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Objects of I.S.S.C.T : "to promote the discussion of the technical problems of the sugarcane industry in both field and factory, by means of conventions held as far as practicable every three years, and to foster at all times the free and frank interchange of technical information by medium of publications or other means."

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ENGINEERING SECTION

Session—Friday, 27th January, 9-15 A.M.

Mr. K. S. Arnold, *Chairman*

The *Chairman* delivered the following opening address.

In this opening address I need only refer briefly and in general terms to the developments which have taken place recently in Sugar Engineering, as many of the aspects are dealt with in the papers presented to the Section, and in the Symposium, and will therefore be the subject of detailed discussion among delegates at the Sectional Meetings. While there have naturally been general improvements in all classes of cane sugar machinery since the Eighth Congress of the Society was held in the British West Indies in 1953, the most notable advances have undoubtedly taken place on cane crushing mills. For this reason it is appropriate that the subject chosen for the Symposium of the Engineering Section should be " Recent Developments in Sugar Cane Mills ". The following is a brief review of the trend of recent developments in cane sugar machinery.

Cane Crushing Mills. In the recent operation of mills the tendency has been further to increase crushing rates, and to this end there has been an appreciable increase in roller surface speeds. Whereas some years ago 30 ft. per min. was to be considered reasonably fast, in some cases almost double this figure is now being achieved, and on certain new milling plants speeds as high as 75 ft. per min. are envisaged.

Cane Feeding and Juice Drainage. The increase in roller surface speed, coupled with the associated increases in crushing rate, have brought into prominence certain milling problems, notably those of cane feeding and juice drainage. In order to assist in the feeding of the fast running mills the use of feeding devices. of various types has been greatly extended, and the fitting of feeder rollers is becoming standard on new installations. The problem of dealing with the much larger volumes of juice arising from higher crushing rates has also received attention, and certain features are discussed in one of the papers presented to the Section.

Automatic operation of Cane Carrier. Concurrently with attention to the mill itself for achieving higher crushing rates, thought has been given to improving the regulation of the cane feed to the plant. Whereas formerly the speed of the cane carrier depended entirely on manual regulation of the cane carrier engine or electric driving motor, efforts are now being directed towards developing automatic control. The functioning of the cane knives has in some instances also been incorporated in the control system to ensure that the feed on the carrier is adjusted in relation to the power demand on the knives, thereby preventing overloading and consequent stalling of the driving motors. By providing a more uniform cane feed to the mills, and a reduction in stoppages due to chokes on carrier and knives, such control makes an important contribution towards higher crushing rates. Two papers presented to the Section describe systems which have recently been developed for the automatic control of cane carriers and cane knives.

Steam Turbine Drive. The application of the steam turbine to the driving of cane mills represents a revolutionary change on this plant, and noteworthy progress has been made over the past three years. At the time of the Eighth Congress only a few installations existed, and delegates were able to see only one unit operating on a mill during their visits to numerous factories. Turbine drive is gaining in popularity and all recent large cane milling plant installations have been provided with this form of drive, which now gives indication of superseding the single cylinder steam engine. One of the papers presented to the Section deals with the application of turbine drive.

Hydraulic Pressure System. The use of gas/oil bottle type accumulators on the hydraulic pressure systems of cane mills is rapidly extending. Many conversions continue to be made from the conventional weight-loaded accumulator to this more convenient and compact type. It is also now being fitted to the majority of new milling plants, and gives promise of becoming the accepted standard type. Some radical developments have also been made in the design of the hydraulic cylinder which applies pressure to the top roller bearings of mills. Certain of these designs have successfully undergone trials, and are now being applied on some new milling plants.

Roller Bearings on Mill Rollers. Over the past few years some manufacturers of mills have changed from journal bearings to roller bearings on the cane crushing rollers, and some plants now being installed in India are fitted with the roller type. It is noteworthy, however, that this is by no means a new development in so far as India is concerned, as two milling plants manufactured by a Calcutta engineering company 25 years ago and installed in Indian factories were fitted throughout with roller bearings. Although obvious advantages exist in the use of roller bearings on mill rollers, their higher initial cost and certain attendant problems have so far held back their general application. The subject of roller bearings is dealt with under one of the items in the Symposium.

Steam Plant. There has been a tendency over recent years to raise the steam pressure employed in cane sugar factories. Where single cylinder steam engines are employed for driving the mills, the steam pressure is restricted to about 150 p.s.i.g. due to cylinder strength considerations. If steam is generated in the boilers at a higher pressure than this, it is necessary to lower the pressure for the mill engines by passing the supply through a reducing valve. This means that upwards of 40% of the total steam generated at the boilers has immediately thereafter to be reduced in pressure, which is not an entirely satisfactory arrangement. As steam turbines are suitable for the highest of steam pressures, the limitation does not apply when turbines are installed for driving the mills. and factories can therefore now quite economically install boiler plants for pressures of 350 lbs. p.s.i.g. or over, and take a direct supply for driving the mills.

By assuring a proper steam balance in a cane sugar factory the bagasse from the mills can provide ample fuel for the total steam requirements without having recourse to high efficiency boiler plant operating at high pressure and, where this condition exists, there is no justification for installing expensive high-pressure boiler plant. It is now, however, often customary to locate subsidiary industries adjacent to a sugar factory with the object of obtaining from the latter a cheap supply of steam and electric power, as will be seen by delegates on some of the factory visits. In this circumstance a higher thermal efficiency must be achieved in the sugar factory if the surplus steam and power required for outside consumption is still to be obtained from the bagasse supply alone.

The higher thermal efficiency required can often only be obtained by generating steam at high pressure, coupled with the employment of bagasse furnaces of high combustion efficiency. For the higher pressures and increased efficiency, boilers equipped with various ancillary equipment such as air preheaters, economisers, forced draft fans and water walls, are now being introduced into cane sugar factories. New types of bagasse furnace have also been developed which are tending to supersede the simpler step-grate and flat-grate types. New methods of feeding bagasse into the furnace have also been devised, included among which is the spreader stoker type which sprays the bagasse into the combustion chamber. Two papers have been presented to the Section on these subjects, one describing a new type of furnace, and the other illustrating designs of boilers and furnaces from the simple low-pressure type up to the more complicated modern high-pressure installations with ancillary equipment.

Vacuum Pans. Developments continue to be made in vacuum pan design for promoting faster boiling by a more rapid circulation of the massecuite. To improve this in the coil pan, the coil cross-section has in certain cases been altered from the circular form to the flattened oval shape, the long axis being placed vertically so that less resistance is offered to the massecuite flow.

Other developments have continued in the direction of ensuring a low-head of massecuite above the heating element of the vacuum pan, such that circulation is assisted and heat transfer increased by the lower hydrostatic head. Vacuum pans having circular ribbon-type heating elements are becoming increasingly popular in sugar refineries, and some have been employed in beet factories. So far, however, this type has not been introduced into the cane sugar factory.

Centrifugals. Further advances continue to be made in sugar centrifugals, mainly in the direction of high-speed and automatic operation. The former simple type of machine 42" dia. running at 960/1150 r.p.m. is now seldomly seen in new installations, and has given way to the modern heavy high-speed machine, running at 1450/1750 r.p.m., equipped with numerous electric or hydraulic devices for the control and automatic timing of the operations in the cycle, and with electric braking. Although the electric-driven centrifugal is extremely popular, certain factories prefer the water-driven machine which is being manufactured for high-speed running and with all the facilities of the electric-driven type.

Although the above advances enable centrifugals to operate on a shorter cycle, to function under a rigid timed control, and effect considerable labour saving, the system is still intermittent, as the basket has to stop for discharging and after recharging has to be accelerated up to full speed again. The advantages of continuous centrifugal operation are thus obvious, and development work is being vigorously pursued towards the production of successful continuous machines. Some forms are now beyond the experimental stage, and one cotinuous type has been installed in an Indian sugar factory for dealing with particular types of sugar, and the supply of similar units to other factories is contemplated.

The above resume mentions only some of the advances made in cane sugar machinery since the last Congress was held nearly three years ago. There will be other improvements which have been initiated in the various cane sugar countries represented by delegates at this Congress, and the opportunity will be afforded during travels, on visits to factories, and at meetings in Delhi to interchange information on the development work which has been carried out, and on the results achieved.

In the Engineering Section the Congress will bring together delegates from many countries representing various aspects of sugar engineering. There will be members from universities and technical institutions with their contributions from the research side, engineers engaged in the direct operation of sugar machinery in the factories with their experience of practical operation of the plant and the problems involved, and representatives of sugar machinery manufacturers with their knowledge of plant design and construction. The Congress presents a valuable opportunity for the expression of opinions from the various view points, the ventilation of problems and obtaining of assistance towards their solution, and provides in India a pleasant and hospitable meeting ground for the co-ordination of ideas towards the advancement of the science and practice of sugar engineering throughout the world.

In the absence of the author the following paper was presented by Mr. A. K. Bose.

Paper

BOILER PLANT FOR SUGAR MILLS

G. W. Summers
Babcock & Wilcox, Limited, London

In selecting boiler plant for sugar mills two distinct features have to be considered, namely, the type of boiler and the type of firing equipment. Both these factors are influenced by some or all of the following considerations :—

(1) The size and type of sugar mill.
(2) The type and quantity of bagasse and auxiliary fuel available.
(3) The type of labour available for operation.

these have proved uneconomic compared with the installation of an air heater, quite apart from the fire hazard involved.

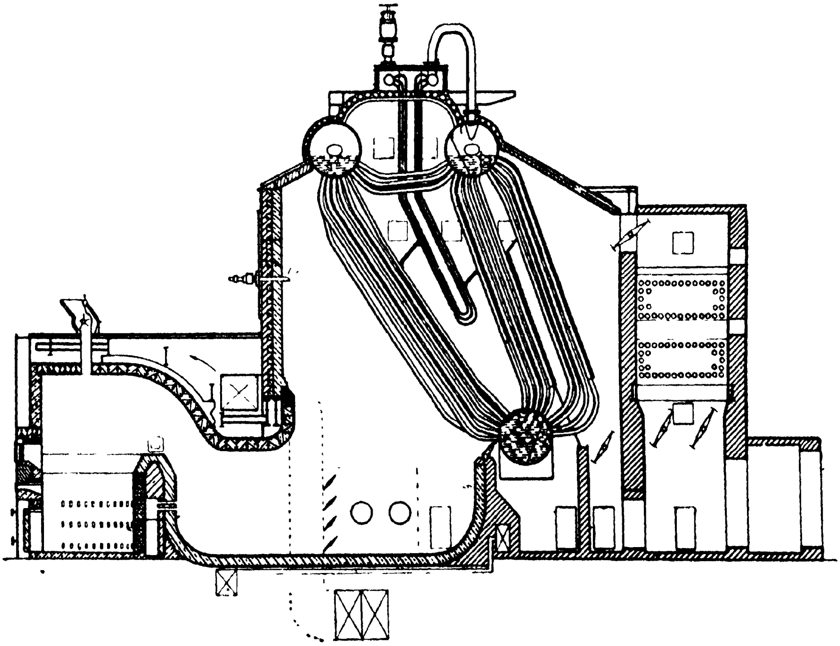


Fig. 4. Tri-drum boiler with horseshoe furnace.

In the large mill, with a substantial steady demand for steam, a more radical approach can be made in the search for maximum boiler efficiency by adopting plant of the type shown in Fig. 5. This is a modern design which is suitable for evaporations up to 150,000 lbs./hr.and comprises a bi-drum boiler with a completely water-cooled furnace set over a Ward hearth. Oil burners in the water-cooled chamber give full evaporation if no bagasse is available, and a tubular air heater ensures high efficiency when burning either fuel. Employing such comprehensive water cooling of the furnace chamber and the arches of the Ward furnace, greatly reduces the amount of refractory firebrick employed, thus producing greater availability and consequent saving in maintenance costs, while at the same time ensuring low heat loss through the boiler casing.

In this type of boiler the quantity of steam generated is high in relation to the free surface in the steam and water drum and, if dry steam is to be supplied to the superheater, it becomes essential to employ some means of separating moisture from the steam. The drum is therefore equipped with a double row of Babcock Cyclone Steam Separators, which not only act as high efficiency removers of moisture but also augment the circulation of water within the boiler.

Fig. 6 shows a similar design of boiler equipped to burn either bagasse or coal. Two types of fuel feeder are mounted in the front wall of the water-cooled furnace, the lower ones being standard Babcock Detroit Spreader Coal Feeders and the upper ones air swept spouts, which, by means of a fluctuating air supp

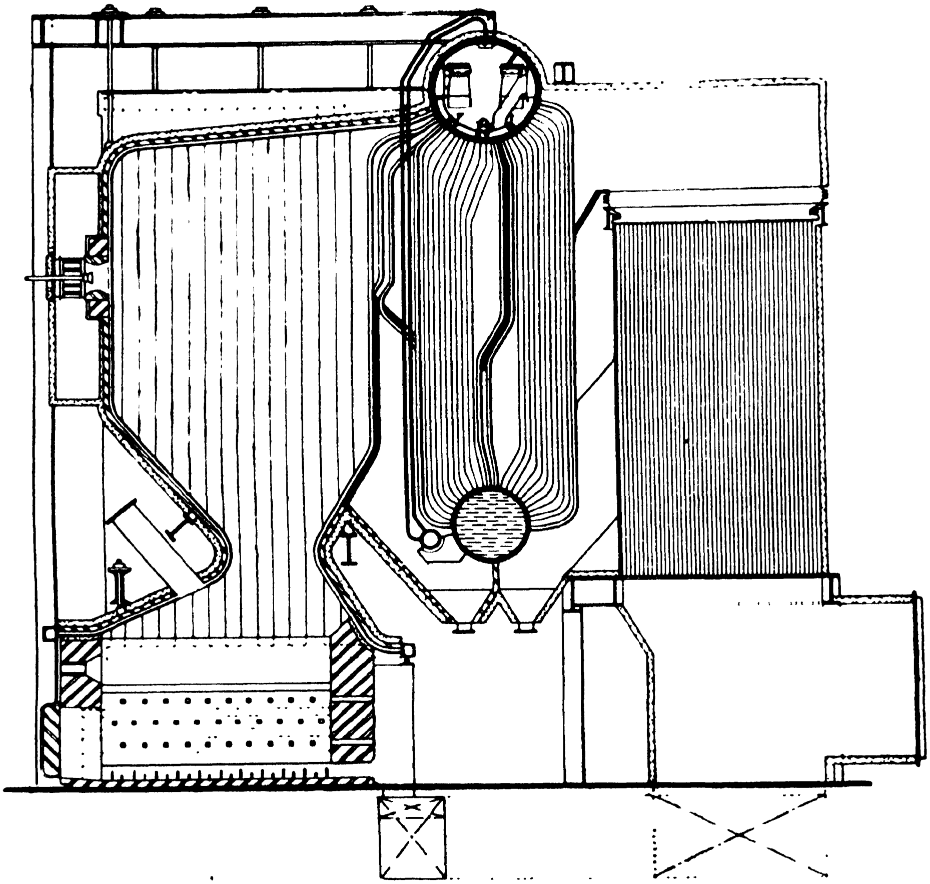


Fig. 5. Bi-drum boiler with Ward furnace.

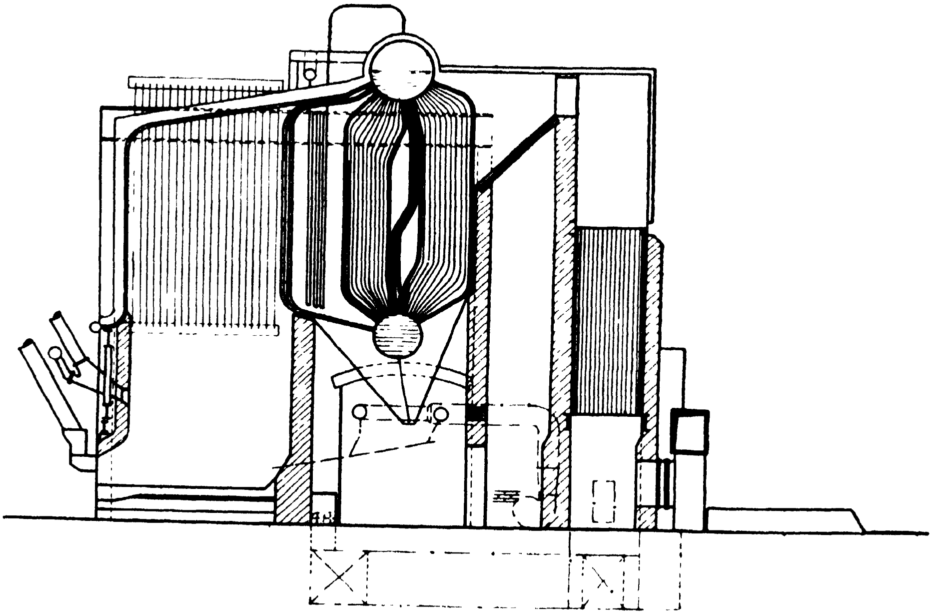


Fig. 6. Bi-drum boiler to burn bagasse and coal.

deliver the bagasse over the full length and breadth of the grate, the latter being of the dumping type. In cases where an auxiliary fuel must be burned and oil is difficult or expensive to obtain, plant of this type can offer a satisfactory solution to the problem, provided certain conditions apply. Firstly, it is essential that feed water of consistently high quality be available : failure to give continual and careful attention to the water supply to a plant of this type can only lead to early tube failures and heavy maintenance charges, which will annul the theoretical savings in operating costs. Secondly, the more highly rated type of boiler, with its necessary fans, fuel feeders, motors and instruments, needs to be operated by adequately trained men. The possibilities for highly efficient working which have been built into the plant can only be exploited by an intelligent use of the controls and instruments provided. The old "rule of thumb" methods, which are adequate for operating units of the type described earlier in this paper, can only lead to disappointment with the more advanced designs. Not only will the desired efficiency fail to be obtained, but maintenance charges will quickly accumulate.

When coal has to be used as an auxiliary fuel and the available feed water, or other conditions, preclude the use of a bent tbe boiler, the same firing methods as shown in Fig. 6 can be employed beneath a straight tube design, and a plant of this type is illustrated in Fig. 7.

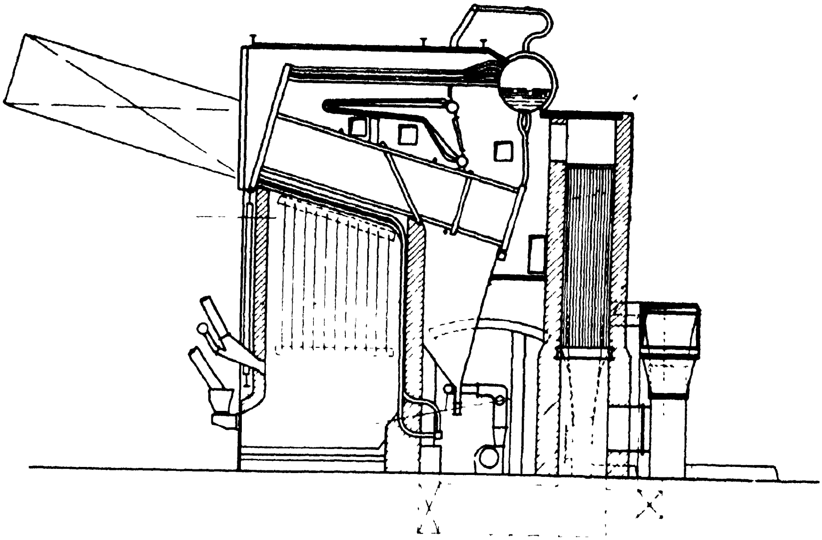


Fig. 7. Cross-type header boiler to burn bagasse and coal.

