11·52	83·23	14·60	0·91	83·43	17·50°	1·070	5·63	
,,	,,	31	Do.	.	C. ½	20 25	13 0	63·03	10·30	82·26	13·20	1·67	79·52	16·60°	1·064	5·10	Unripe.
March	,,	2	Dhour	.	C. ½	49 20	31 35	64·10	9·43	84·62	12·46	2·03	72·06	17·29°	1·067	4·03	Diseased cane, a few good sticks from this, on 24th February, gave analysis of juice :— Sucrose Glucose Purity 15·4 0·89 87·0 Brix degrees. 17·7.
,,	,,	26	J. 33	.	C. ½	127 19	80 15	63·05	14·58	83·88	19·40	1·09	86·41	22·45°	1·095	6·37	Sown in trenches. Lying for 12 hours before it was crushed. Fresh sticks, on 16th March, gave a nalysis of juice :— Sucrose Glucose Purity 20·40 0·32 91·48 Brix degrees. 22·3.

IV. Statement showing Average Analysis of Products, 1916-1917.

(*i*)

Sugars			Gurs				Molasses					
Quality	Sucrose	Remarks	Quality	Sucrose	Invert sugar	Remarks	Quality	Sucrose	Invert Sugar	Co-efficient of purity	Total Solids (Brix's)	Remarks
First sugar (first quality)	99·30	From the crystallize, dried in the laboratory	First gur	76·11	6·42	From cane juice direct	First molasses	45·32	14·11	57·80	78·53°	Molasses from juices slightly acid to litmus paper. This was made into *gur* but had to be remelted as it could not be sold.
First sugar (second quality)	98·60	From *kalsis*, dried in laboratory	Second gur	71·45	7·40	Mixture of juice and first molasses	Do.	55·02	6·17	75·38	73·01°	Molasses from juices slightly pinkish to phenol-phthalein. This was made into *rab* again.
Second sugar	97·30	..	Third gur	64·27	11·15	First molasses gur	Second molasses (thick)	46·56	14·40	58·82	79·23°	Contained no washings.
Third sugar	95·70	..	..	..	..	..	Second molasses (thin)	48·40	7·02	73·24	65·90°	Washings after the thick molasses had gone out.
Boorie	90·2	Small lumps of sugar with bits of *kalsis*	..	..	..	..	Third molasses	43·80	14·51	54·95	79·70°	

Stuff	Sucrose	Invert sugar	Ash	Water	Organic matters other than sugars	Co-efficient of purity	Total solids (Brix's)	Rendement*	REMARKS
Second sugar . .	97·10	0·45	1·21	0·72	0·52	97·8	..	..	Full analysis of a sample of sun-dried sugar.
First *gur* . . .	77·20	5·87	2·70	..	..	..	..	57·83	Average analysis.
Second *gur* . .	71·60	7·19	3·05	..	..	..	..	49·15	Average analysis.
Third *gur* . .	66·00	11·50	6·25	9·50	6·75	72·92	..	32·63	Full analysis of a sample.
First molasses . .	44·60	14·16	5·62	25·65	9·97	59·98	..	10·77	Ditto.
Second molasses .	44·80	15·66	5·67	21·05	12·82	56·75	..	9·30	
Juice . . .	15·35	1·34	0·47	80·32	2·07	80·03	19·18°	12·81	Full average analysis of a few samples.
Filter press mud .	9·58	..	..	..	..	..	..	..	Average analysis. The filter press was found insufficient to cope with the scums, when the Factory worked day and night, and so it only worked for about a week.

* For 1st and 2nd *gurs*, which was sold to Pilibhit Factory, the formulæ, Sucrose—(5 ash + Invert sugar) has been used. For others the usual formulæ, Sucrose—(3½ ash + Invert sugar).

V. Statement showing Weekly Averages, 1916-1917.

Factory started work on 6th December, 1916, at 4 p.m.