The problem of ash removal from bagasse furnaces has received considerable attention from boiler manufacturers with the twin aims of reducing the unpleasant manual labour involved and also maintaining load on the boiler while ashing is in progress. The use of continuously moving or, alternatively, intermittently dumping grates has been shown to be practicable, provided close and skilled attention is given to the fire, but these systems are not trouble free and various problems still have to be solved. Meanwhile work is continuing on this question.

One important factor remains to be mentioned. Boiler plant is expected to last for thirty years or more and therefore the mill owner, when purchasing new equipment, must try to look ten or even twenty years ahead and foresee the pattern of development of his mill. Although he may have excess bagasse today, this condition can easily be changed in the future. If this happens, where will he turn for auxiliary fuel? Is the present steam demand likely to grow substantially? If so, will the existing supply of raw feed water be adequate? Where changes in circumstances are foreseen the boiler and furnace design selected should be such that suitable modifications are possible when the time arrives and can be carried out at minimum expense.

We are thus brought back to our starting point. Sugar mill boiler plant can be designed to meet nearly every combination of circumstances, and in many cases a number of alternative designs will meet the need, but only the mill owner can properly weigh all the factors affecting the selection. The best solution in any specific case will often only be found by close collaboration with an experienced Boiler-maker.

DISCUSSION

Mr. W. M. Livie asked what was to be considered the continuous rating for boilers with modern equipment using the Ward furnace.

Mr. Bose replied that for evaporations up to about 30,000 lbs. steam per hour the step-grate furnace was suitable, but above this figure the Ward furnace had advantages and was to be preferred. With the step-grate furnace evaporation rates of 4 to 4.5 lbs. per sq. ft. heating surface per hour gave an economical rating, but with the Ward furnace the figure could be appreciably higher.

Mr. Livie asked what effect the stepping-up of the rating had on the economical combustion of bagasse.

Mr. Bose replied that while the step-grate furnace fell off in combustion efficiency as the evaporation rate was increased, the Ward furnace was much more flexible in this respect and maintained high efficiency over a wide range of rating.

Mr. J. P. Mukherji mentioned that with high evaporation rates more care had to be exercised in respect to the quality of the feed water, and that it was generally advisable to provide chemical treatment for the make-up.

Mr. G. H. Jenkins mentioned that in Queensland the higher rating of boilers resulted in incomplete combustion and losses from unburned fuel unless secondary air was introduced in the furnace. By this means it was possible to maintain efficient combustion even when ratings were increased upto 8 lbs. per sq. ft.

Mr. J. R. Leclezio asked whether air pre-heaters were to be preferred to economisers for increasing boiler efficiency.

Mr. Mukherji stated that he was in favour of air pre-heaters as these increased combustion efficiency. As, however, air pre-heaters involved the installation of forced draught, and often required the provision of water walls to minimise furnace maintenance, he now considered the equipment too complicated. As the cost of an economiser was about half that of an air pre-heater system, he now favoured the former. He mentioned that a number of factories in the Deccan had installed economisers with good results.

Mr. Bose stated that for boilers of small and moderate capacities—up to say 30,000 lbs. steam per hour—an economiser is to be preferred, but for larger sizes air pre-heaters with water walls were the best proposition.

The Chairman commented that although the evaporation figure based on lbs. per sq. ft. of heating surface increased appreciably by the addition of economisers and/ or air pre-heaters with water walls, it had to be recognised that the ancillary equipment in itself added further heat transmission surface to the plant, and it was therefore misleading to judge ratings by reference only to the heating surface of the boiler proper. The ancillary equipment also made the plant more complicated and increased maintenance costs. Under sugar factory conditions it was often cheaper, and more convenient and flexible for operation, to install an additional boiler when more steam was required.

Mr. J. O. Sason enquired whether under sugar factory conditions boilers were to be preferred with straight or bent tubes.

Messrs. Mukherji, Soni, Bose, Livie and Sapra contributed to a discussion on this aspect. Where there was no serious scale forming, the bent tube type was favoured as this eliminated the use of hand-hole covers, which were an expensive maintenance item. Where, however, scaling of tubes was liable to be serious, then the straight tube type was to be preferred as it allowed more thorough cleaning of the inside tube surfaces. It was also considered that the inclination of boiler tube was important, and that steeply inclined tube assisted in the draining of sludge to the mud drum.

In the absence of the author Mr. Jeavons presented the following paper.

Paper

A RECENT DEVELOPMENT IN THE EFFICIENT BURNING OF BAGASSE

W. C. Carter

John Thompson Water Tube Boilers Ltd.,
Wolverhampton, England

In 1947 a considerable number of Sugar Factories, particularly in British Guiana, were operating inefficiently, insufficient bagasse for the steam demand being available and wood and other fuels being necessary to supplement the firing.

At most of the factories under review, the boilers were of the 3 or 4 drum type, provided with two banks of tubes and fired generally by means of stepped grate furnaces. The generally accepted basis for rating of boiler plant throughout the industry at this time was to provide heating surface at a rate of 3 to 3.6 lbs. of steam per hour per square foot of boiler heating surface. On this basis factories handling 90 tons of cane per hour required some 6 to 8 boilers each having a heating surface of some 6,000 sq. ft.

Mr. Eisner, the Technical Adviser to Bookers Sugar Estates, British Guiana considered that the above evaporative rate could be appreciably raised by certain relatively simple modifications to existing types of bagasse furnaces. He approached the author for his co-operation in the development work, which was readily given.

INITIAL DEVELOPMENT

The furnace arrangement proposed is indicated in Figure 1, which is typical of a number of boiler conversions carried out during the initial stages of development.

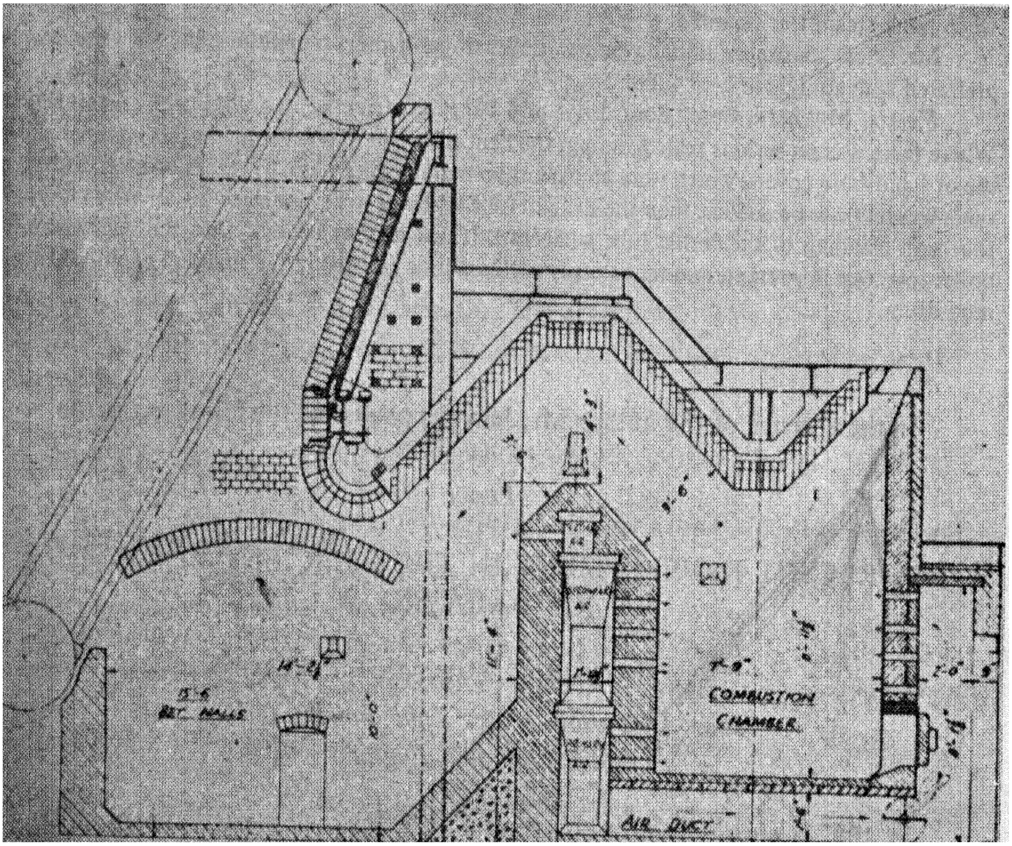


Figure 1.

It will be noted that in general the conception of the arrangement of brickwork and arches was substantially similar to that in fairly general use with stepped grate furnaces ; the first essential difference, however, being that the fire bars were replaced by a bed of bagasse—since it was proposed that the furnace should run full of bagasse (to the angle of repose of the bagasse in the furnace) and thereby be grateless. It will be appreciated that in effect in this arrangement we had left ourselves a " back-door ", as in the event of the furnace not working to expectations it would be a relatively simple matter to revert to a normal stepped grate ; or even at worst it might be considered as another version of the many " hole in the floor " type furnaces previously employed.

Some further points of explanation are, however, required as appreciably better performance conditions were expected than from any of these previously used arrangements. The furnaces or cells utilised the full width of the boiler between walls, for example, in the case of a 6,000 sq. ft. heating surface boiler, 12′ 2″ between walls, two 5′ 6″ wide cells were provided with a 14″ centre dividing wall. Forced draught was arranged as indicated at the front and rear of each cell, with provision for secondary and tertiary air also under pressure. It was quite confidently expected with the width of cells employed and the burning area provided, coupled with the employment of forced draught, that an increase in rating of the boiler of some 50% would be obtained and that if hot forced raught was used even higher ratings might be obtained.

A further feature visualised in this original arrangement was an endeavour to make the furnace self feeding, the intention being to dispense with any regulation of the bagasse whatsoever at the carrier and simply to control the output from the boiler by regulation of the forced draught. This requirement meant, as stated, keeping the furnace full of bagasse at all times and the ensurance of this by an adequate system of feed chutes—rotary type feeders being disregarded as not in reality constituting feeders, but being at best only a poor form of air excluder and certainly not ensuring continuity of feed automatically with the evaporation. It was considered that simple chutes from the furnace mouths to the opening in the carrier, maintained full of bagasse at all times would not only effectively exclude all air from entering the furnaces at these points but if arranged at an angle equal to or greater than the natural angle of repose, would also feed by gravitation.

TRIALS AND RESULTS

When the first unit was commissioned all the predicted burning performance was easily obtained, it was found possible to run from one week-end to the next without cleaning the furnace or combustion chamber, so that boiler cleaning could be carried out at the same time as evaporator cleaning. Further, due to the moderate ratings and temperatures in the furnace, little slagging was experienced, this being generally local to the burning line and in the top of the furnace due to the furnaces not being maintained full of bagasse at all times.

CRITERIA FOR SELF FEEDING

This required feature of self feeding to ensure a full furnace of bagasse was found to present a number of difficulties. The first chutes tried connected the carrier opening to the furnace opening at approximately constant area, and since these openings were at right angles it meant that the bagasse had to be turned through 90 degrees in falling down the chute. This the bagasse refused to do of its own volition, and considerable investigation took place regarding the correct arrangement of feed chutes to ensure self feeding. These investigations indicated the following necessary characteristics for self feeding chutes for bagasse :—

(1) The chutes must diverge on ALL sides from the carrier opening to the furnace opening.

(2) The inside of the chute must be completely free from obstructions of any kind, even bolt heads must be avoided, otherwise bridging will occur and self feeding stop.
(3) Minimum angle of any valley angle of chutes must be 55 degrees to horizontal.
(4) No attempt must be made to turn bagasse in any direction, either sideways or vertically.
(5) Uniform take off from carrier must be achieved by staggering feed chutes.

Following these investigations it was found possible to provide chutes which would ' self feed ' the furnace and so ensure a rate of flow of bagasse in accordance with the burning of the fuel in the cell, which was in turn dictated by the forced draught supplied in accordance with the boiler load. One control only for evaporation had therefore been achieved.

The success of the burning characteristics of the furnace and the simplicity of its self feeding features indicated a wide application in the cane sugar industry, and consequently patent protection was taken out.

SECOND STAGE IN DEVELOPMENT

Fortunately at about this time Mr. Eisner had in hand the complete reconstruction of an old sugar factory in British Guiana and it was decided as a result of the success experienced with the **THOMPSON-EISNER** furnace (as the new furnace was now called) that appreciable reductions in the amount of boiler plant provided could be made. It must, however, in full record of

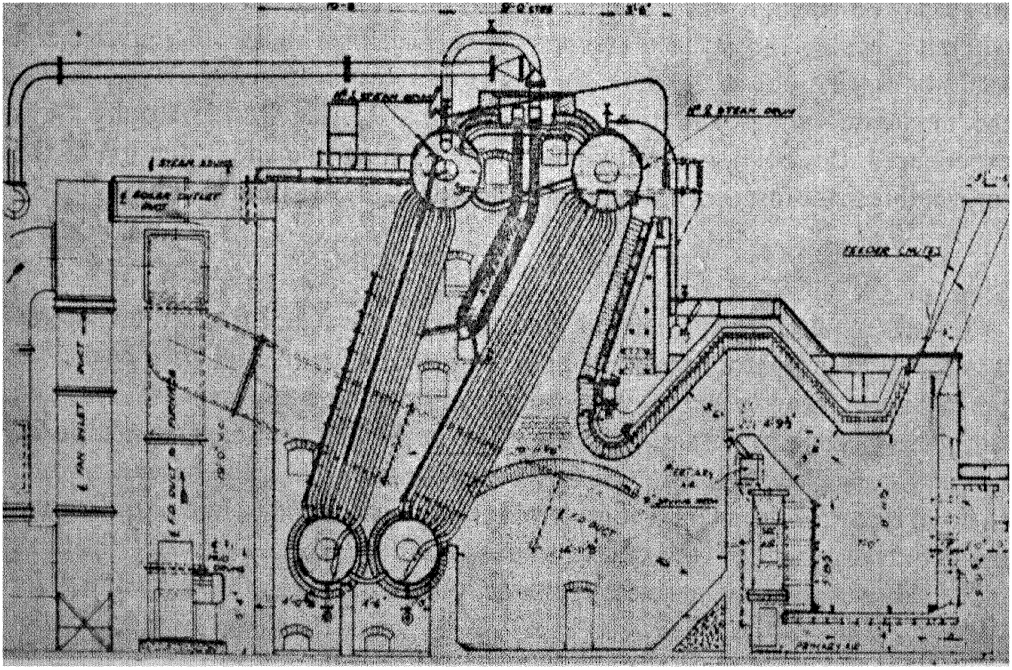


Figure 2.

the facts be stated that, although the existing milling plant, etc., was being used, substantial steam economies were also being effected by the reconstruction.

The plant was originally 6—6,000 sq. ft. boilers together with a similar boiler for the attached distillery, and the throughput was some 90 tons of cane per hour. It was decided to maintain the same throughput but to reduce the number of boilers to 3 (same units), together again with a similar boiler for the distillery.

It will be readily realised that this meant that the rating of the boilers for the factory was to be approximately double, i. e., to some 6/7 lbs. of steam per sq. ft. per hour. At the same time the operating pressure of the boilers was increased from 160 p.s.i. to 200 p.s.i. to allow back pressure turbines to be installed for electricity generation.

Although the original results were so satisfactory, it was decided in this next stage to make provision for air heaters on two of the units in case the ratings predicted were not obtained at a satisfactory boiler efficiency with cold forced draught, and Figure 2 shows the arrangement installed ; the provision at the rear of the boiler for the later installation of air heaters, if necessary, will readily be seen. The twin staggered feed chutes per boiler, taking up the full width of the carrier are also indicated, these chutes also, of course, open out from the carrier opening to the furnace mouthpiece in the direction of the carrier, i.e., in the boiler width.

CONFIRMATION OF PREDICTIONS

The remodelled factory went into full commission some four years ago and it is gratifying to report that all the economies predicted in the steam utilisation side were realised and that the steam production from the boiler plant on bagasse alone was more than adequate to meet all demands without necessity to resort to supplementary wood or other firing. Therefore, due in large measure to the steam economies effected in the factory, it has not been necessary to effect economies in bagasse consumption by improving the boiler efficiency and so the air heaters have not been installed; in fact, surplus bagasse is now becoming an embarrassment.

Further, due to these economies, it has been found that the actual rating on the 3 factory boilers on full load throughput of 90 tons of cane per hour, is only of the order of 6 lbs. of steam per hour per sq. ft., and consequently on occasions it has been found convenient and easily possible to run the factory on 2 boilers only, and this was readily demonstrated during a recent visit to the factory. This means, of course, that the boiler rating was at least 8 ; the percentage of fibre in the cane at this factory is usually, on yearly average, 12 to 13.5.

The success of this installation confirmed most positively and conclusively the experiences recorded in a number of other boiler units of all types to which T. E. furnaces had been adapted. We therefore decided to prosecute the installation of this particular furnace on all new and projected boiler plants for sugar factories.

PROGRESSIVE APPLICATION

At the same time larger boiler units were being considered, particularly for factories in America and therefore in the general interests of space and economy a 2-drum type unit was developed. A typical design of 2-drum boiler with T.E. furnaces is shown in Figure 3, and units of this type have been supplied for evaporations from 35,000 lbs./hour to 108,000 lqs./hour, in most parts of the

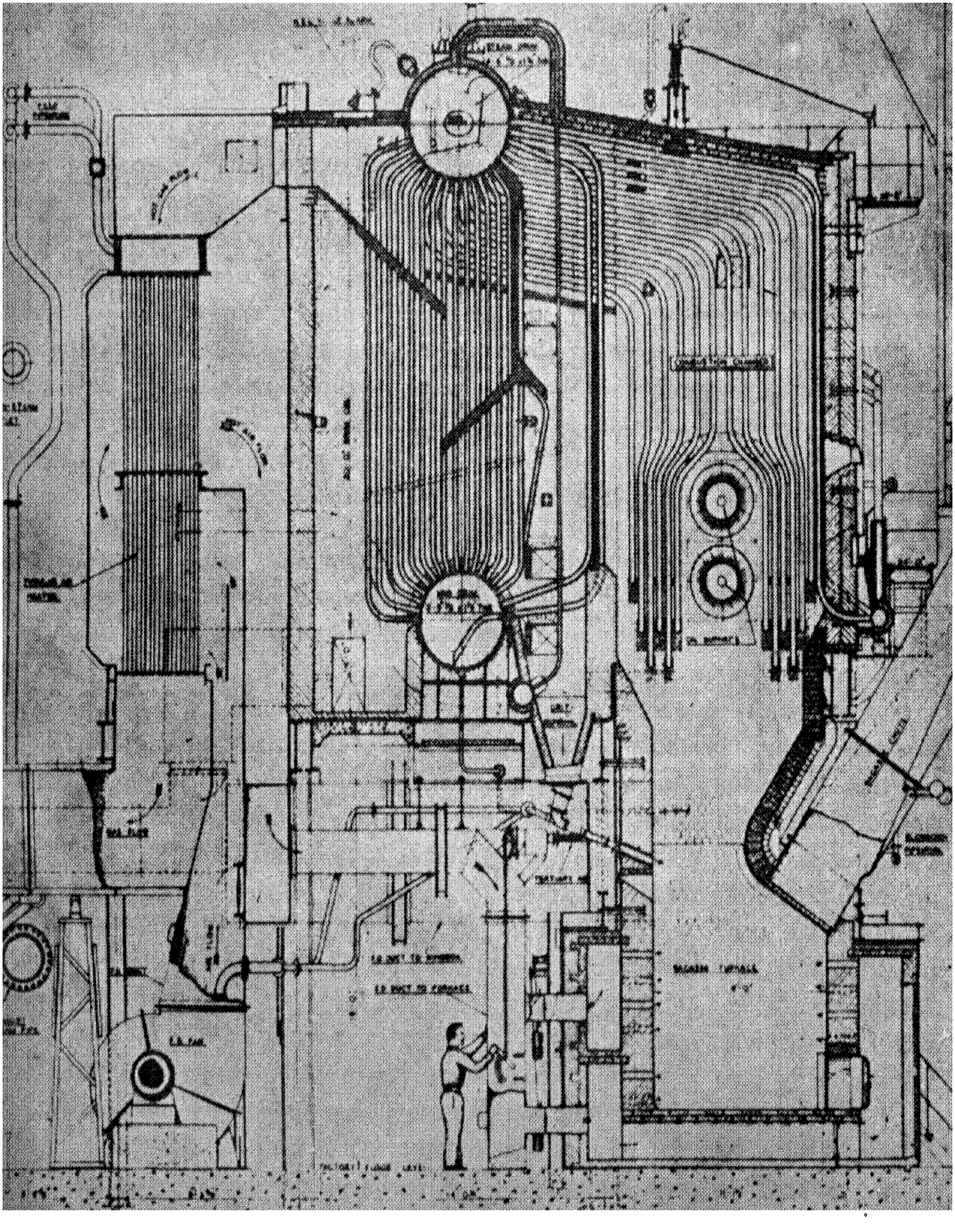


Figure 3.

It will be noted that the boiler is provided with a large main bank of tubes and water walls which are remote from the actual furnace itself. This arrangement of boiler, with its appreciable reduction in brickwork, is known to be very flexible and capable of rapidly meeting load fluctuations, and this has proved the case when adapted to bagasse firing, particularly when fitted with T.E. furnaces, due to the very marked flexibility of the furnaces to meet load demands, coupled with the appreciable store of bagasse in the furnace itself and associated feed chutes, which in most cases amounts to a supply of bagasse of some 20 minutes

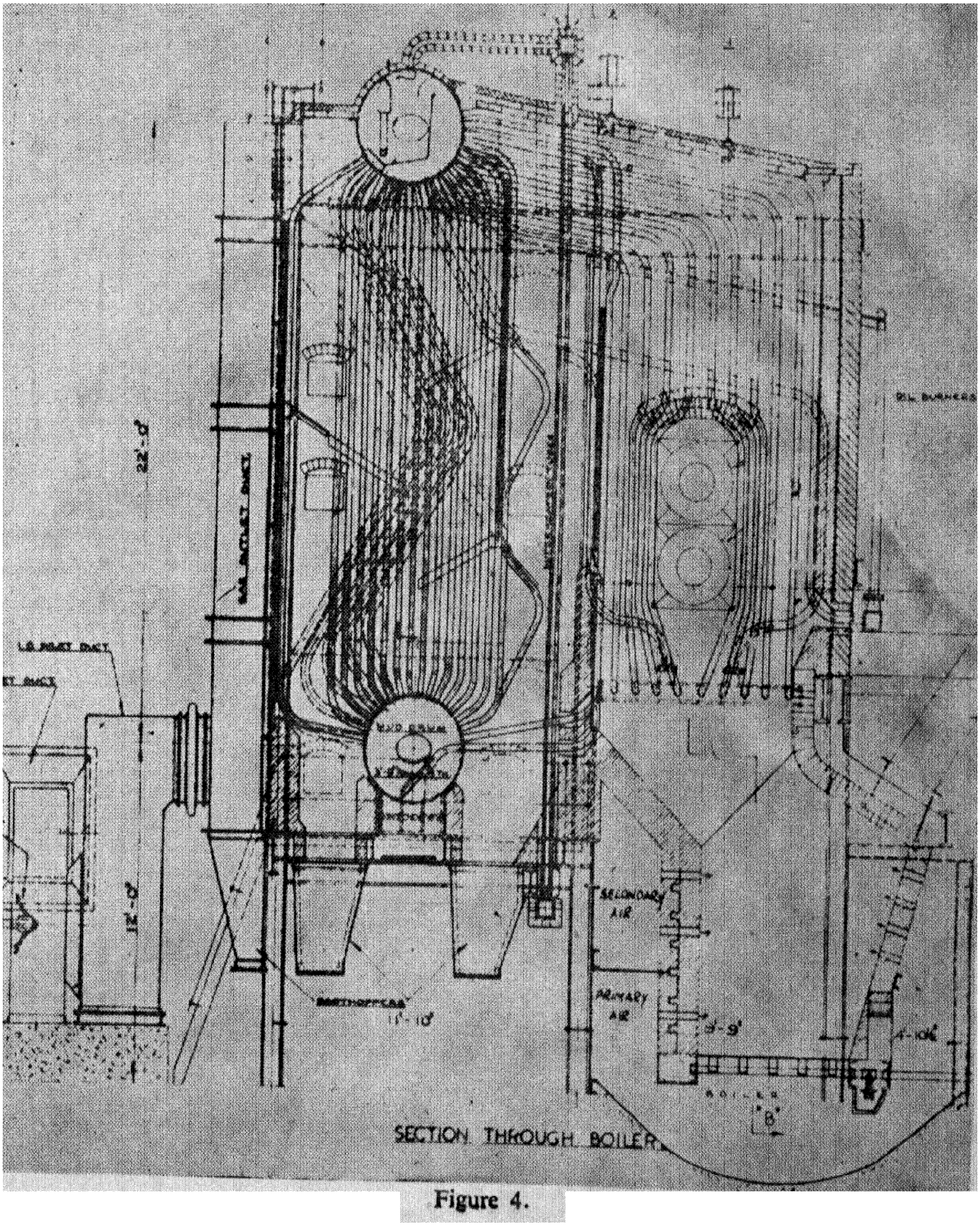


Figure 4.

steaming. Thus temporary stoppages due to cane chokages, etc., have been accommodated without undue difficulty.

A suggested draw-back to this type of unit in this same connection is often suggested, namely, its lack of thermal storage to meet sudden load demands. Theoretically speaking, assuming the feed can be burnt at all times in accordance with the load demands, then the actual thermal storage of the boiler is unimportant. However, as will be stated later, this point of view has received consideration although it will be appreciated that fitting a furnace with almost instantaneous

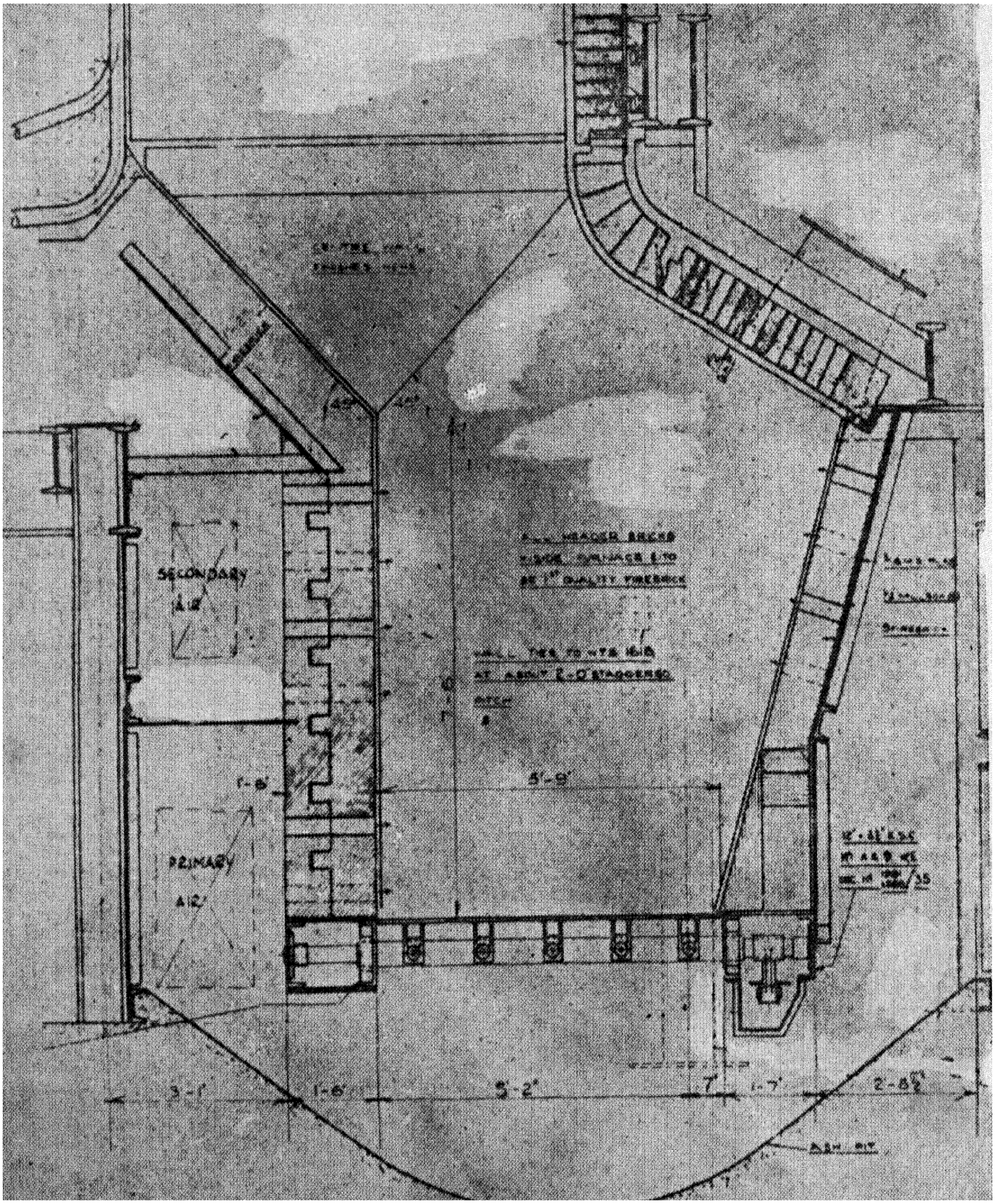


Figure 5.

response to load demands has rendered this consideration more or less unnecessary.

Particular attention is also drawn to the height of the combustion chamber provided, this has proved very successful in minimising grit carry-over and although grit re-firing is generally provided, this has not always been found necessary.

Over 100 furnaces have now been supplied to existing and new boilers and one of the latest arrangements of boiler and T.E. furnace in the course of manufacture is shown in Figure 4. This unit is one of two being supplied to two reconstructed factories in British Guiana in consultation with Mr. Eisner.

It will be noted that in the interests of economy the overall height of the unit has been reduced compared with Figure 3. A further point is the arrangement of the superheater which, with its simple straight tubes, should facilitate general cleaning both internal and external, and reduce maintenance. The furnace arrangement is also simplified to facilitate the accommodation of feed chutes, and, equally important, the whole of the cell brickwork has been arranged independent of the main boiler brickwork, so that in the unlikely event of furnace brickwork renewals being required, it will not be necessary to disturb water wall tubes or boiler brickwork etc. This is more clearly indicated in Figure 5.

One final point in regard to the boiler shown in Figure 4, is that this is for the same duty and has approximately the same heating surface as the boiler shown in Figure 2, the water capacity of the 2-drum Integral Boiler is 22 tons compared with 21.4 tons for the 4-drum Beta.

ASH DISPOSAL

Reverting to Figure 5, it will be noted that the bottom of the furnace is shown in the form of a dump grate, instead of being constructed in refractory as on all previous units. It has already been stated that the furnace capacity is such that the units can remain in service from one week-end to the next without ashing being required. Some factories, however, particularly those with standby evaporators and refineries intend operating continuously and this new feature is included to make this possible without resorting to the complications of spreader stokers, etc.

The dump grate is not intended to take any part in the burning of the bagasse and the simplicity of the general furnace design is maintained ; it will be possible to discharge ash from the furnace, however, at regular intervals without interfering appreciably with the boiler operation as the main and furnace cleaning doors will be shut when the grate is operated the forced draught shut off and no excess air will enter the cells as is so common on most other types of furnaces. A photograph of the first of the dump grates is shown in Figure 6, and its installation and operation is awaited with considerable interest and confidence.

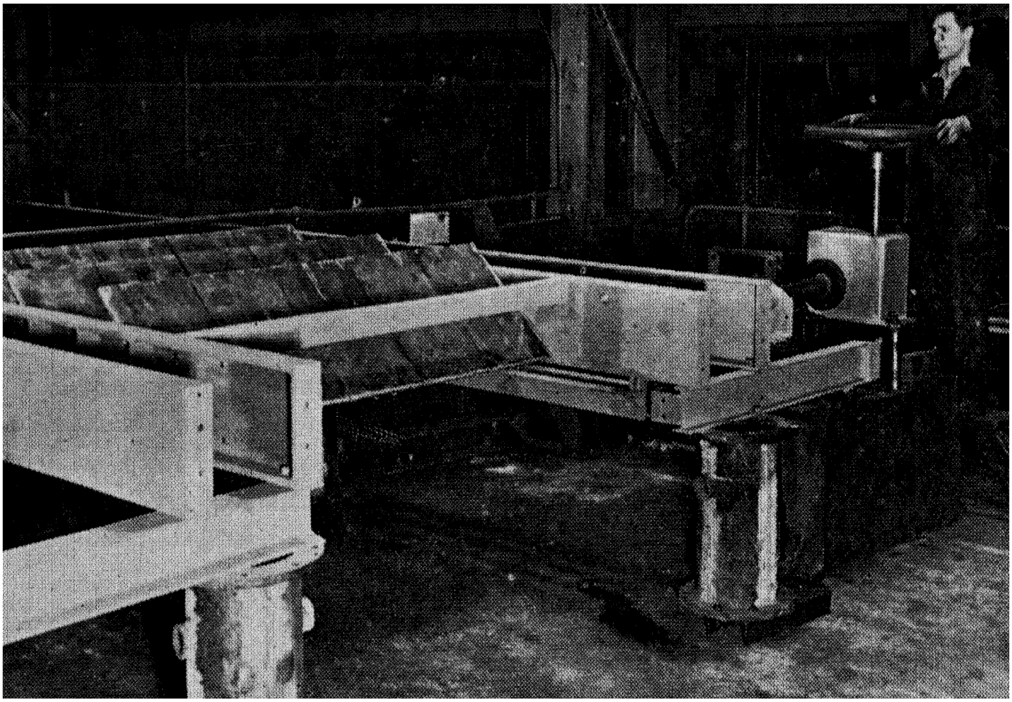


Figure 6.

FINAL ASSESSMENT

It is hoped that this account of the development of the Thompson-Eisner Furnace will be found of interest and indicate its potentialities. The most important advantages may be summarised as follows :—

1. By careful attention to the shape of the furnace and its associated feed chute, the furnace is self-feeding and accordingly one variable in the operation of the unit is eliminated, namely, the necessity to control the feed of bagasse to the boiler. It is therefore only necessary to control the air to the furnace to control the rating of the unit, contrary to all other furnaces where it is necessary to control both the bagasse and the air. Further, since the feeding of the bagasse is automatic, no so-called rotary feeders are necessary ; these, in fact, are not feeders at all but merely air excluders.
2. The burning area of the T.E. furnace is the inclined face of the wedge and not a cone as is common with all other horse-shoe or cell type furnaces. Due to the fact that air is only admitted at the front and rear of the furnace and not at the sides, the burning area possible in a given width is greater than with similar furnaces. This means that if the same quantity of bagasse is burned, the carry-over from the fuel bed is reduced owing to the lower rating or, conversely, higher outputs may be obtained.

3. Most sugar factories, particularly in the West Indies, shut down one day per week for evaporator cleaning, the capacity of the T.E. furnace is such that under normal operation the furnaces will operate from one week-end to the next week-end without the necessity for intermediate cleaning. This is contrary to actual operating experience with all other types of cell, hearth or spreader stoker firing. In the case of the cell and stepped grate applications, cleaning of the furnace is necessary every 8/16 hours, depending on load conditions. In the case of spreader stoker firing, unless of the continuous discharge type, ashing and removal by hand, with resulting reduction in load, is necessary at least every shift.
4. Consideration of the T.E. furnace together with its associated feed chute will indicate the reason for the increased periods which the furnace can run without the necessity for cleaning. The ash which is formed during combustion (this must inevitably collect despite the claims of makers of many other types of bagasse burning equipment) collects in the bottom of the furnace, and as this is relatively large a considerable amount of ash can accumulate in the furnace before interference is experienced with the combustion conditions.

   It will also be appreciated that the relatively large storage capacity of the T.E. furnace and its feed chute gives some reserve for temporary interruptions in the supply of the bagasse to the boiler, due to the difficulties sometimes experienced with the bagasse carriers and milling plant. Depending on the load on the unit, a reserve of fuel of up to 20 minutes is available. This is appreciably greater than with any stepped grate, horse-shoe or cell type furnace, and, further, represents a substantial advantage over the spreader stoker installations, in which case if the bagasse fails for *two minutes or more* the load must be immediately reduced on the boiler or supplementary firing adopted, otherwise the pressure falls rapidly.
5. Due to the attention paid to the design of the furnace, namely, its simplicity (which is a fundamental point in all good designs) mechanical operating parts such as rotary feeders, spreaders and throwers are unnecessary. The maintenance of the furnace, therefore, is practically negligible and is only in respect to the brickwork.

ACKNOWLEDGMENT

The author cannot close without paying tribute and expressing his highest appreciation to Mr. Eisner for his original conception of this simple, efficient, arrangement for burning bagasse and his whole-hearted prosecution of the idea in British Guiana.

DISCUSSION

Mr. O. M. Henzell asked whether with the Eisner furnace there was a danger of fire due to the blow-back of flame should the feed chute become temporarily empty.

Mr. Jeavons replied that as there was a negative pressure in the combustion chamber there was little danger of blow-back.

Mr. A. K. Bose asked whether there was any control of the bagasse by means of furnace doors.

Mr. Jeavons replied that the feed chute was maintained full of bagasse and led directly on to the sloping heap in the furnace. The amount of bagasse flow was regulated by the rate of combustion from the heap inside the furnace.

Mr. W. M. Livie enquired about the draught to be used with the Eisner furnace.

Mr. Jeavons replied that 1″ water gauge draught was adequate, and that if higher draughts were used there was liability of holes being blown through the bagasse mass. He also mentioned that six Eisner furnaces were operating in Pakistan, and one in India.

Mr. Jagjit Singh enquired regarding the evaporative rate obtained by installing Eisner furnaces

Mr. Jeavons replied that in certain cases an increase had been obtained from 3.5 to 6 lbs. per sq.ft.with very little lowering of boiler efficiency.

Mr. J. R. Leclezio enquired about the angle of inclinaton of the bagasse chute.

Mr. Jeavons stated that the minimum angle should be 70°.

Mr. Livie asked what was the gas temperature in the combustion chamber.

Mr. Jeavons stated that this was about 2,000°F.

Mr. S. K. Somaiya enquired whether the furnace was liable to heavy clinker formation, and whether it was easy to clean.

Mr. Jeavons stated that the furnace could work continuously for seven days, and that thereafter it might take 7/8 hours for complete cleaning. For ash removal only 2/3 hours would be necessary. He referred to the new type of dump grate described in the paper which enabled the furnace to remain in continuous service. He stated that the walls of the furnace are cooled by the incoming air, and that there is very little clinker formation on the walls themselves.

Mr. Jagjit Singh then presented his paper.

Paper

ECONOMIC UTILIZATION OF BAGASSE IN SUGAR FACTORIES

JAGJIT SINGH

National Sugar Institute, Kanpur, India

One of the problems of the Indian Sugar Industry is excessive fuel consumption in sugar factories. In most factories not only is the entire bagasse consumed in the boilers but extra fuel is also required, thus increasing the cost of production of sugar. In most cases by appropriate investigation considerable fuel economy can be effected, and the profits of the factory thereby substantially increased.

IMPORTANCE OF HEAT BALANCES

In order to have efficient use of fuel in a sugar factory the first step is to strike the heat balance between the production of steam in the boilers and consumption of the same for power production and processing. This would generally bring to light extravagant processes and practices, so that measures for substantial steam saving can be drawn up.