Week ending	Total cane crushed during the week	Total juice extracted during the week	Percentage of extraction	Average analysis of juice.				Sucrose in bagasse	Sucrose in filter bag's mud	Number of working days in the week	Remarks
				Sucrose	Invert Sugar	Co-efficient of purity	Total solids (Brix's)				
	Mds. Srs.	Mds. Srs.									
9th December, 1916	438 13	287 15	65·56	13·94	1·39	78·66	17·72°	5·85	10·60	4	Working in the day only.
16th December, 1916	The factory remained closed.										
23rd December, 1916	(i) The chimney was raised up, as the draught was insufficient, the fan having broken.										
30th December, 1916	(ii) The Sugar Engineer, Expert went to Peshawar to consider the question of sugar manufacture in N.-W. F. Province.										
6th January, 1917	(iii) Christmas Holidays.										
13th January, 1917	1,617 29	1,057 5	65·35	14·00	1·47	77·37	18·09°	4·76	10·70	6	Working day and night.
20th January, 1917	1,909 2	1,196 30	62·69	14·10	1·86	75·86	18·59°	4·64	11·64	6	Ditto.
27th January, 1917	1,820 20	1,168 10	64·17	15·40	1·64	77·66	19·82°	5·03	12·02	6	Ditto.
3rd February, 1917	1,336 38	871 15	65·17	14·92	1·33	79·34	18·80°	4·83	11·90	5	Ditto.

10th February, 1917	538 5	360 5	66·92	13·97	1·52	77·90	17·93°	5·41	12·80	4	Worked in the day only. The weather was very rough during the week. Heavy rains and high winds prevailed throughout. 71 maunds 37 seers of cane at the factory and some at the fields was lying for 48 hours before it could be crushed. No carts were available to cart cane. That is why the Brix has appreciably gone down.
17th February, 1917	636 22	397 0	62·37	14·78	1·41	78·60	18·81°	5·43	12·90	5	Day only. The cane supply to the factory lessened.
24th February, 1917	93 7	63 5	67·74	15·90	1·65	77·79	20·44°	5·84	12·40	1	Village cane finished.
3rd March, 1917	430 28	310 20	72·92	15·43	0·93	81·72	18·88°	5·47	13·80	3	All farm cane, Uba and Agaul varieties.
10th March, 1917	273 31	191 35	70·08	14·77	1·20	79·14	18·64°	5·18	14·20	3	Ditto.
17th March, 1917 24th March, 1917	Cane season was practically finished. The time was occupied in remelting *gur*, which was made out of the 1st molasses and which could not find sales on account of the prejudices of the people who would buy nothing but *bhelis* or *gur* in lumps										
31st March, 1917	95 36	66 5	68·95	18·10	0·41	88·03	20·56	5·21	14·60	1	Thick Pounda canes from the Government farm.
7th April, 1917	205 12	136 15	66·42	No chemical analysis was done. Things were packed up.							
TOTAL	9,396 3	6,106 0	64·98	14·66	1·45	78·36	18·70	5·13	12·24	44	Out of 44 days, the factory worked day and night for 23 days.

VI. Statement showing the Out-turn for 1916-17.

	Mds.	Srs.	Chs.	
I Sugar	177	28	15	
II „	33	17	0	
III „	2	15	0	
Roorie	9	36	12	
	223	17	11	
1 Gur	377	27	12	
I and II molasses *gur* in *bhelis* . .	4	18	8	
Rab in tank (sold)	134	35	0	
Rab in *kalsis* (267)	93	18	0	calculated.

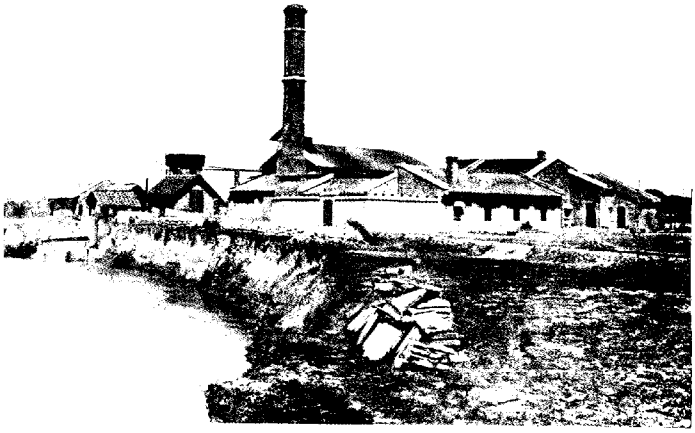


Fig. 1. EXPERIMENTAL FACTORY, BAREILLY.