SURVEY OF FACTORIES

In order to collect the necessary data for striking the heat balance a systematic survey has to be conducted in the factory. During the period of survey, accurate recording of temperatures, pressures and vacuum, and metering of steam and water used and condensates returned during various manufacturing processes, have to be done. A complete record of steam generated in the boilers and quantity of fuel consumed has to be maintained and the percentage of steam passed through power generators and the portion that is directly supplied to processing have to be determined. The total power developed to drive the various power consuming units has to be ascertained. For the purpose of the survey, complete set of control instruments and testing equipment and whole time attention by a competent staff of engineers are required. The Fuel Economy Scheme sponsored by the Government of India, Ministry of Food & Agriculture and working at the National Sugar Institute, Kanpur is doing this useful service to the Industry since 1948. All the meters and testing equipment required for the purpose of survey are carried by the surveying staff. Complete surveys in about 6 to 7 factories are conducted in each season by installing the testing equipment and collecting the necessary data.

As the processing in a sugar factory is subjected to uncertain variations, the working data are collected for a period of 8 to 10 days in each factory and overall average figures are used for the preparation of heat balances. But the drawback with average figures, is that these do not give any indication regarding the fluctuations and variations in consumption occurring during processing. The allowance that is required to be made for fluctuations in preparing the specification and design of the machineries for balanced working will be discussed later.

OBSERVATIONS MADE DURING SURVEY

The survey carried out in 45 sugar factories in the last seven crushing seasons had revealed some important facts. It has been found that evaporation in the boilers in the case of semi-electrified plants varied from 55 to 70 percent on cane. In completely steam driven plants, the evaporation varied from 70 to 90 percent on cane.

In most of the sugar factories, not only the consumption of steam was much above the normal but the steam generating plant efficiencies were found to be poor and evaporation rate per sq. ft. of heating surface low. The mill extraction and boiling house efficiencies were below normal.

In Northern India the average fibre in cane is high (about 16 percent) ; yet, most of the sugar factories have been consuming considerable amount of extra fuel (wood and coal) in addition to burning all the bagasse produced. The causes of such abnormal working have been summed up below.

The expansion of the sugar industry in India in 1932 was most phenomenal due to protection given to the industry. Many industrialists in their eagerness to get plants quickly did not take advantage of the experience and knowledge that were available in other countries and accepted whatever type of plants were offered to them by the manufacturers. Greater emphasis was laid on cheapness than on proper design. The result was that cheap units were supplied which were large steam consumers with the result that the exhaust steam became practically uncontrollable.

The second factor which was responsible for unbalanced working condition was that in most cases it was found that plants installed had too small a capacity to handle all the cheap cane that was available near the factory. In order to increase the crushing, only the boiling house capacity was extended and mills were worked to crush double their rated capacity without making any alterations in design for high surface speeds etc. The result was that moisture in the bagasse produced was high due to which the calorific value of fuel was decreased which resulted in further inefficiency in the generation of steam in the boilers. Although some improvements in milling efficiencies were made by taking expert advice on proper settings, trash plate profiles, mill grooving, hydraulic loads, speed of mills, method of maceration etc., satisfactory results could not be achieved since the normal horse power per ton of fibre and maceration percent fibre were not available due to capacities of mill engines and evaporator capacity being inadequate.

While many additions and alterations were made to the plants, the steam and exhaust mains were not altered appropriately ; consequently, a high pressure drop occurred between boiler and the individual power units and high local exhaust pressures were developed in exhaust mains. As a matter of fact, each factory had its own problems due to faulty layout, operation etc.

It was noted during survey that in some of the factories highly superheated steam was used for energy production with the result that exhaust steam retained sufficient superheat. There was a general impression in the mind of technical staff of those factories that the higher temperature of superheated steam should make it more efficient than saturated steam (at the same pressure) for processing.

The factories were advised to desuperheat steam before using it for processing. The following discussion would show that there was no advantage in using superheated steam which on the other hand retarded the delivery of heat.

While superheating increases steam temperature considerably it adds little to the total heat. Although it increases the heat content per lb., superheat makes the steam expand, so that the heat content per cubic ft. is less than that of saturated steam at the same pressure.

The high heat transfer coefficient of condensing steam is caused by the turbulence resulting from the large change in volume during the condensation from vapour to liquid. Superheated steam would take some time before it loses its superheat. Over that region of the calandria wherein the condensation does not occur the heat transfer coefficient would be low, thus the efficiency of the evaporator would come down.

RESULTS ACHIEVED

Based on data obtained during survey and the heat balance, recommendations were made regarding the improvements needed in the operation as well as regarding the additions and alterations necessary.

As a result of this extension service to the industry during the past seven years, very beneficial and encouraging results have been achieved and the factories which were consuming large amount of extra fuel such as wood and coal, have now become self-sufficient on bagasse and in some cases bagasse has become surplus and is being used to effect an improved working of plant, with a veiw to increase the profits.

As the Government of India have given permission for the installation of quite a few new factories and for the extension of some of the existing plants under the Second Five Year Plan to meet the increasing demand of sugar of country, it would be advantageous to discuss in this paper the necessary conditions for designing a sugar factory for economical working by taking a practical case of factory having balanced working, where power was developed as a by-product from steam in meeting the demand of processing.

Steam requirement for power production and processing. Sugar factories use power and heat. The demand of heat for processing is fairly high. If steam, on its way to the heating processes is passed through an engine or turbine having high thermal efficiency, the necessary power required to drive the factory can be produced as a by-product from high pressure steam generated in boilers without any appreciable increase in fuel consumption, and exhaust would be available for processing. It contains the total original amount of heat less the small amount used for power generation and radiation losses. In this connection it is important to note that variations in the energy requirements of the different factories are inconsiderable ; but the production of exhaust steam can vary considerably since the steam consumption per H.P. hour varies very widely depending on the thermal efficiencies of the energy units installed. For the same amount of energy production the exhaust production in a factory where individual steam units are installed would be much higher than in a factory where energy is produced centrally by efficient electric power units and various individual loads are run by electricity. When exhaust produced exceeds the requirement of processing the exhaust would blow out to atmosphere. Since blowing of exhaust steam means wasting of valuable heat, it has to be prevented. If the selection of the prime movers is made such that the average steam requirement of processing is passed through the prime movers in generating the required power for driving the factory, it would lead to frequent blowing off of exhaust steam during slack demand periods and use of large amounts of live steam during the peak periods. In a properly balanced factory in which power is produced as a by-product from steam used in processing it is necessary that under normal working conditions exhaust should not blow out to atmosphere. In order to satisfy this condition the factory must be designed so that there is a certain margin available between the average requirement of prime movers and the average quantity consumed in processing. In order to clearly specify this margin which would not permit exhaust to blow out to atmosphere the nature of fluctuations in demand of processing has to be studied.

In order to work out the above,

I. the steam demand for processing,

II. the total power requirement of factory, and

III. consumption of steam per H.P. hour will be discussed by taking a particular case of a factory which had economical working.

STEAM REQUIREMENT FOR PROCESSING

When exhaust is not blown off, the problem of heat balance is to make a balance between the heat recovered in steam from the combustion of bagasse and consumption of same by the plant for :—

(1) Power
(2) Heating of juice
(3) Evaporation
(4) Pan boiling
(5) Miscellaneous heating and washing requirements, and
(6) Radiation losses.

The heat balance of the heat that is recovered in steam from the combustion of bagasse will be discussed later.

To facilitate comparative study of the heat balances of the different factories, the heat requirement of each operation is expressed in terms of the weight of steam condensed from and at 212°F. One lb. of steam gives out 970 B.T.U. on condensation.

Heat of vapourisation or latent heat decreases as the exhaust pressure increases. So, the actual steam consumption of processing units working at higher exhaust pressure than zero lb. gauge would increase in the inverse proportion of their latent heats.

In order to discuss the conditions for economical utilization of bagasse we take the case of a particular factory which was crushing about 1070 tons of cane per day, i.e., about 44.6 tons cane per hour. In this factory steam consumption was 58 percent on cane and exhaust did not blow off to atmosphere. Mills were driven by drop valve engines and the rest of the units were electric driven. The electric power was generated centrally by power units having high thermal efficiencies to drive the individual electric leads. Live steam was generated in boilers having 160 lbs. per sq. inch maximum pressure which were fitted with superheaters to superheat steam to 150°F. The radiation losses in this factory were low as the equipment was arranged in a compact way. The live steam lines from the boilers to the power house and Mill Engines were short as were also the exhaust lines from the power house and Mill Engines to the boiling house.

In these calculations, it is assumed that in this factory the whole of the steam generated in boilers was available for processing.

The necessary power was generated by the adiabatic heat drop in steam in the power generators from steam pressure and temperature obtained at the engine stop valve and dry or overheated exhaust was obtained for processing at the exhaust pressure maintained in the exhaust main. This point would be further clarified when we discuss power units.

The working of processing units was under strict control as for example regarding the water used for dilutions of juice, syrup and molasses etc., at various stages of processing.

Average cane crushed per hour was 100,000 lbs. With 19 percent maceration on cane the mixed juice was 85% on cane. The initial temperature of raw juice was 70°F. The normal conditions of working of boiler pressure, exhaust and vacuum were 145 p.s.i.g., 150° F. overheated steam, 5 lbs. dry or slightly superheated exhaust, and 26″ vacuum respectively.

The performances of boilers in this factory was quite normal. 58000 lbs. of steam was generated per hour and about 25000 lbs. of bagasse having 48.5 percent moisture was consumed per hour. The efficiency of the generation plant was 60.5 percent on gross calorific value of bagasse. On the average about 9000 lbs. of bagasse per hour was being saved. The heat balances for consumptions of steam in the factory and generation of steam in the boilers are discussed below.

1. *Power.* Sufficient power must be generated to meet the demand of crushing and boiling house requirements. The corresponding heat equivalent of this power is calculated.

The actual power requirements of a factory may vary considerably with the general layout of the plant and operational units installed but the following formula gives a fair average. The hourly consumption of energy in K.W. corresponds to the amount of cane in tons crushed daily. So the necessary power required for a factory crushing 1070 tons cane per day is 1070 K.W. or 1435 H.P. Taking 2546 B.T.U. as equivalent to one horse power-hour, the heat equivalent of 1435 H.P. hours is 36,53,510 B.T.U. per hour which corresponds to the condensation of 3760 lbs. of steam from and at 212°F. per hour. This corresponds to 3.76% steam on cane.

The steam which has passed through the power units is available as exhaust steam and contains the total original amount of heat less the small quantity used for power. It is of course further diminished by radiation losses in the power units for which allowance must be made. If the exhaust is superheated its temperature would be high. The difference of actual temperature of exhaust observed and temperature that corresponding to saturated steam pressure of exhaust would give the superheat in exhaust.

The steam consumption of the processing is given below :—

2. Juice heaters	13480	lbs./hr. steam
3. Quadruple effect	15300	,, ,,
4. Vacuum pans	20420	,, ,,
(Note :—Steam requirement of the pans is discussed under head (4) below.)	Total 49200	

To this is added steam consumed in

5. Heating miscellaneous	5800	lbs./hr. steam
6. Radiation loss	3000	,, ,,
(Note :—Item Nos. (5) & (6) are discussed below in their serial order)	Grand total 58000	

Heat diagram is shown in sheet No. 1 (for processing steam).

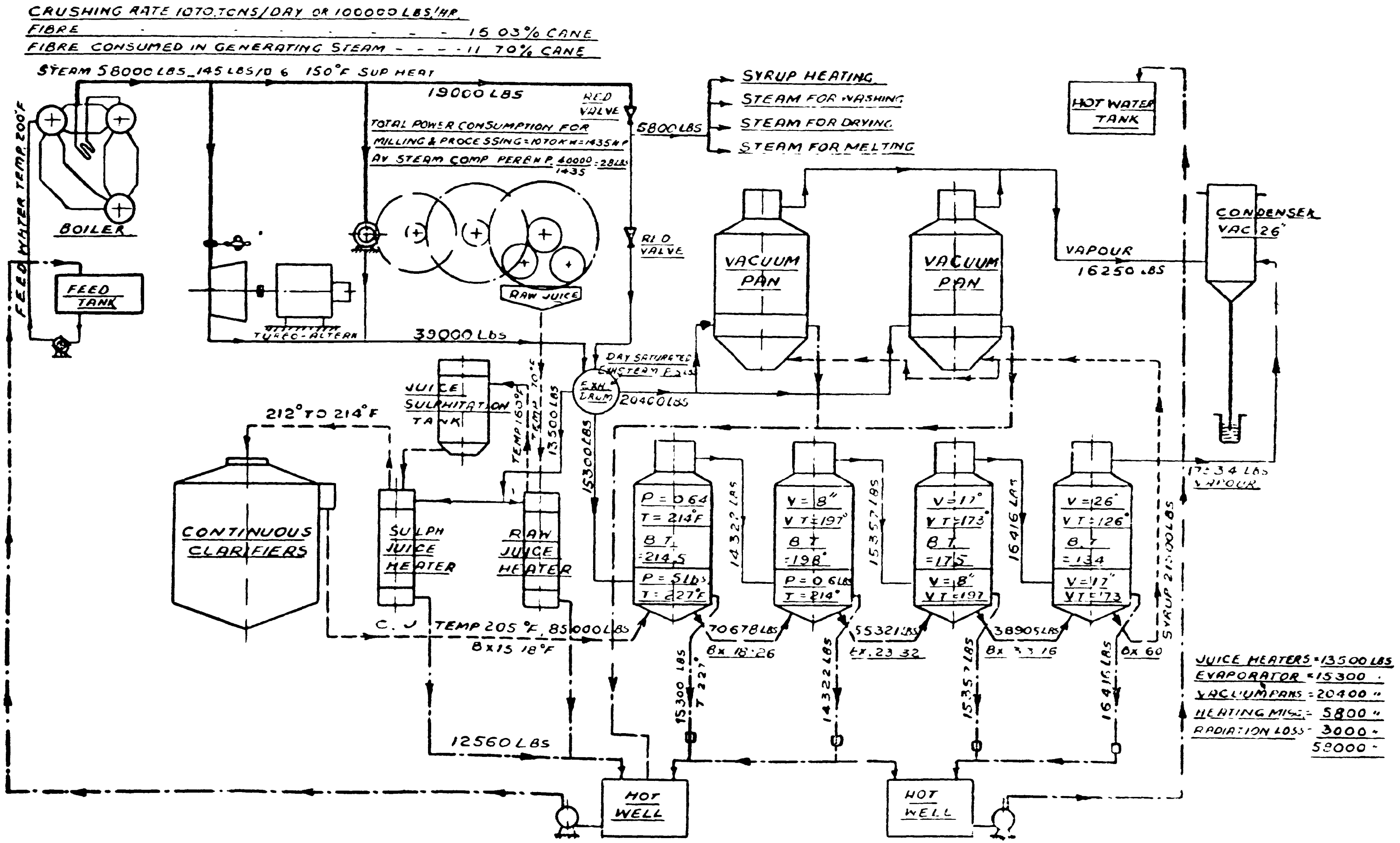
Vacuum pan boiling. The average demand of vacuum pans station was 20420 lbs. per hour, but actually serious oscillations in steam demand occurred between wide limits. The fluctuations and variations in steam consumption on the pan floor are due to following reasons. In the first place there is a tremendous difference in steam consumption between the beginning and end of the strike. In the second place different boilings have got widely different steam consumption depending upon the purities brixes and viscosities of massecuites. In the third place on discharging or cutting over a pan the steam is completely cut off from that pan. The most extravagant steam consumer is the graining pan because the density of syrup is low during the initial stages of boiling. The evaporation is extremely rapid and the steam consumption correspondingly high. The vicious part of it is the fact that the pan will use an enormous amount of steam even though no pressure is recorded in the calandria.

The average consumption of steam in pan boiling was found by actually metering the condensates from pan station.

Bad pan floor work can make all the difference in steam consumption in spite of all the precautions in other directions. With proper control of work at pan station the fluctuations in demand would still be plus 50 percent to minus 50 percent.

With average consumption 20,400 lbs./hr.
Maximum demand would be 30,600 lbs./hr.
Minimum demand would be 10,200 lbs./hr.

The fluctuations on the total steam demand of processing would be less because the steam demand of heating and evaporating units is more or less of constant nature at normal working.


CRUSHING RATE 1070 TONS/DAY OR 100000 LBS/HR.
FIBRE - - - - - - - 15 03% CANE
FIBRE CONSUMED IN GENERATING STEAM - - - - 11 70% CANE
STEAM 58000 LBS_145 LBS/□ 6 150°F SUP HEAT
19000 LBS
RED VALVE
5800 LBS
SYRUP HEATING
STEAM FOR WASHING
STEAM FOR DRYING
STEAM FOR MELTING
TOTAL POWER CONSUMPTION FOR
MILLING & PROCESSING = 1070 K.W. = 1435 H.P.
AV STEAM COMP PER B.H.P. 40000/1435 = 28 LBS
BOILER
FEED WATER TEMP 200°F
FEED TANK
TURBO-ALTERN
RAW JUICE
R.D VALVE
39000 Lbs
DRY SATURATED EX STEAM 5 LBS
EXH DRUM
20400 LBS
15300 LBS
13500 LBS
TEMP 70°F
TEMP 160°F
JUICE SULPHITATION TANK
212° TO 214°F
CONTINUOUS CLARIFIERS
SULPH JUICE HEATER
RAW JUICE HEATER
C. J
TEMP 205°F 85000 LBS
Bx 15 18°F
12560 LBS
VACUUM PAN
VACUUM PAN
VAPOUR 16250 LBS
HOT WATER TANK
CONDENSER VAC 26"
P = 0 64
T = 214°F
B T = 214.5
P = 5 lbs
T = 227°F
V = 8"
V T = 197°
B T = 198°
P = 0 6 LBS
T = 214°
V = 17°
V T = 173°
B T = 175
V = 8"
V T = 197
V = 26°
V T = 126°
B T = 134
V = 17"
V T = 173
14322 LBS
15357 LBS
16416 LBS
17534 LBS VAPOUR
70678 LBS
Bx 18·26
55321 LBS
Bx. 23 32
38905 LBS
Bx 33 16
Bx 60
SYRUP 21000 LBS
15300 LBS
T 227°
14322 LBS
15357 LBS
16416 LBS
HOT WELL
HOT WELL
JUICE HEATERS = 13500 LBS
EVAPORATOR = 15300 "
VACUUM PANS = 20400 "
HEATING MISC. = 5800 "
RADIATION LOSS = 3000 "
58000 "

	Max. rate lbs./hr.	Min. rate lbs./hr.	Average steam consumption lbs./hr.
Juice heating	13,500	13,500	13,500
Evaporation	15,300	15,300	15,300
Pan station	30,600	10,200	20,400
	59,400	39,000	49,200

The minimum demand of exhaust steam at normal working would be 39,00 lbs./hr. Total steam demand of factory under consideration was 58,000 lbs./hr This shows that if 67% of steam produced by the boilers is passed through the prim movers, no exhaust would be blown during the valleys in processing steam demand

(5) *Miscellaneous Heat Demand.* Under the head of miscellaneous liv steam requirement for heating purposes the following items are of importance.

1. Steaming of mills and carriers and tanks etc.
2. Steaming of filter presses for drying the press cake.
3. Washing and calendering of press cloth.
4. Steaming and washing of pans.
5. Heating of syrup, molasses and for remelt of sugar.
6. Steaming of C. F. machines for sugar drying.
7. Heating of air for drying sugar on grasshoppers or in sugar driers

Out of these, steam used at filter press station and sugar house is generall metered. Steam requirement for miscellaneous heating has been estimated a 5800 lbs./hr.

(6) *Radiation loss and steam leakages.* One of the greatest difficultie with which steam user is faced in obtaining the maximum thermal efficienc from his plant is the loss of heat by radiation through the plates of boilers, stea pipes etc. This is a great disadvantage possessed by steam plant and whic cannot altogether be avoided. But in order to reduce this disadvantage to minimum the boilers and steam pipes have to be properly lagged with a suitabl non-conducting composition. The layout of the factory has to be so well designe that minimum length of steam pipes are used to keep radiation loss to a minimum

The other disadvantage associated with it is that this dissipation of hea causes a certain amount of steam to condense and form water in pipes. Th condensate thus formed has a serious feature that the water is carried alon the pipes and if not drained would enter into cylinder of an engine and seriou break down may result. When the condensate from the pipes or processin equipment is discharged through cocks, usually steam escapes along with it an heat loss occurs through steam leakages. Much loss of heat in every factor occurs due to faulty system of the draining of condensate. During the surve of factories in order to reduce this loss to a minimum and efficient operatio of processing units the problem of quickly draining of condensates and efficien trapping of steam was studied thoroughly and suitable recommendations wer made.

THE POWER REQUIREMENT OF A FACTORY

It has already been pointed out that for a given capacity, variations in power requirements between differently equipped factories are rather small whereas the production of exhaust steam can vary considerably because of the large variations in the thermal efficiencies of the energy units installed.

The total power required in case of the factory crushing about 1070 tons of cane daily would be 1435 I.H.P.

It has already been shown that only 39,000 lbs. of dry saturated steam at 5 to 7 lbs. per sq. inch gauge would be the requirement of processing during the valleys in demand. In order that exhaust at no time should blow off to the atmosphere, that means all the energy required for driving the factory should be produced by 39,000 lbs. of steam per hour in the prime movers while working with the limits of pressure available at the stop valve of the engine and exhaust pressure. Further it is assumed that no loss in weight of steam had occurred in prime movers and exhaust steam is obtained dry saturated, or slightly overheated.

In order to determine the conditions of steam at the engine stop valve and thermal efficiencies of the prime movers to be installed to achieve the above stated desired results at specified back pressure, the following discussion would be interesting.

THE STEAM CONSUMPTION PER H.P. HOUR

Steam power ratio—$\frac{39000}{1435} = 27.18$ lbs./hr. per I.H.P., for a balanced factory of about 1070 tons per day capacity.

Assuming a back pressure of 10 p.s.i.g. we shall have to find out pressure at the engine stop valve and degree of superheat in steam and the thermal efficiency of the prime mover so that above rated consumption of steam is obtained per I.H.P. hour.

Assuming an efficiency ratio of 0.7 (drop valve engines to drive the mills and multi-stage turbine to drive the central power house), the steam pressure ought to be 130 p.s.i.g. and the superheat should be 120°F. at the mill engines and turbine stop valves. Consumption of steam would be about 26 to 27 lbs. per H.P. hour and the exhaust from the power units would be slightly superheated. Since the exhaust would be slightly superheated, no loss of weight of steam would take place in the power units.

Taking into account the pressure drop from boilers to mill engines and turbines and as well as the variation in boiler pressure, the boilers should be capable of giving steam at a maximum pressure of 160 p.s.i.g. and 150°F. superheat.

Turbines as Prime movers. Several unfortunate instances have indicated the need for competent and careful examination of the effects of various types of turbine units on the economy of each particular factory in order to avoid undesirable results. In the examination of costs of turbines it is usually found that the larger the unit the lower the cost becomes per H.P. If the units are of sufficient size it is usually possible to afford at a small additional expense, such features as automatic governing with sectionalised nozzles which assure maximum economy. Many manufacturers do not have sufficient demand for this device on their smaller units.

Simple curtis turbine of 1000 H.P. capacity has efficiency ratio 0.5 and steam consumption 36 lbs. per H.P. while working within pressure limits of 130 and 7 p.s.i.g., using saturated steam. It costs Rs. 80,000/- only F.O.R. Indian Port, where as a multi-stage turbine of combined impulse and 28 reaction stages of same capacity working between same pressure limits has steam consumption of 26 lbs. per H.P./hr., and it costs Rs. 2,30,000/-. So in order to have balanced working it is worth while to have a costly machine with the lower steam consumption than to go in for a cheap machine.

The general tendency during the last four years has been for electrification of the auxiliaries with the installation of cheap curtis turbine-alternator set. This change over has not been very beneficial because firstly, curtis turbine steam power ratio is high and secondly, the consumption per H.P. hour increases further because the turbine is made to run on half load as only part of the steam units are replaced in the first instance by electric driven units.

Steam : power ratio of high speed vertical engines. In sugar factories in India, mostly boilers of 160 maximum p.s.i.g. are installed and crushing capacities are 30 to 40 tons cane per hour. We believe that normal scheme for changing over the existing steam driven plants to semi-electrification should be in two stages by the installation of high speed vertical steam compound engines of about 400 to 450 B.H.P. coupled to alternators.

Steam engine driven alternator set comprising one 275 K. W., 3 phase, 50 cycles, 400/440 volts, 375 r. p. m. alternator directly coupled to steam engine of good make such as of the Belliss and Morcom 400 B. H. P. compound steam engine working at a steam pressure of 120 p.s.i.g. at the stop valve and 10 p.s.i.g. back pressure while using 100°F. superheated steam, consumes steam only 23.4 lbs. per B.H.P. per hour at full load.

A factory crushing 35 tons of cane per hour needs about total power 1150 B. H. P. to run the factory. Mills require about 425 B.H.P. and rest of the units 725 B. H. P. So two, 400 B. H. P. steam engine alternator sets of above stated specification can develop all the power needed to drive the factory excepting the Mills under the semi-electrification scheme. In the first stage only one steam engine alternator set may be installed and steam units having low thermal efficiencies such as Duplex pumps and individual small steam engines driving the auxiliaries should be replaced by electric C. F. pumping sets and motors etc.

Full scheme of changing over steam driven plants to semi-electric drive were prepared for a number of factories on the above suggested lines. It was observed that by implementing the recommendation that were made for the first stage, the factories saved considerable amount of bagasse. The plants were completely balanced when the recommendations were fully implemented by the factories by changing over the existing plant to semi-electric drive and no loss of steam through the roof occurred under normal working conditions and total steam requirements of these factories was about 60 percent on cane.

In the case of a factory of 1070 tons capacity a day, the team consumption of which has been discussed in detail in this paper, we have assumed that concentration of juice was done in standard quadruple effect. In case a new factory is installed of same capacity in which the scheme of processing is followed as shown on page 38 in which vapours are bled from all the bodies for juice heating and loss through condenser is reduced to minimum, the steam demand of the processing would be reduced by 8% on cane which would necessitate that energy should be generated more efficiently, due to 67 percent margin maintained between the average consumption of factory and prime movers for economical working. The question now again would arise how far the steam pressure must be increased to meet this reduced steam consumption per B. H. P. hour

$$\text{i.e., } \frac{33500}{1435} = 23.34.$$

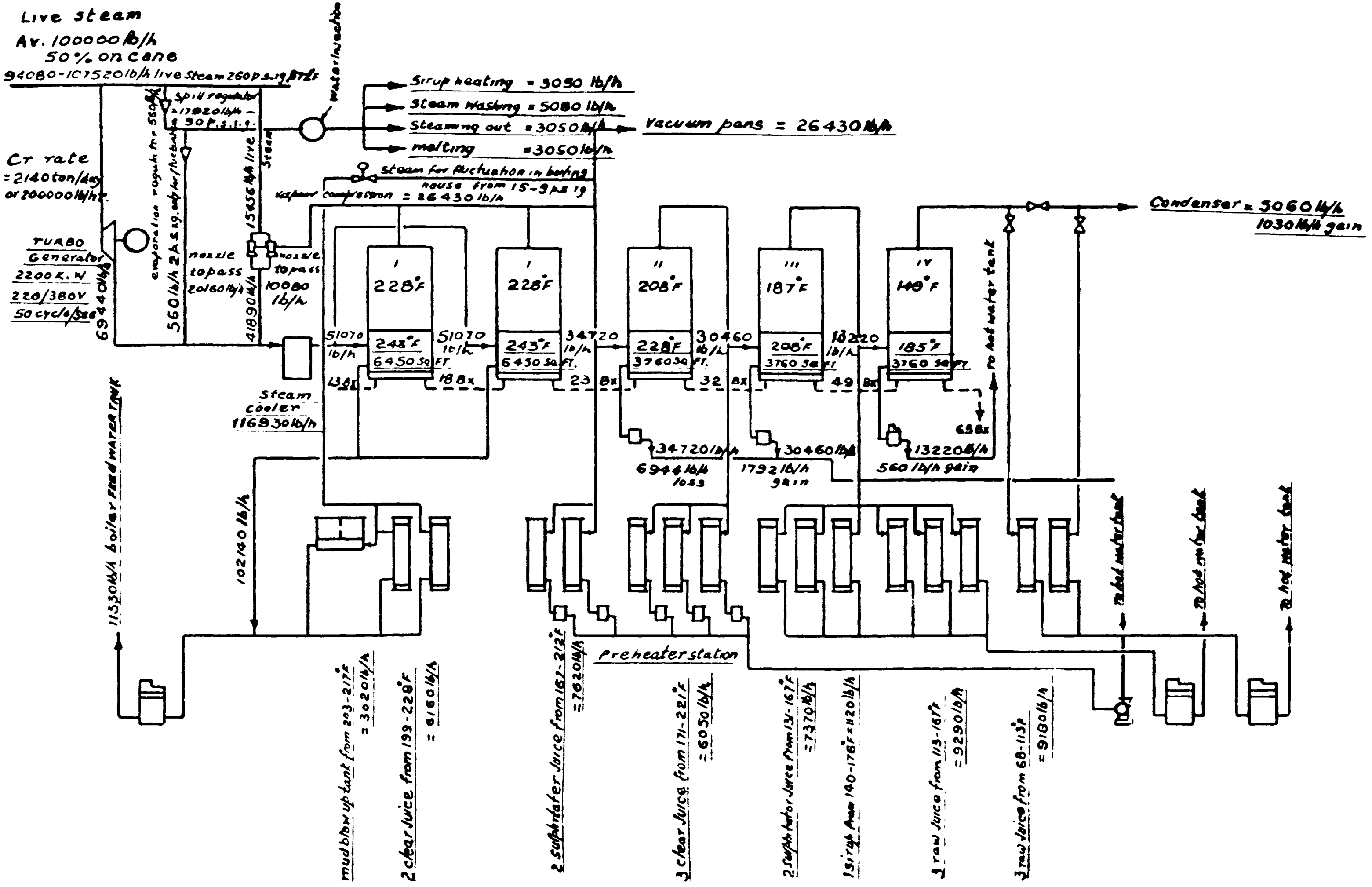
In the new factory of 1070 tons crushing capacity that may be installed it would be necessary to install boilers of 250 p.s.i.g. with steam temperature 650 to 700°F. and multi-stage turbo-generator set of 1000 K.W. capacity. Thus this machine shall have spare power of bout 200 to 250 K.W.

Turbo-alternator should be of the back pressure type but with a surface condenser so that the machine can be run partly or fully as a condensing turbine according to the demand for processing steam. A machine of this type may cost about Rs. 3,00,000/- complete with its condenser and auxiliaries. Its steam consumption at full load with 10 p.s.i.g. back pressure and 26 in. vacuum would be 22 lbs. per K.W. hr. and condensing 17 lbs. per K.W. hr.

B. Steam generation plant efficiency. It is a standard practice to judge the merits of a furnace and efficient combustion of fuel from the heat balance of the boiler unit.

In the practical case of the factory under review which was crushing about 44.6 tons of cane per hour and had balanced working, the generation of steam in the boilers on the average was 58% on cane. The boilers are installed with improved design of furnace, which was prepared by the Fuel Economy Section of this Institute. The design of boiler furnace has been shown on page 41.

From the furnace tests made during the past seven years it is concluded that with proper design and control effective combustion may be obtained with cold air and with simple and comparatively inexpensive settings and good combustion is the main requirement for obtaining high boiler efficiency together with high evaporation rate. In the boiler furnaces constructed according to the improved design prepared by us, it was possible to complete the combustion with low excess air. The high temperatures in the combustion chambers were developed due to adequate volume of combustion chamber and restricted opening provided for flow of gases into the chamber under the boiler tubes, by long screening area provided by baffles at the rear end of combustion chamber. Due to intimate


Live steam
Av. 100000 lb/h
50% on cane
94080-107520 lb/h live steam 260 p.s.i.g. 572°F
Cr rate
= 2140 ton/day
or 200000 lb/hr.
TURBO
Generator
2200 K.W
220/380V
50 cycle/sec
69440 lb/h
evaporation regulator 560 lb/h
560 lb/h 2 A.S.I.g. only for /Nechanix
spill regulator
= 17820 lb/h -
90 P.s.i.g.
nozzle
topass
20160 lb/h
41890 lb/h
15456 lb/h live
steam
nozzle
topass
10080
lb/h
water injection
Sirup heating = 3050 lb/h
Steam washing = 5080 lb/h
Steaming out = 3050 lb/h
melting = 3050 lb/h
Vacuum pans = 26430 lb/h
steam for fluctuation in boiling
house from 15-9 p.s.i.g.
vapour compression = 26430 lb/h
Steam
cooler
116930 lb/h
I
228°F
243°F
6450 sq FT
51070
lb/h
13 Bx
I
228°F
243°F
6450 sq FT.
51070
lb/h
18 Bx
II
208°F
228°F
3760 sq FT.
34720
lb/h
23 Bx
III
187°F
208°F
3760 sq FT
30460
lb/h
32 Bx
IV
149°F
185°F
3760 sq FT
18220
lb/h
49 Bx
65 Bx
34720 lb/h
6944 lb/h
loss
30460 lb/h
1792 lb/h
gain
13220 lb/h
560 lb/h gain
To hot water tank
Condenser = 5060 lb/h
1030 lb/h gain
102140 lb/h
11530 lb/h boiler feed water tank
mud blow up tank from 203-217°F
= 3020 lb/h
2 clear juice from 199-228°F
= 6160 lb/h
2 sulphitater juice from 187-212°F
= 7620 lb/h
Preheater station
3 clear juice from 171-221°F
= 6050 lb/h
2 sulphitator juice from 131-167°F
= 7370 lb/h
1 sirup from 140-176°F = 1120 lb/h
3 raw juice from 113-167°F
= 9290 lb/h
3 raw juice from 68-113°F
= 9180 lb/h
To hot water tank
To hot water tank
To hot water tank

mixing of gases and air high temperatures in the combustion chamber were developed. The unburnt carbon particles entering the combustion chamber were completely burnt and " fly ash " loss was completely eliminated.

Older designs with small combustion volumes and low fire bridges were found to give high losses of both sensible heat in flue gases and solid unburnt fuel and gases.

The maximum and minimum demand for steam in a factory of 1070 *tons capacity per day under discussion are given belew* :—

The average crushing rate	1,00,000 lbs./hr.
The average demand of steam	58,000 lbs./hr.
Rate of minimum demand	47,800 lbs./hr.
Rate of maximum demand	68,200 lbs./hr.

The maximum and minimum demand of steam was plus 17.5 percent and minus 17.5 percent of average rate of production.

The above figures do not take into account the fluctuations in demand of prime movers. Under actual operational conditions the fluctuations may be about plus 20 percent and minus 20 percent of the average rate of combustion.

In case the highly fluctuating saturated live steam demand of processing is met from a separate boiler then the fluctuations on the other boilers supplying superheated steam to the prime movers would be practically eliminated. However, for having effective control on the working of boiler station it is essential that position of boiling of various strikes in different pans should be signalled to boiler station so that work at boiler station may be so regulated that too often blowing of safety valves or drop in pressure can be avoided as far as possible.

It has been suggested to install an accumulator between the boilers and the process steam main. It is, however, somewhat controversial and doubts have been expressed as to whether such an expensive apparatus is strictly required in a sugar factory.

Boiler heat balance

Principal dimensions of the battery of boilers installed in the factory under discussion are given below. Total boiler heating surface in operation is 15000 sq. ft. Three boilers of H.S. 5000 sq. ft. each are in operation in the above stated factory.

Furnace proportion

The sectional elevation of bagasse furnace installed with the boiler is given in Sheet No. 3 on page 41 and its main proportions are given below :—

Grate area of boiler	97 sq. ft.
Ratio of H.S. to grate area	51.6

Volumes.

Furnace	365 cu. ft.
Combustion chamber	765 „
Transfer space	420 „
Total volume	1550 „

Ratios

Combustion chamber/furnace volume =2.09
Heating surface/c.c. volume =6.53
Heating surface/furnace and c.c. volume =3.22

Boiler test results

Boiler heat balance was prepared on gross calorific value

Boiler efficiency	60.50
Condensation loss	18.85
Sensible heat loss	15.29
Unburnt gas loss	0.60
Unaccounted losses	4.76
	100.00

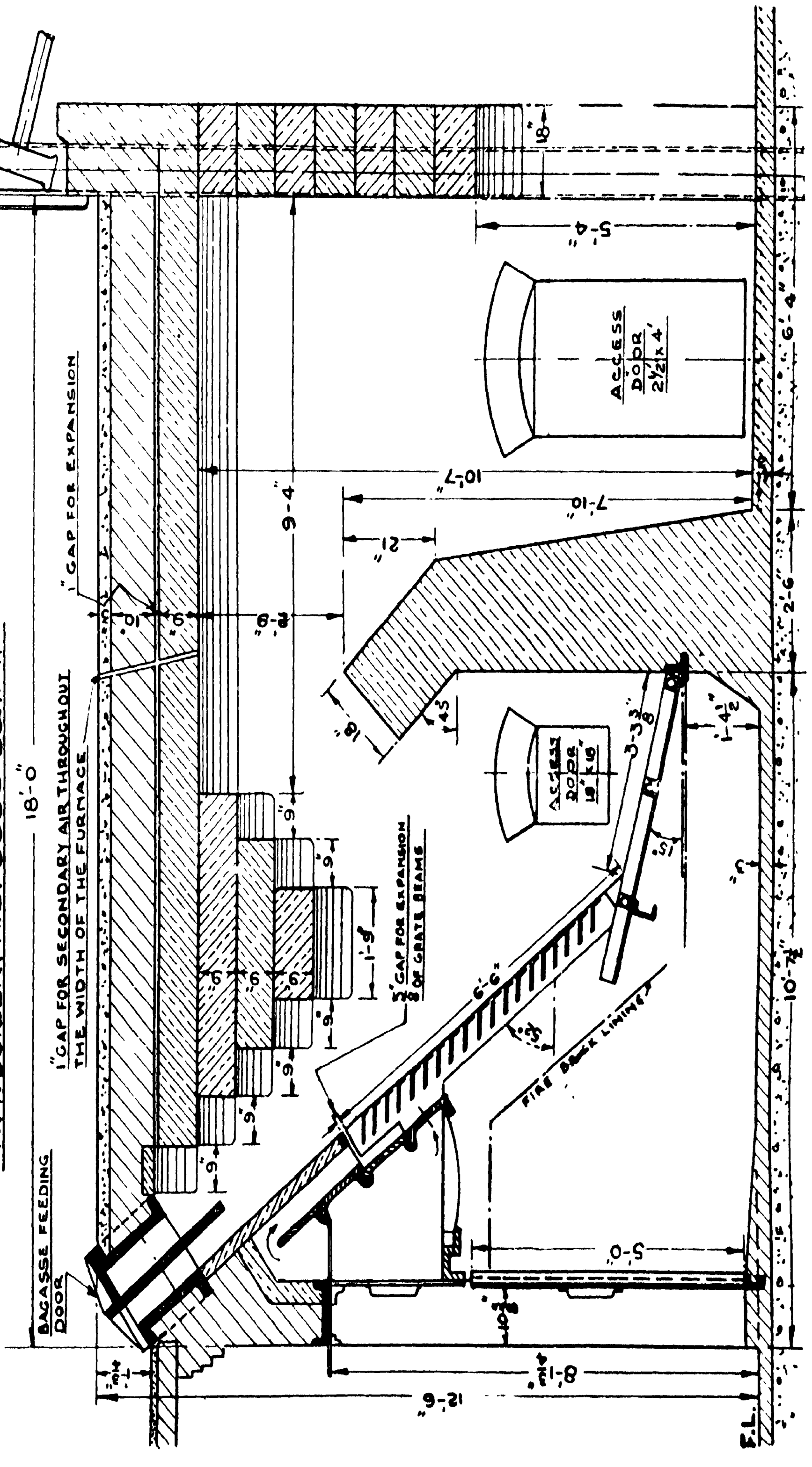
Diagrammatic representation of heat balance of steam generation plant is shown on page 42.