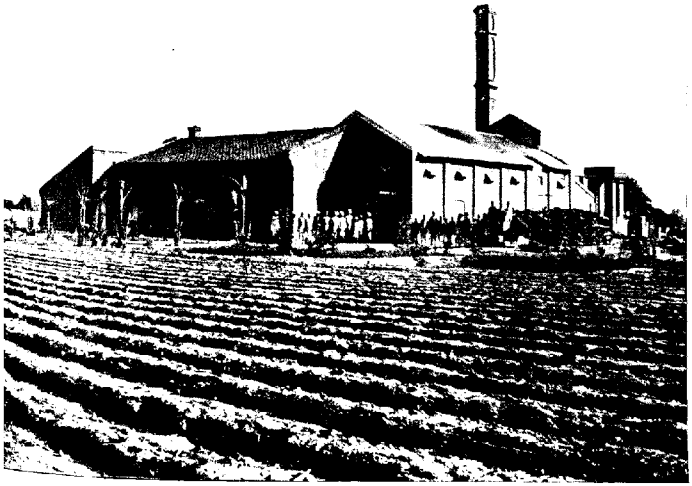
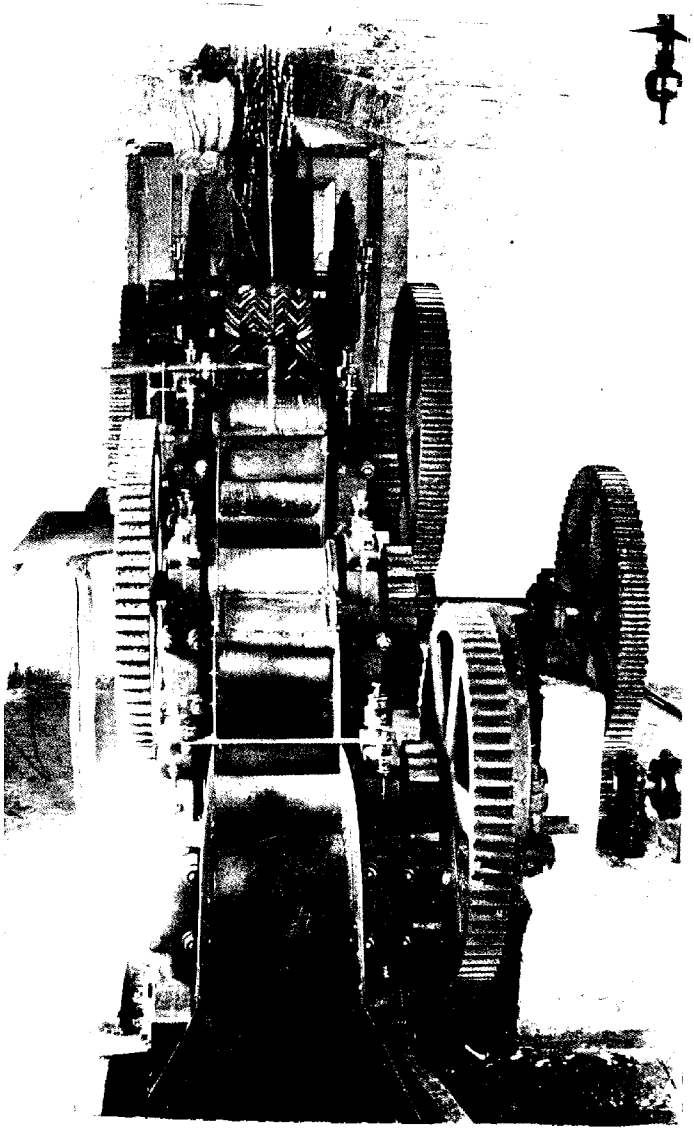


Fig. 2. LAND PREPARED FOR SUGARCANE.



FRONT VIEW OF CANE MILL.