1.	Duration of test hours	8
2.	Average total evaporation per hour lbs.	58,000
3.	Average evaporation lbs./sq. ft./hr.	3.86
4.	Average boiler working pressure p.s.i.g.	145
5.	Av. temp. superheat °F.	150
6.	Total heat in one lb. of steam B.Th.U.	1276
7.	Feed water temp. entering boiler °F.	200
8.	Total heat added B.Th.U. of steam in boiler	1108
9.	Av. crushing rate per hour lbs.	1,00,000
10.	Av. bagasse percent cane	34
11.	Av. total bagasse produced lbs./hr.	34,000
12.	Av. ,, ,, consumed lbs./hr.	25,180
13.	Av. evaporation per lb. of bagasse	2.304
14.	Bagasse not used lbs./hr.	8820
15.	,, ,, ,, % produced	25.94
16.	,, ,, ,, % consumed	8.820
17.	Pol. % bagasse	3.0
18.	Moisture % bagasse	48.50
19.	Gross calorific value B. Th.U./lb.	4219
20.	Net calorific value B.Th.U./lb.	3424
21.	Condensation loss B.Th.U./lb.	795
22.	Condensation loss % G.C.V.	18.85
23.	% CO_2 in flue gases leaving boiler	13.8
24.	% CO in flue gases leaving boiler	0.2
25.	% excess air supplied	50
26.	Temperature of air entering boiler	86°F.
27.	Temperature of flue gases leaving boiler	530°F.
28.	Combustion chamber temp.	2000°F.

IMPROVED DESIGN OF BAGASSE FURNACE

FOR

W.T. BOILER, H.S. 5000 SQ. FT.



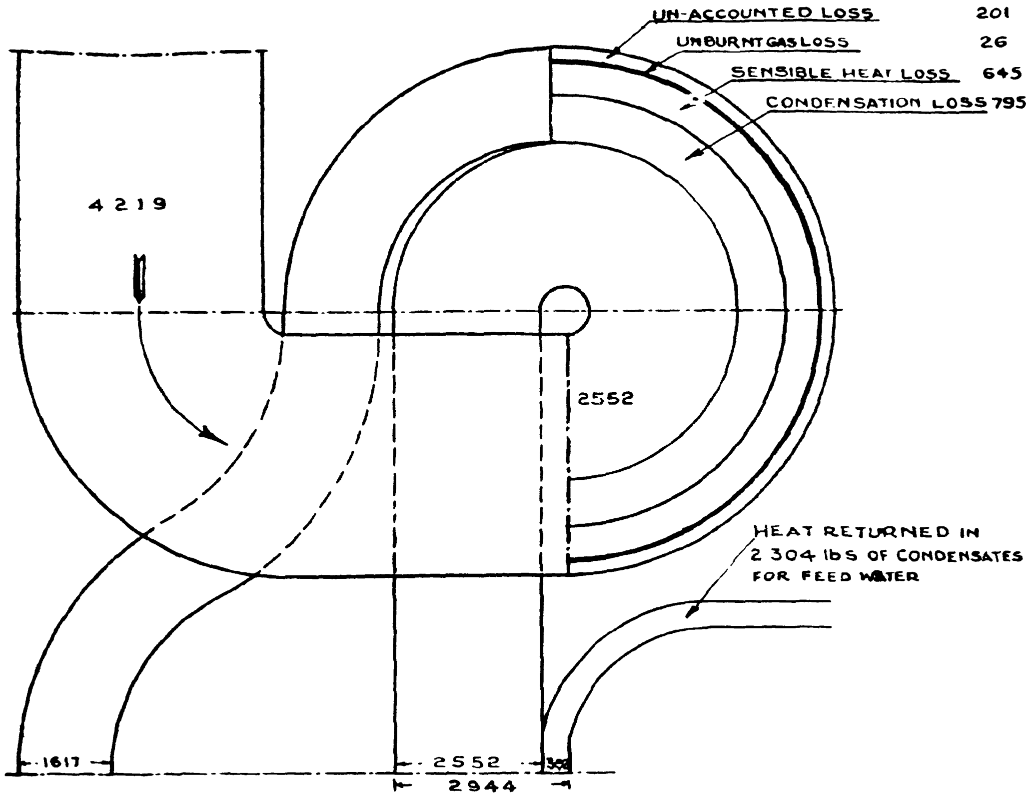
SECTIONAL ELEVATION

2 SUCH FURNACES EACH 5'-0" WIDE.

HEAT DIAGRAM

EXPRESSED IN BRITISH THERMAL UNITS

(B. Th U)



Av	Pol % Bagasse	3·00
"	Moisture % Bagasse	48·5
"	Gross calorific value.	4219
"	Net calorific value	3424
"	Boiler Pressure	145 lbs/□"
"	Degree Sup Heat	150°F
"	Heat in one lb steam	1276 B.th.u
"	Boiler Feed water Temp.	200°F
"	Heat added per lb of steam.	1108 B.th.u
"	Evaporation per lb of Bagasse	2·304
"	Equivalent evaporation from & at 212° F.	2·63
"	Heat recovered in steam per lb of Bagasse.	2552
"	Boiler efficiency % Gross calorific value.	60·5%
"	Condensation loss.	18·85%
"	Sensible heat loss	15·29%
"	Unburnt gas loss.	0·60%
"	Un-accounted loss	4·76%
		100%

Draught in water inches

29.	Back of boiler just over damper	0.65"
30.	Base of chimney	1.0"
31.	Sensible heat loss	15.29% G.C.V.

In order to further improve the generation plant efficiency the following methods are employed to recover sensible heat loss occurring in waste gases.

Considerable heat is wasted through the chimney as sensible heat loss. By installing air preheaters and economisers a substantial amount of heat can be recovered from waste gases. Many factories have recently installed modern gilled tube economisers and tests have shown that the recovery of heat from waste gases was about 6 to 7 percent gross calorific value of the bagasse. The good heat recovery was due to the fact that high heat transfer co-efficients are obtained in the economiser. The desirable maximum recovery, however, can be attained only when following conditions are met. The heat absorbing surface must be kept free from deposit of the dirt which is inevitably present in the flue gases. The accumulation of the dirt in the passages increases the resistance to the flow of gases and reduces the amount of air available to the fuel, thus slowing down combustion and heat release in the boiler itself and reducing steam output. Also deposits of dirt on the heating surface, because of their insulating effect, retard the transference of heat from the gases to the water. Factories located in zones where fibre percent in cane is low it becomes essential to install economisers having adequate heating surface for recovery of heat from the waste flue gases so as to make the generation plants self-sufficient in bagasse.

ACKNOWLEDGMENT

The author wishes to record his grateful thanks to Professor K.S.G. Doss, D.Sc., F.R.I.C., F. Inst. P., F.A.Sc., Director, National Sugar Institute for his keen interest in the work.

DISCUSSION

Mr. W. M. Livie asked over what period of factory operation had the figures been taken.

Mr. Jagjit Singh stated that the period was 7/8 days and that the steam consumptions had been calculated by measuring condensates by means of Kent meters. The investigations had shown that the steam consumption in Indian factories producing large grain sugar was 65/68% on cane.

Mr. Agarwal asked what was considered the best method for making up the shortage of exhaust steam in the factory.

Mr. Singh said he preferred to supply live steam directly to the vessels, and not to admit live steam into the exhaust system, as this increased the back pressure causing inefficient operation of all the prime movers.

Mr. J. P. Mukherji stated that the direct supply of live steam to vessels was difficult to control, and led to extravagant use of steam. He preferred introducing live steam to the exhaust main by means of an " overflow " valve. He described a system where exhaust steam was maintained at 7.5 p.s.i.g. for supply to heaters and evaporators, the surplus being allowed to overflow into a main kept at 3 p.s.i.g. for supply to calandria vacuum pans.

Mr. G. H. Jenkins considered that the exhaust steam system should be regarded more from the point of view of the process requirements than the efficiency of prime movers, and also that steady pressure conditions should be maintained in order to assist the process operations. He stated that Queensland practice is to maintain a uniform 10 lbs. p.s.i.g. pressure in the exhaust system. He considered this pressure should be maintained within ±0.5 p.s.i.g. and advocated the use of automatic controllers for ensuring the conditions.

Mr. J. O. Sason suggested the use of thermo-jet compressors to augment the steam supply in cases where the exhaust pressure is too low for efficient process work.

Mr. Mukherji pointed out that the various methods suggested for overcoming a shortage of exhaust steam presupposed that there existed in the factory a source of steam supply which could cope instantaneously with wide variations in process steam demand. He considered the situation was best met by the use of a steam accumulator.

Mr. O. M. Henzell said that he had recently visited South Africa and in some factories had seen steam accumulators installed for balancing the steam pressure conditions.

The author presented the following paper.

Paper

SUGAR FACORY LUBRICATION

J. K. McClennan

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The correct lubrication of the machinery in a sugar factory is an important contributory factor towards continuous and satisfactory operation of each unit and of the plant as a whole.

This paper describes the lubricating methods most suited to the various types of machinery employed in the modern sugar factory. Recommendations are given also on the qualities of lubricants for particular requirements, and the precautions required in the storage and dispensing of oils and greases in order to ensure best economy in their use.

STEAM ENGINES

Sugar factories in India employ both horizontal and vertical steam engines, the lubrication of which is not difficult. It is essential for continuous operation, however, that the correct lubricant be selected, optimum feeds determined and the best method of application used. The lubrication of steam engines can be divided under cylinder lubrication (including valves and glands), and other lubrication covering the external parts or the crank-chamber.

The choice of cylinder oil depends primarily upon the properties of the steam. The method of selecting according to either pressure or temperature is satisfactory for saturated steam, as the two are related. As this does not hold for superheated steam, the best way is to select the correct grade according to temperature. For sugar mills in India operating on saturated steam below 500°F., and this applies to the majority—the position can be simplified by the selection of one type of cylinder oil. A filtered, compounded, cylinder oil of approximately 125 to 145 seconds Redwood viscosity at 212°F. will be suitable for all steam engines in the factory.

The function of a cylinder oil is to eliminate wear between piston rings and cylinder walls, and to act as a seal against steam blowby. The compounding in cylinder oil is necessary to combat the washing effect of moisture. The compounding causes the oil to emulsify in the presence of water and thereby to stick to the metal surfaces instead of being washed away. A good grade of cylinder oil has a high viscosity index (resistance to thinning under the influence of high temperature) and therefore provides an effective lubricating film even under high temperature conditions. A filtered cylinder oil gives less carbon formation in the cylinders and around the valves under high temperature conditions.

There are three instances where the above product might not be entirely suitable, but these are only of a temporary nature. As exhaust steam from the steam engines is used for heating purposes in the boiling house, it should be free from oil. If oil separation is not efficient, it may be necessary to use a straight mineral cylinder oil until such time as the situation is corrected. The second instance is when the cylinder oil leaks from the steam cylinder into the crankcase of vertical enclosed engines. A compounded cylinder oil will cause the bearing oil to emulsify in the presence of water. A straight mineral cylinder oil should therefore be used, until the situation is corrected by replacement of packings or provision of suitable shields on piston or valve rods. The third instance is where cylinder oil is applied through dose cups or other inefficient means as is sometimes found on duplex steam pumps. Here a secondary grade might be used as the benefits of a high grade product cannot be realized when applied through such devices.

It is generally accepted that the best way to introduce cylinder oil is through an atomizer in the steam line. The atomizer should be located at a position in the steam line depending on steam velocity and the location of the steam separator (if present) and the steam valve. The oil can be introduced into the atomizer either by a hydrostatic or a mechanical lubricator. The mechanical lubricator is generally preferred as it does not have to be manually started and stopped, has a positive action, and is easier to regulate. In the hydrostatic lubricator the oil flow depends on the rate of condensation of steam which in turn varies considerably with engine room temperatures.

There are two generally accepted methods of estimating the amount of cylinder oil required by a particular engine. One method uses the swept cylinder surface as a measure, and the other the rated horse power of the engine. A figure of one pint of high grade, suitably compounded cylinder oil per one million sq. ft. of swept surface is usually used. The second method is to be preferred as it is easier to calculate. From experience it has been found that 1 lb. per 1000 rated horse power hours for horizontal engines, and 1 pint for 10,000 rated horse power hours for vertical engines is adequate, this last figure being that recommended by one of the largest manufacturers of vertical steam engines. The difference in the rate of feed between horizontal and vertical cylinders is due to the weight of the piston, slower speed, larger clearances and other mechanical differences in the former.

The main mill engines in the majority of Indian sugar factories are fully loaded, if not over-loaded, and the tendency is therefore to feed more cylinder oil than is necessary. Actually it is easier to lubricate engines operating on heavy loads than those operating on light loads, due to better atomization of the oil and less condensation of the steam. When it is decided that the cylinder oil feed to an engine is excessive, reduction must only be carried out gradually. Visual examination of rods and valves and cylinder surfaces will usually indicate whether or not adequate oil is being fed to the cylinder. The rubbing surfaces should show complete oil films with little, if any, excess oil in clearance spaces or in the exhaust system. If the engine should begin to chatter, squeak or groan, the oil feed to the valves and cylinder is obviously inadequate.

The other parts of steam engines requiring lubrication are the main bearings, crankpin bearings, crosshead pins and guides, eccentrics and valve gear, and governor. In vertical enclosed engines these parts are lubricated from the crankcase by a circulation system. A suitable lubricant must have the correct viscosity, good oxidation resistance and good demulsification. A high grade turbine oil meets these requirements. The viscosity of the lubricant will depend upon the horse power of the engine, the recommendation being a Redwood viscosity of 90 to 110 seconds at 140° F. for engines upto 200 horse power, a viscosity of 130 to·150 seconds for 200 to 500 horse power, and a viscosity of 180 to 200 seconds for engines above 500 horse power.

In horizontal open steam engines the external moving parts are lubricated by a variety of methods. In most cases sight feed oilers are employed, although some main and outboard bearings are ring oiled. An oil containing additives to impart good film strength and having a Redwood viscosity of 160 to 180 seconds at 140 °F. will be found suitable for the lubrication of these parts regardless of the method of application.

CRUSHER AND MILL ROLL BEARINGS

The lubrication of crusher and mill roller bearings represents the toughest job in sugar factories as the bearings carry extremely heavy loads, the shafts rotate at slow speeds making it hard to maintain a continuous oil film between journal and bearing, and ingress of juice and bagasse to the bearing surfaces is difficult to avoid.

Most of the mill and crusher bearings in the Indian sugar factories are oil lubricated by means of mechanical lubricators. Those factories still using sight-feed oil cups, wick oilers, or hand application would derive definite benefit from the installation of mechanical lubricators. Less oil consumption with increased lubrication efficiency will result. This service requires a heavy bodied oil, preferably compounded with an additive to increase the film strength and resist the washing effect of water or juice that may enter the bearing. The Redwood viscosity of the mill roll bearing oil should be between 160 and 190 seconds at 212°F. The compounding in the oil will result in satisfactory lubrication with considerably lower consumption. Usually about one pound per eight hour shift for six bearings 12" x 16" in size is sufficient.

During the past few seasons some factories have been evaluating both greases and gear shield type products for mill roll bearing lubrication in order to effect a saving in lubrication cost. According to reports both products have been successfully used. The main obstacle to the use of grease seems to be the difficulty of obtaining a mechanical lubricator which will apply it in regular measured amount. Grease has been applied by large screw-down grease cups, by home-made weighted lubricators, and there is a case where a 19-feed mechanical lubricator has been supplied by a leading manufacturer of lubricant dispensing equipment.

COMPRESSORS AND VACUUM PUMPS

Most of the compressors and vacuum pumps in Indian sugar factories are of the reciprocating type, open or enclosed, driven either by steam engine or electric motor. For all cylinders a turbine type oil is recommended having a Redwood viscosity of 90 to 150 seconds at 140° F. which is the same oil as recommended for oil lubricated ball or roller bearings and for crankcases of vertical steam engines.

Contrary to the general belief, the cylinder of an air compressor or vaccum pump does not require the same amount of lubricant as the cylinder of a steam engine of similar size ; actually it requires only one quarter of the amount. This is due to the facts that the air cylinder is not subjected to as high a temperature or pressure, or to the same washing effect of moisture.

The oil feed rates recommended by the makers should be adhered to when starting up new compressors or vacuum pumps. After running for some time, an inspection should be made through the valve opening to see that the cylinder and valves are being lubricated properly. The surfaces should have an oily feel, but no oil as drops should be present. The safest method of regulating cylinder oil feed is by this visual inspection method.

The same oil as used for cylinder lubrication should be used in the crankcase of enclosed compressors or vacuum pumps. If the bearings are not enclosed, then the same oil should be used as for the external lubrication of horizontal steam engines.

GEARS

The gears in the Indian sugar factories are practically all of the open or semi-enclosed type. Spur, herringbone and worm gears are the common forms employed. We are most concerned with the transmission and crown gears on the mills, and the worm gears on the crystallizers. The first two categories are either entirely open or else dip into shallow slush pans, while the latter dip into slush pans.

The above gears are subjected to heavy pressures and should be lubricated with a heavy, viscous, adhesive oil in order to protect them against excessive wear. A product of the gear shield type having a Redwood viscosity of 800 to 950 seconds at 212° F. will be found suitable for both open and slush pan applications. A product of this consistency can be applied by brush or swab without heating, except possibly during cold weather. Products of this type of heavier consistency are available and widely used but they must be heated for application. Also available are gear shield lubricants which have been cut back with a volatile solvent to facilitate application. The solvent evaporates and the product remaining is of the consistency of the original lubricant. As far as can be ascertained these products have not as yet been widely accepted in Indian sugar factories.

The gears should be thoroughly cleaned before the first application of the gear shield type of lubricant. This is important if a conventional grease has been previously applied, as the two types are not compatible.

HYDRAULIC PRESSURE SYSTEMS

The hydraulic pressure system on the mills consists of a pump, accumulators and hydraulic cylinders in the caps over the top roll bearings. A hydraulic medium which will also lubricate the pump is desirable, and many systems are lubricated with an emulsion of one part of soluble oil and forty parts of water. This medium is inexpensive and particularly suitable when the system is not oil-tight.

If a soluble oil is not used, then we have always recommended a turbine type oil as is used in other varieties of hydraulic systems. This product will be the same as that used for oil lubricated antifriction bearings, compressors, etc. The exceptional stability of this type oil will allow its use almost indefinitely. We are aware, however, that a variety of other products are in use. Some use filtered oil from the external bearings of steam engines either straight or mixed with castor oil. Others prefer an even heavier oil. There does not seem to be any agreement as to a universally acceptable type of product.

In some cases centrifugals are driven by a small Pelton type of hydraulic turbine. The water pressure is supplied by a pump and this hydraulic system is of the closed type. In order to prevent rusting in these systems, an emulsion of one part of soluble oil and forty parts of water is used. The same soluble oil is used in this situation as is used in the hydraulic pressure system for mill rolls and crushers.

BEARINGS

Most bearings in the Indian sugar factories are of the plain journal type. Exceptions may occur in electric motors, shafting and centrifugals, where ball and roller bearings are becoming popular.

The plain gear train bearings are subject to heavy loading, and are lubricated by a variety of methods, i.e., hand oiled, sight-feed oil cups, ring oiled, and gravity circulating systems. The last method is to be preferred, as it assures a good supply of oil to the bearing, and affords an opportunity for continuous filtration of the oil. An oil suitable for this service should have good stability, when used in ring-oiled or circulation systems, and good film strength when applied by hand or sight-feed oiler. The product should also be heavy bodied to take care of the heavy load, and to form a good lubricating film under the slow speed conditions. The same oil is recommended for this service as for the external lubrication of steam engines, namely, a product having a Redwood viscosity of 160 to 180 seconds at 140°F. This is also suitable for other journal bearings in the factory, such as those on cane knives, shredders, line shafting, carriers and conveyors, centrifugals, etc.

Ball and roller bearings can be either oil or grease lubricated. For those that are oil lubricated a product of the turbine oil type is recommended. This type of product has both resistance to oxidation and corrosion which is necessary for continued use in a bearing system. An acceptable product is one having a Redwood viscosity of 90 to 150 seconds at 140°F. This is the same as has been recommended for vertical steam engine crankcases, compressors, vacuum pumps, and oil tight hydraulic systems.

For grease lubricated ball and roller bearings a good ball bearing grease of medium consistency is used. Most of these have either a soda or soda-lime base, although there are good greases available having a lime base only. A soda or soda-lime base grease is essential where temperatures are above 165°F. while a lime base grease is necessary for wet conditions.

It must be stressed strongly that ball and roller bearings should not be over-lubricated. If they are oil lubricated, the oil level should not be allowed to extend above the centre of the lowest ball or roller. Bearings designed for hand packing with grease should not be filled above ½ to ⅔ full. If lubricant is introduced through a grease plug, a drain plug should also be provided. Grease should be applied with the bearing running and with the drain plug removed. After applying the new grease the drain plug should not be replaced until grease has stopped issuing from it and the bearing has had time to purge itself of excess lubricant.

PUMPS

Pumps in sugar factories are used for juice, maceration water, massecuite, mud, syrup, molasses, magma, etc. The more common types employed are steam reciprocating and centrifugal, and to a more restricted extent rotary, diaphragm and plunger types. A general practice in most factories is to use a lower grade cylinder oil for steam reciprocating pumps then for the cylinders on the main mill engines, as the oil in the former is usually fed through inefficient dose cups. It is more effective and economical, however, to fit mechanical lubricators on pump steam cylinders, and to use the same high grade cylinder oil as for mill engines. The supporting bearings of centrifugal and rotary pumps are usually ring-oiled plain bearings or oil or grease lubricated ball bearings. The lubricants recommended for oil and grease lubricated ball and roller bearings should be used.

Diaphragm and plunger type pumps are usually hand oiled and should be lubricated with the same type of product recommended for external lubrication of horizontal steam engines.

LUBRICATION SCHEDULE AND REMOVAL PERIODS FOR ENCLOSED SYSTEM

A complete lubrication schedule for all machines in a factory should be worked out in co-operation with lubrication specialists. Portions of the schedule pertaining to individual departments should be typed on stiff paper in chart form, and displayed in conspicuous places in the department. These charts will instruct the oiler how often to lubricate the various parts on the machines.

Some factories have successfully introduced a colour code system of lubrication. This system helps to ensure that the correct lubricant is applied in the correct place regardless of the experience or intelligence of the oiler. Each oil or grease is assigned a separate colour. This colour is painted on the barrel of lubricant when received in the oil store, on the containers used for transporting it to the various locations in the factory, on the oil cans or grease guns used for applying it, and on the machine points where it is to be applied.

A schedule should be maintained for the removal of lubricants from enclosed systems such as the crankcases of compressors, vacuum pumps and vertical steam engines, and from ring-oiled bearing, grease lubricated ball and roller bearings etc. Except in the case of vertical steam engine crankcases, the oil charges should be removed after each crushing season. The oil systems should be thoroughly cleaned and new or filtered oil introduced. In the case of grease lubricated ball or roller bearings, the old grease should be removed, the bearings and assembly washed in kerosene, then light oil, and new grease introduced.

On account of the possibility of water and cylinder oil contamination, the crankcase charges of vertical steam engines should be removed and centrifuged each fortnight when the factory closes for cleaning. If severe water contamination is occurring, the water should be drained from the lowest point on the crankcase each day, or even oftener.

SUGAR FACTORY LUBRICANTS CONSUMPTION

A figure of 0.010 to 0.012 ton/maund of lubricants per 100 tons/maunds cane crushed has become a standard figure for economical lubrication of a sugar factory in India. This figure was established for a factory using steam power and having a normal length crushing season. It is high for an electrified factory, and low in cases of short crushing seasons.

Close supervision of lubrication must be practised in order to achieve the above figures. Adequate but not excessive oil feeds must be established for steam cylinders, crusher and mill roll bearings and hand or sight feed cup oiled bearings. Mechanical lubricators should be fitted to all steam cylinders, and the oil fed through atomizers in the steam line. The oil that leaks from external bearings on horizontal steam engines should be collected by providing suitable tray arrangements. This collected oil can be passed through a simple cotton waste oil filter and reused for the same bearings. A gravity circulating system should be installed for the lubrication of gear train bearings in order to provide for continuous reuse of the oil.

After removal, the charge from all enclosed systems should be filtered through a simple cotton waste filter, if a centrifuge or more elaborate filter is not available, and thereafter reused as a new charge or for make-up. The oil and water periodically drawn from the crankcase of enclosed vertical steam engines should be stored in drums and centrifuged to remove the oil portion for reuse. The oil that collects in the drip trays under the faucets of oil storage barrels can be used for the lubrication of chains and sprockets on conveyors in place of new oil.

BASIC LIST OF LUBRICANTS FOR SUGAR FACTORIES

A sugar factory can generally be successfully lubricated with 6 oils and 2 greases. It is obviously a good practice to use the least number of lubricants possible, consistent with good lubrication practice. The following list is proposed as a minimum requirement.

Type of Product	*General Uses*
1. Compounded Steam Cylinder Oil of 125 to 140 seconds Redwood viscosity at 212°F.	All steam cylinders
2. Bearing Oil of 160 to 180 seconds Redwood viscosity at 140°F.	External bearings of steam engines, transmission gear bearings, most ring-oiled plain bearings, etc.
3. Turbine Type Oil of 90 to 150 seconds Redwood viscosity 140 °F.	Crankcases of vertical steam engines, oil tight hydraulic systems, ball and roller bearings, compressors and vacuum pumps, etc.
4. Heavy Bodied Compounded Oil of 160 to 190 seconds Redwood viscosity at 212 °F.	Crusher and mill roll bearings.

5.	Soluble Oil.	Hydraulic pressure systems.
6.	Gear Shield Type Product of 800 to 950 seconds Redwood viscosity at 212° F.	Open and semi-enclosed gears.
7.	Ball and Roller Bearing Greaseof medium consistency.	All grease lubricated ball and roller bearings.
8.	General Purpose Cup Grease of stiff consistency.	All grease cups on plain bearings.

STORAGE AND HANDLING OF LUBRICANTS

Barrels of lubricants at sugar factories are all too often stored on end and out-of-doors. High grade lubricants are expensive and the supplier takes particular care to ensure that his customer receives the products in clean containers and in an uncontaminated condition. When lubricants are stored outside for any length of time and it is not uncommon for an unopened barrel to lie at a sugar factory for two years or more they may become contaminated with water and dirt, the barrel may rust through and the brand name may become obliterated. Furthermore, the lubricant may deteriorate in quality due to age and variations in temperature, which is particularly the case with greases.There is also a tendency to use the latest consignment received instead of the earlier stocks.

Barrels from which oil is being dispensed should be placed on their sides on racks, and faucets inserted in the small bungs. This arrangement renders dispensing easy and, if trays are placed below the faucets to catch drips, oil economy, will result. Grease should be dispensed with metal paddles and the tops of the containers securely replaced. Grease is more susceptible to contamination than oil due to the open-type containers in which it is normally packed, and contaminants will furthermore not settle from grease as is usually the case with oil.

Where oils are transported from the oil storage in large containers for subsequent filling of oil cans, the containers should be provided with secure covers and preferably with draw-off cocks near the bottom. Oil contamination is bound to occur if the oil is carried in open pails. Grease should also be carried in closed containers and not on odd pieces of paper or wood.

The attendant responsible for dispensing oils and greases should be provided with a lubricant issue chart which should be displayed in a prominent position. This chart will show each of the main machines for which lubrication is required and will give the daily consumption against each.

CONCLUSION

Provided a scheme of lubrication for a sugar factory is devised and maintained in accordance with the general recommendations given in this paper, and appropriate qualities of oil and grease are used on the various parts, plant operation should be satisfactory and be accompanied by economical use of lubricants. Not only is it necessary to devise a proper lubrication plan for a factory, but it is necessary thereafter to have responsible persons in control to ensure that the plan is rigidly carried out, and the requirements properly observed by all attendants.

DISCUSSION

Mr. Agarwal felt that the author had a preference for oil as against grease for the lubrication of mills.

Mr. McClennan replied that taking all factors into account, and assuming entirely efficient application of the lubricants, oil was to be preferred. He also mentioned that in general the cost of equipment for oil lubrication on mills was lower than for the equivalent equipment necessary with a pressure grease system.

Mr. Vidyarthi said that he had used grease with satisfactory results for some years. Previously with oil lubrication, the bearings regularly ran hot. The change to grease lubrication had also reduced the lubrication bill.

Mr. O. M. Henzell said that in the British West Indies grease lubrication applied by the Farval system was the most popular.

Mr. W. M. Livie stated that Australian practice favoured grease for mill lubrication.

Mr. G. H. Jenkins considered that the question was not whether grease or oil was to be preferred, but rather that the system of lubrication should be efficient and well maintained, and the lubricant applied to the bearings under pressure and in properly regulated quantities. One system or the other was often wrongly condemned when the fault lay in careless operation and poor maintenance of the lubrication equipment. Sometimes the lubricant did not even reach the bearings.

The author presented the following paper.

Paper

SOME OBSERVATIONS ON THE USE OF STEAM IN THE CANE SUGAR FACTORY

A. CONSTANDSE

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INTRODUCTION

In the average cane sugar factory the process steam demand is, or rather should be, greater than the power steam demand. By using all exhaust steam from the prime movers for process the steam heat can, theoretically at least, be fully utilised. Power is a bye-product, and the capacity of the steam generating plant is to be based on the process steam demand plus energy requirements of prime movers and unavoidable heat transmission losses.

Blowing-off of steam, whether live or exhaust, represents not only a waste of valuable heat but also loss of good boiler feed water. In order to avoid blowing-off of exhaust steam there should be a safe margin between the average production of exhaust steam and the average consumption of low pressure process steam.

It is generally understood that the required margin is achieved when about 75% of the average overall process steam demand is met by the prime movers, leaving sufficient balance to cope with fluctuations, and also to provide steam for such purposes where the use of exhaust steam is not recommended for process work. However, there are many installations where the margin should be different. For instance, a plant which operates only a small number of large vacuum pans and has at times to meet additional heavy power demands for irrigation must have a larger margin between the average exhaust steam production and the average process steam consumption than a factory which has a fairly steady power demand and less fluctuations in process steam consumption. A plant which can afford a smaller margin can also employ cheaper prime movers, boilers and pipings.

Fluctuations in steam demand can be reduced by a well-designed steam accumulator. A steam accumulator has the additional advantage that it increases the boiler efficiency by reducing peak demands on the boilers. This is especially useful for factories which want to economise on fuel. A steam accumulator can also be useful in combination with turbine drive for mills, as turbines are more sensitive than engines to fluctuating steam pressure. However, a good steam storer is expensive and generally speaking less attractive for plants which have a surplus of unmarketable bagasse.

In order to select the most suitable steam conditions and prime movers one should know, firstly, the average consumption of process steam which can be supplied as exhaust steam and, secondly, the fluctuations in process and power demand which may be expected during normal working of the factory. It is, however, always safe to choose prime movers and steam conditions somewhat more efficient than appears at first necessary as, not only does the power demand have a tendency to rise, but there will also be less inclination and no justification in economising in the use of process steam when such would only result in frequent blowing-off of exhaust steam.

CANE MILL DRIVE

The cane mills can be driven either by steam engines, turbines or electric motors, and each system has its limitations.

When only saturated steam is available one should think twice before introducing turbine drive. A turbine is an admirable piece of machinery, and has the advantage that it supplies clean exhaust steam for process work. On the other hand a turbine requires superheated steam, a steady steam pressure and an economical load for efficient operation. Also, wet steam is detrimental to the blades. The degree of superheat should be such that the steam is dry at every stage in the turbine, and even a few degrees of superheat at the exhaust is not harmful for the process. Where a higher degree of superheat is desired in order that the exhaust steam is consistently superheated, a de-superheater may be employed to ensure dry process steam.

The following figures supplied by makers show the effect of fluctuating load and steam conditions on the specific steam consumption of two types of turbines for mill drive :

(a) Short Multi-Stage Turbine for Mill Drive, 500 B.H.P., designed for 150 p.s.i.g. stop valve pressure and 10 p.s.i.g. back pressure.

Load B.H.P.	Stop Valve Pressure	Superheat	Lbs. Steam/B.H.P./hour
500	150	Nil	32.2
300			37.4
500	110	Nil	35.4
300			39.1
500	150	150°F.	27.4
300			32.0
500	110	150°F.	30.3
300			34.7

(b) Small Single Stage Turbine for Mill Drive, 200 B.H.P., designed for 150 p.s.i.g. stop valve pressure and 10 p s i.g. back pressure.

Load B.H.P.	Stop Valve Pressure	Superheat	Lbs. Steam/B.H.P./hour
500	150	Nil	40.7
300			[illegible]
500	110	Nil	45.8
300			50.3
500	150	150°F.	35.4
300			41.[illegible]
500	110	150°F.	40.2
300			43.6

Steam engines have less fluctuations in thermal efficiency within a fairly wide range of load and working conditions, but, are not recommended for high steam temperatures, say above 500°F., on account of lubrication difficulties. Several designs of steam engines, with separate inlet and exhaust valves and non-throttling governors, attain a better efficiency than single stage or short multi-stage turbines at lower saturated steam pressures. Full admission engines, e.g., duplex pumps, undoubtedly have the lowest efficiency and, although engines controlled by hrottling governors are better, both types must be classified as high exhaust roducers.

Motor drive is costly, and in certain countries variable speed motors are lifficult to maintain. Standard motors may be employed, driven by a separate urbo-alternator designed for wide speed fluctuation, but with this system the peed of the mills cannot be individually regulated. Motor drive otherwise ossesses several marked advantages, viz., minimum lengths of steam lines, lowest team transmission losses, and minimum number of prime movers. In fact, two arge turbines of equal output are generally the only prime movers, of which one upplies power to the mill motors and the other drives all other motors. A third urbine may also be maintained as a stand-bye. Motor drive, in combination ith steam of high pressure and high superheat for the turbo-alternator, undoubtedly ields the lowest quantity of exhaust steam. However, all factors considered, urbines are generally to be recommended for mill drive when superheated steam is vailable, particularly steam of high pressure and high superheat. With saturated team, and especially at a pressure of less than, say 200 p.s.i.g. engines are to be referred.

OTHER DRIVES

Individual steam drives usually mean high heat transmission losses, but few are always necessary. For instance, one boiler feed pump must be steam riven and a few other steam driven units may be advisable or essential for process equirements. However, the use of many small individual steam drives involves waste of valuable heat.

In order to supply electric power for driving machinery in the boiling house nd elsewhere, and for lighting purposes, a turbo-set is acceptable even for less avourable steam conditions, as the load conditions are better than for mill drive. Small factories which require power of less than say 500 K.W., and which generate only saturated steam, should preferably employ a steam engine electric power set. In all other cases a turbo-alternator may be installed, the turbine design depending on the quantity of exhaust steam required. It must be emphasised, however, that a turbine is best suited to superheated steam. If saturated steam only is available the blades should be made of high quality stainless steel to withstand corrosion. A water separator will remove drops of water above a certain size, but it cannot convert wet steam into dry saturated steam. In actual practice steam is either wet or superheated ; dry saturated steam exists only in text books. Further, steam loses heat when passing through a turbine, and a turbine of reasonable efficiency which operates on slightly superheated or so-called dry saturated steam produces wet exhaust steam.

The question arises as to whether it would be advantageous to use a pass-out turbine. This depends on the particular circumstances. If there is a steady and regular demand for steam at a pressure between that at the stop valve of the turbine and that at the exhaust, a demand which cannot be met by exhaust steam, and the power demand is large, then a pass-out turbine may be considered. A pass-out turbine, however, is expensive and its efficiency is seriously impaired if the quantity of pass-out steam is subject to wide fluctuations.

PROCESS STEAM

What should be the process steam pressure? Generally speaking, the lower the better, provided the design of the plant permits it. For most process purposes it is the latent heat of steam which is mainly utilised, and the latent. heat of low pressure steam is larger than that of higher pressure steam. For example, one pound of saturated steam at 20 p.s.i.g. pressure releases 940 B.T.U. on condensation,whereas 960 B.T.U. are released by one pound at 5 p.s.i.g. pressure There is obviously no sense in supplying higher pressure steam for process when the larger quantity sensible heat is not utilised and low pressure steam could do equally well. Furthermore, a higher back pressure increases the steam consumption per B. H. P./hour of the prime movers, which means that a plant designed for lower process steam pressure permits the use of cheaper prime movers than a plant designed for higher back pressure.

Existing plants which frequently blow-off exhaust steam can increase the margin between the average production of exhaust steam and the average consumption of process steam by reducing the back pressure, (provided of course their boiling house allows it) and into the bargain their prime movers can develop more power. As a rule it is good policy to blow off the exhaust steam safety valves at a pressure only slightly (say 1 lb./sq. inch) higher than the desired process pressure, because blowing off exhaust of a lower pressure means less heat wasted than blowing off at a higher pressure. Further, though flash heat can be utilised there is a greater tendency for flash heat to go to waste at a higher than at a lower process steam pressure.

An efficient use of process steam includes :

(i) Distribution of the steam with minimum losses.

(ii) Good quality steam, free from impurities and incondensable gas and neither superheated nor wet.

(iii) Efficient steam trapping.

(iv) Returning the condensate to the boilers with minimum heat losses.

Good distribution involves short pipings of sufficient bore, properly lagged, and with the least number of bends and tees. Any fault in distribution means a waste of heat.

Dry saturated steam does not exist, but nevertheless the aim should be to deliver the nearest approach to this ideal steam to juice heaters, evaporators and pans, free from incondensable gas and impurities. In the pipe lines cooling takes place but, if process steam is made to leave the prime movers (or boilers) superheated with a view to ensuring that it is dry at the delivery end, it may at some point still be superheated which will retard heat transmission while the remoter units may receive partly condensed steam. Fortunately neither a few degrees of superheat nor a small percentage of moisture has a serious practical effect. However, steam which is consistently superheated will require to be passed through a de-superheater before being useful for process work.

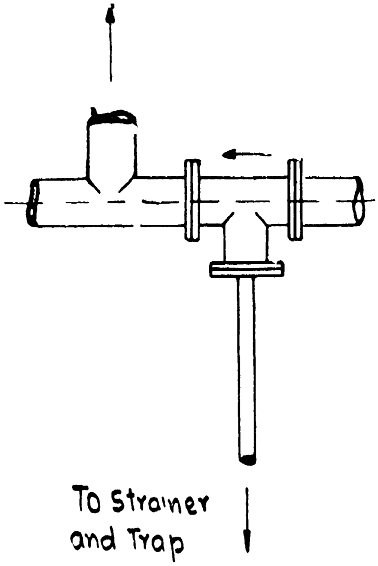
Pipe lines should have condensate collecting pockets at several places, especially at remote ends and lower levels, discharging through a strainer and trap. Collecting pockets should be provided even when the steam is not normally wet as, due to priming or other reasons, water is liable to collect in any steam pipe line. It is to be emphasised that collecting pockets must be of ample diameter and not smaller than, say, an equal tee piece. Steam mains are often seen with small collecting pockets, or worse still with only a small bore pipe connected to a trap. Such " draining systems " are practically useless. A few correct draining arrangements are shown in sketches 1 to 4.