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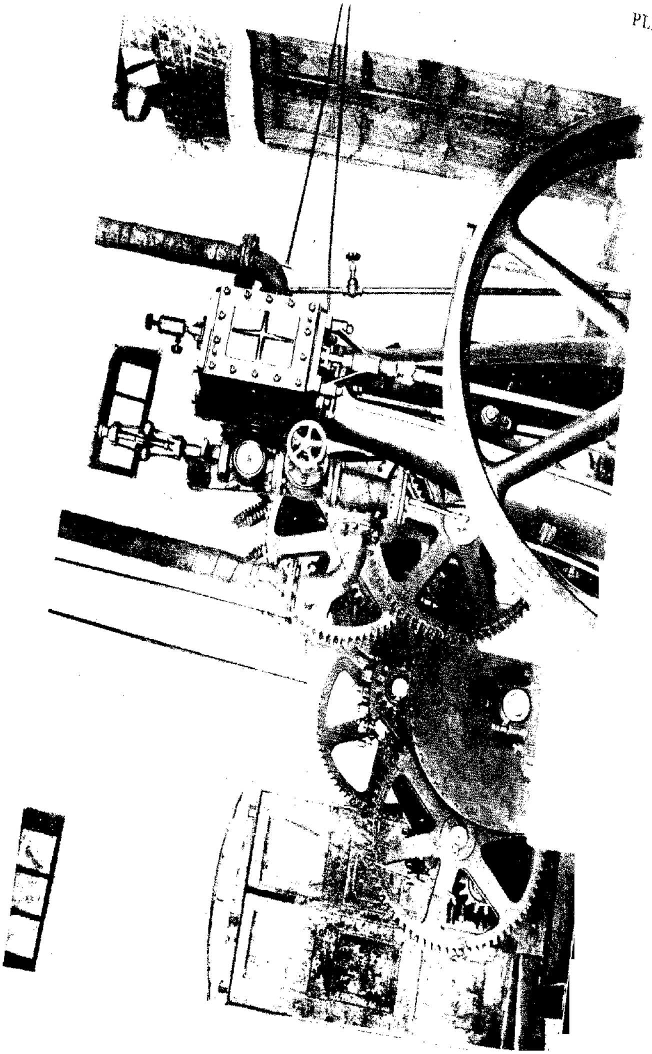
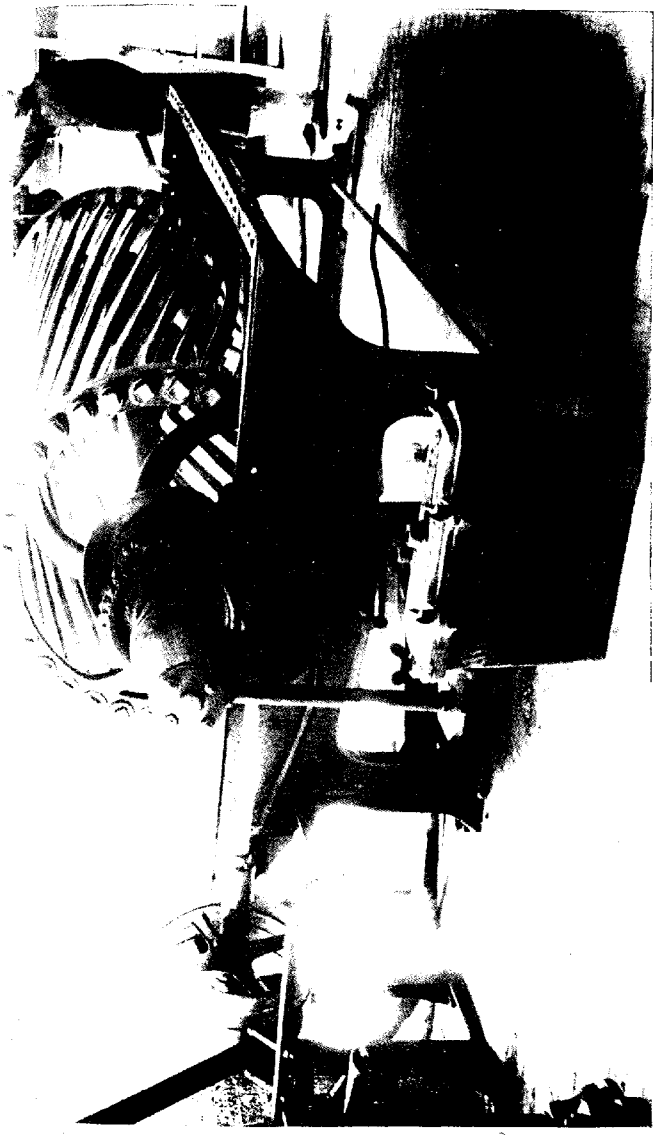
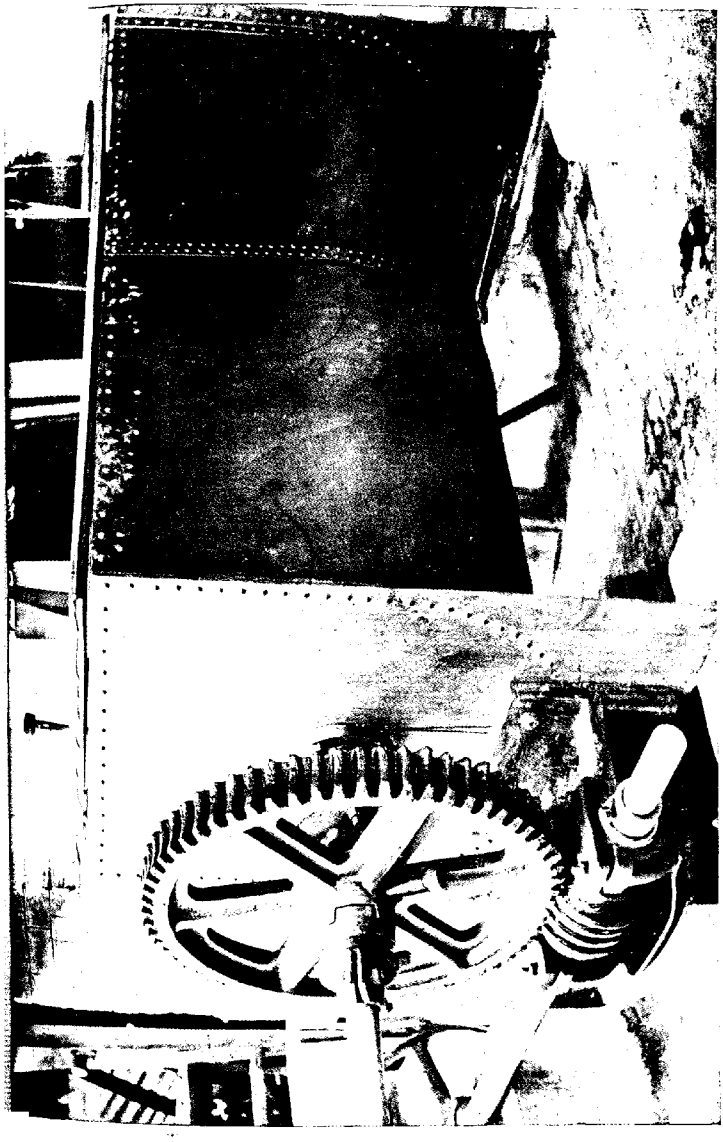


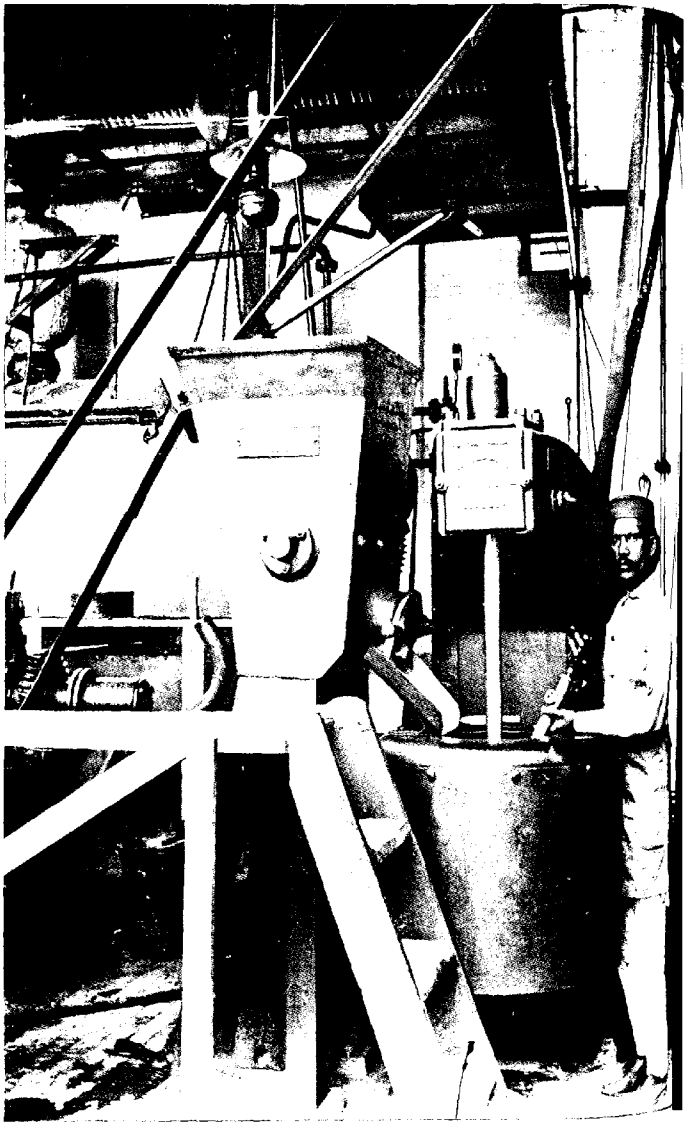
PLATE IV



FILM EVAPORATOR.



CRYSTALLIZER.



A, PUG MILL; B, LIMING TANK; C, CENTRIFUGAL MACHINE.

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