When handling steam which usually contains water and oil it is advisable to pass this through a separator before permitting it to reach the heating surfaces. However, the increasing use of compounded cylinder oils makes the efficient separation of oil from exhaust steam extremely difficult. The types of separators commonly in use are centrifugal, impingement, and scrubber. Centrifugal separators have maximum efficiency at a fixed load only and are therefore unsuited to fluctuating velocities and quantities. The other two types separate only larger particles, at their best not below 5 microns, and are therefore less efficient for the separation of compounded oil from exhaust steam. There is a new type which may prove useful for sugar factories, namely the ultrasonic precipitator.

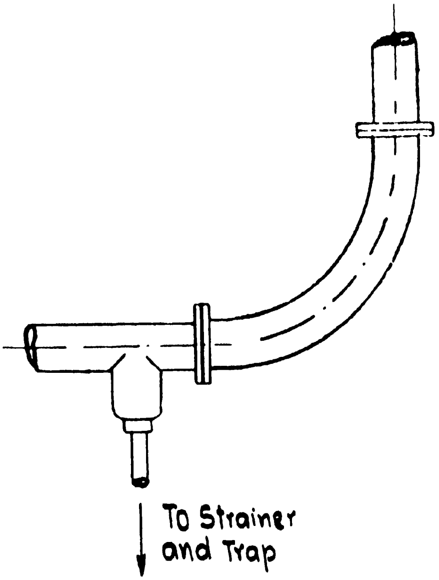
Turbines ensure clean exhaust steam for process, and this alone is an important reason for installing turbines instead of reciprocative engines as prime movers. Oil in exhaust not only fouls the heating surfaces, but the decomposition products corrode steam lines and boilers.

Between the steam and the heating surface are several films. Often there is a scale, of oils and their decomposition products or other impurities present in steam or vapour which is extremely resistant to heat. Then there is the water film. Water is a poor conductor of heat, and hence we must endeavour to have the steam reach the heating surfaces as dry as possible, and also to drain off condensate from the heating surfaces as rapidly as possible. There is also incondensable gas, mainly air, which is even more detrimental to heat transfer than water.

One effect of air in the steam space is that it reduces the effective steam pressure, causing a lower temperature difference between the steam and the material being heated. Air also has a great insulating capacity. An air film one-thousandth of an inch thick resists heat transfer to the same degree as a wall of copper one foot thick. Juice heaters, evaporators and pans are all fitted with air vents, but sufficient attention is sometimes not given to the proper placing of these vents. Generally speaking the principal air vents in the vessels should be at the farthest points of steam travel, which are not necessarily at the longest distance from the steam inlet. The correct position of the air vents depends mainly on the tube spacing and the direction of steam flow. More use might be made of automatic air vents in place of hand-operated air valves and cocks. In practice the use of manually operated air vents results either in wastage of steam or vapour, or in insufficient escape of air.



SKETCH 1



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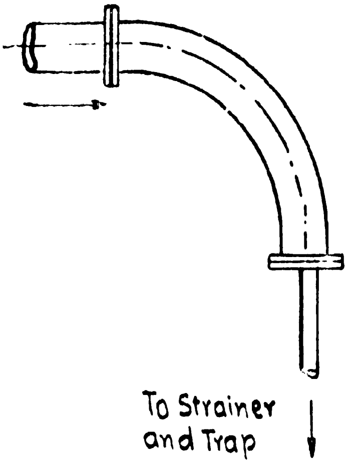

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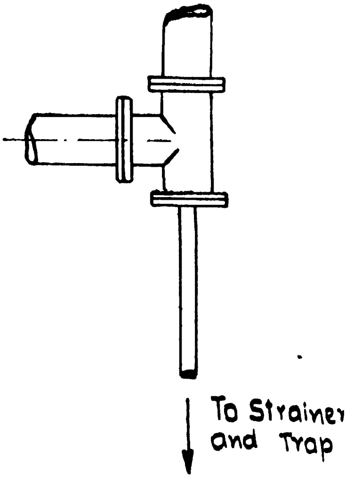

SKETCH 4

STEAM TRAPS

The flow of condensate from the steam space to the trap should a made as easy as possible, which means that the condensate should fall by gravity to the trap with the minimum number of bends and horizontal lengths of pipe, and the condensate lines should be of ample bore.

It is advisable to fit a strainer before every trap in order to prevent dirt from entering. Small particles of dirt may pass through, but larger pieces are liable to jam the trap valve. A sight glass after every trap is useful so that it may be seen whether or not the trap is functioning properly. As calandrias are usually heated by low pressure steam or vapour, low-pressure-difference traps with large water passages are here necessary.

Traps may be divided under two main groups, thermostatic and mechanical. In the thermostatic group there are the balanced pressure, the liquid expansion and the metallic expansion types. The balanced pressure thermostatic type is suitable for fluctuating steam pressures within its range. It discharges air, is easy to maintain, but it is not suitable for superheated steam and cannot withstand water hammer. Both the liquid expansion and the metallic expansion thermostatic traps close at one temperature only. Although adjustable, they are not suitable for fluctuating pressures and temperatures. The liquid expansion type is otherwise a trap which can stand up to vibration and water hammer.and will freely discharge air. It can also handle medium-superheated steam.

Among mechanical traps are the ball float, open bucket and inverted bucket types. The ball float type is a very versatile trap, and is found in several modifications. The trap can work within wide and sudden fluctuations of pressure and load, and discharges condensate rapidly. This makes the trap very suitable for draining condensate from juice heaters and vacuum pans. The trap can be fitted with internal air release or steam lock release. Steam locking is a common cause of water logging and is experienced, for instance, when condensate lines are improperly laid out or very long, and in coil heated tanks or pans where the coil is rising to the trap.

With traps subject to air binding as is the case with some simple float and open bucket types the difficulty can be overcome by fitting a thermostatic air vent bye-pass round the trap. While a manual cock on the trap can also be used to prevent air binding, this is not to be recommended as it will usually be left open thereby wasting heat, or will not be opened long enough thus causing air locking. Ball float traps should not be used where water hammer is likely as the mechanism may be damaged. Traps with an internal air release should not be used on superheated steam.

The open bucket trap can withstand shock and load fluctuations, and is therefore specially suitable for draining water from steam mains subject to water hammer. It is a robust type of trap, but it is bulky and slow in discharging air. If therefore this type is used an air vent should be fitted as explained above.

While the inverted bucket type of trap does not suffer completely from air binding, it does not instantly release air. The trap is less suitable for handling load fluctuations, and steam goes to waste when the water seal is lost. The advantages are that it is light and handy, can withstand a fair amount of water hammer (though not to the same extent as the open bucket type) and it can be used on superheated steam.

Every trap can lift condensate when there is a pressure difference between the trap and the delivery end, roughly 2 feet for every 1 p. s. i. pressure difference. It is not advisable to employ an ordinary trap for lifting, when the condensate has to be drained from a steam space supplied by low pressure steam, exhaust steam or vapour. In such cases a lifting trap should be used. A lifting trap discharges the condensate by the action of live steam or compressed air pressure, and the lift is accordingly limited by the pressure available. The condensate non-return valves, steam inlet valve and exhaust valve should be tested for leakage at least once per year, while the operating steam (or air) and the condensate should pass through strainers. Leaky valves are a common source of failure with lifting traps. Provided it is properly installed and maintained in good working order, a lifting trap is economical in steam or air.

If an ordinary type of trap is used for lifting condensate from a low pressure steam space, the trap has to build up sufficient back pressure in order to function, and the drainage of condensate is thereby impaired. Also, when an ordinary trap has to lift condensate the air vent, which has to open to the atmosphere, is liable to discharge both air and water, creating a rather messy affair.

The height of lift of a lifting trap, however, is limited by the steam or air pressure, and for higher lifts a pump is the only solution.

VAPOUR BLEEDING

Bleeding vapour from the first vessel of the evaporator, and even from the second and third is a well known method of reducing process steam consumption. Bleeding vapour from the evaporator means essentially utilising part of the heat which would otherwise go to waste in the condenser. The procedure is useful when there is a sufficient margin between the production of exhaust steam and the consumption of low pressure process steam. An additional advantage is a smaller condenser with corresponding reduction in cooling water requirement.

A bleeding evaporator may be compared to a pass out turbine, with the difference that the bleeding evaporator supplies extra vapour as a by-product, and the bleeding turbine extra power as a by-product. The bleeding evaporator has several drawbacks. Its efficiency-like that of the bleeding turbine-suffers when the quantity of pass-out vapour is subject to fluctuations. If the vapour off-take is more than designed, the supply of vapour to the following vessels becomes short resulting in lower evaporator out-put. If the quantity of vapour bled is less than designed, the evaporation rate of the pass-out vessel is reduced, which also results in a reduced evaporator out-put. Fluctuations in bleeding are normally followed by fluctuations in exhaust steam pressure, which in their turn fluctuate the steam consumption of the prime movers. Another drawback of vapour bleeding is the higher brix at which the juice leaves the pass-out vessel. This may cause decomposition of certain juice components, especially when handling juices of unripe or over-ripe canes which have a high percentage of reducing substances and other easily decomposable constituents.

When the process steam consumption has to be reduced it is more satisfactory to employ a straight quintuple evaporator than a bleeding quadruple, and the saving in process steam is nearly as much as is obtained by having the juice heaters operating on bled vapour. If still more process steam is to be saved, then bleeding may be restored to. It must be installed with care, however, as the steam supply must serve the requirements of the manufacturing process without upsetting the smooth running of the plant.

When juice heaters are heated by vapour from the evaporator, instead of by exhaust steam, a larger heating surface is required for the heaters on account of the samall temperature difference between vapour and the material heated.

STEAM MEASUREMENT

It would be advantageous if every factory had steam meters fitted in the mains to the prime movers and for process make-up, and employed also portable recorders or indicators for checking the performance of certain apparatus from time to time. Meters in the lines to prime movers will immediately show mechanical defects, and may, for instance, also explain an unexpected rise in back pressure. It is further useful to have meters in process lines which lead direct from the boilers.

For measuring high pressure steam flow the inexpensive orifice type of meters is suitable. This type can be supplied as indicating, recording and/or integrating. For measuring low pressure steam flow and vapour flow an orifice meter can in many cases also be employed, provided the instrument has a low differential head. With a differential head of 20″ water gauge the approximate pressure loss at maximum flow could be 12″ w.g. and at half flow a quarter of this figure. It is desirable to place the meter below the main to ensure a positive pressure on the meter, and, if the meter is under vacuum, it is advisable to arrange for a separate water supply to the cooling chambers. If it is desirable to reduce the pressure loss to the barest minimum-as in the case of meters permanently fitted in low pressure exhaust or vapour lines-a short venturi or Dall tube may be employed.

DISCUSSION

Mr. Chandrasikhren said that there was a tendency in Indian sugar factories to introduce electrification, and asked whether this would upset the steam balance.

Mr. Constandse replied that semi-electrification of the factory need not cause a shortage of exhaust steam for use on pans. He also stated that the steam system in a factory should be based primarily on the process steam demand, and that this should allow for a fluctuation over a range of 25% in the steam for the pans.

Mr. J. P. Mukherji asked for an explanation of this 25% variation.

Mr. Constandse replied that, in the average factory to which no outside electric power is supplied and with pans of the normal number and size, the fluctuation in steam demand by the pans might require a capacity margin of 25% in the boilers.

Mr. J. H. Nicklin asked the reason for disliking the bleeding of steam from an evaporator.

Mr. Constardse replied that with the higher pressure required in the first vessel of the evaporator there was danger of decomposition of sugar and that, if steam economy was a factor, he preferred to use a quintuple effect evaporator.

Mr. Rahim enquired whether it was necessary to use live steam for boiling bold grain.

Mr. Constandse replied that this would depend upon the design and circulation of the particular pan and that, where the conditions were satisfactory, it should not be necessary to use live steam.

The author presented the following paper.

INFLUENCE OF STRUCTURE OF CANE ON THE "STEAMING" QUALITY OF BAGASSE AND ON MILL WORK

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STEAMING QUALITY

Steaming difficulties in the Gauribazar Factory have been progressively increasing during recent years and by the process of elimination a careful study of the difficulties has pointed suspicion towards the fibre construction of the cane being milled and it would appear that Co. 419 cane produces a bagasse of comparatively inferior ' steam raising ' value.

Calorimeter combustion tests in Cuba, Louisiana, and other countries reveal that bagasse from cane of numerous varieties when absolutely free from moisture, contain approximately the same number of heat units (B.T.U.), and subsequent investigations have confirmed these conclusions (1) and it can, therefore, be accepted that theoretically the bagasse of canes under cultivation in this country have the same heating value, as it is significant that Deerr has recorded that in actual practice bagasse of some varieties ' steam ' much worse than others and he observed that this phenomenon was associated in particular with cane known as ' white transparent ' or ' rose bamboo ' and in Demarara with ' seedlings ' generally (2). It was this observation which prompted a study of these factors in Gauribazar Factory.

According to Dymond (1942) (3) the thermal value of resultant bagasse was determined by the quality of fibre and in his study of two varieties Co. 290 and Co. 281, he found that theba gasse of Co. 290 was inferior to that of Co. 281, so far as its steam raising quality was concerned. On this basis it would appear that the physical structure of the bagasse of Co. 419 is responsible for the low fuel value. In suggesting a possible relation between the physical structure of the bagasse with fuel value Geerligs has concluded that cane with high fibre content give a bagasse of superior value and an apparently denser bagasse also has a higher fuel value (4).

A tendency towards low thermal value may also be due to one or more of the following factors.

(i) A fibre with the lower limit of recorded heat of combustion.
(ii) A fibre which retains after crushing, a higher quantity of water.
(iii) A low percentage of fibre in cane.
(iv) A bagasse of low apparent specific gravity (5).

In these particulars it would appear that Co. 419 did not differ materially from other canes as, in the study of the low steam raising quality of Co. 419 cane at Gauri Factory it was observed that the moisture % bagasse in this variety was no greater than in the case of other varieties milled under identical conditions. Although in the early part of the season the fibre % cane of Co. 419 was somewhat lower than other canes (16.55% against 17.41%), from the middle of January the percentage of fibre in this cane was almost the same as other varieties. It was observed, however, that when Co. 419 was milled the fibre-structure-breakdown was greater than in other canes and measurement revealed that the fine particles as ' dust ' in the bagasse from Co. 419 was in the order of 18% as against 8% in CoS. 416.

That the percentage of dust affected boiler performance, as far as efficient combustion was concerned appeared to be true as it was observed that when this bagasse was fed to the furnaces there was a considerable amount of fly off to the flues. It was noticed also that the bagasse burning in the furnance was dull red instead of the usual bright red or white. Heriot (1920) had also observed that a very porous bagasse burnt under natural draught allows too much air to enter between the grate-bars per unit weight of bagasse burnt, and such excess air increases the heat losses in the chimney (6). This leads to the conclusion that the bagasse from Co. 419 has an actual lower apparent specific gravity than bagasse from other canes, and on the basis of Geerligs observation supports the contention that for this reason also, the steam raising value is detrimentally affected.

As the milling condition of Co. 419 and other canes were identical it was felt that the reason for the difference in bagasse firing quality was directly due to a difference in physical fibre construction. It was this suspicion which prompted the investigation to ascertain whether the anatomical structure of Co. 419 could give a lead on the peculiar behaviour of the resultant bagasse as far as steam raising properties are concerned.

The fact that no such difficulty has been experienced in factories in the Deccan where this variety constitutes about 90% of the crush lends support to the theory that differing environmental conditions and manuring practice in that region may effect the structure of the cane and be responsible for the difference. In any case, such an explanation for the difference is not without substance, and to cite one instance, it was found that in soils deficient in Boron the lignified fibre of sugarcane cells are small, poorly developed and loosely arranged (7).

MILLING QUALITY

Apart from the influence which the physical structure of cane exercises on the " Steaming " quality of the resulting bagasse, there is also the influence which this structure has on the milling properties of the cane. It is very noticeable that certain of the Bo. varieties introduce difficulties in milling, which are not experienced in other varieties and that these canes frequently lead to an appreciable reduction in the normal crushing rate of a milling plant.

As Bo. varieties became rapidly popular among growers in North Bihar, increasing difficulties were experienced in serveral factories. Important among the difficulties was " slippage " i.e., the inability of the cane roller to " bite " which resulted in milling interruptions and prevention of a continuous movement of the bagasse blanket. Additional labour was employed using bamboos, to force the blanket into the feed rollers and an increase of maceration water was resorted to in order to improve cohesion of the bagasse blanket.

ANATOMICAL STUDY OF CANE STRUCTURE

It was felt that the structure of the cane of this variety would also give an explanation for the peculiar behaviour of this variety and for this purpose as well, anatomical study of the following varieties was undertaken.

(1) Co.419 ; (2) Co.453 ; (3) Co.513 ; (4) Bo. 11 ; (5) Bo. 10 ;(6) Bo. 24 ; and (7) Bhurli.

Of these varieties, Co.453 is a normal milling cane and Co.513 is fair. Bhurli, a low fibre indigenous cane, was also studied as this variety, before the large scale introduction of Co. canes, was reported to have given steam difficulties. The behaviour of Bo. 24 at the mills was more or less similar to Bo. 11 and Bo. 10 was intermediate.

In view of the difference observed in the structure of the cane grown not only in different areas but also in canes grown in the same area and in different parts of the same stalk, for the purpose of this study, samples were taken from the top, middle, and bottom portions of the stalk and free hand transverse sections (and longitudinal sections of the middle internode) were taken of both node and internode and their anatomy studied with reference to the following features :—

(1) Rows of epidermal cells.
(2) Number of rows and lignification of the sub-epidermal cells.
(3) Number of rows of the rind cells and degree of lignification of rind cells.
(4) Density of the vascular bundles in the rind and the vascular regions,
(5) Number of vascular bundles/unit area (1 millimeter square).

(6) Number of rows and the lignification of Sclerenchyma cells of the bundle sheath in the rind and the central regions.
(7) Portion of the bundle sheath well lignified.
(8) Lignification of the Parenchyma cells.
(9) The ratio in development between the Parenchyma and Sclerenchyma cells.

RESULTS OF ANATOMICAL STUDY

Since the internodal tissue constitutes the major portion of sugarcane, the structure of this tissue has considerable influence on the general behaviour of a variety in the factory, for this reason a brief reference on the structure of this tissue in the more important varieties is given below :—

Co. 453 :—There are three rows of sub-epidermal cells. The vascular bundles are oval to irregular in shape, 3.5-5.5/sq.mm., in the rind and 1-1.5/sq. mm., in the centre, have highly lignified bundle sheaths. The parenchyma cells are loosely arranged with medium lignification.

Co. 419 :—There are two to three rows of sub-epidermal cells and 8—12 rows of moderately lignified flat cells arranged in a compact manner. Vascular bundles are 2-2.5/sq. mm. The bundles are oval to irregular in shape. 80% of the space of the bulk is occupied by parenchyma which is fairly well lignified in the middle and not so well at the bottom.

Bo.11 :—There are 4-5 rows of sub-epidermal cells. The rind cells are highly lignified. The vascular bundles/unit area is 2- 4.5. The bundles are irregular and the sclerenchyma cells are big and juxtaposed to one another, whereas in the middle although the bundles are lesser in number, they are highly lignified. In the centre the vascular bundles per unit area are smaller and oval with highly lignified sclerenchyma cells on the upper side of the bundle. The parenchyma occupies 75 to 80% of the space of the bulk.

Bo.24 :—There are 2-4 rows of sub-epidermal cells. There is a reduction in the number of rows of rind cells from 30 to 12 as we go from top to bottom. The cells are loose. There are 3-3.5 bundles/sq. mm. In the middle region it is noticeable that there is only one big bundle per sq. mm., in this respect almost resembling the top region of Bo. 11. The parenchyma consisting of a mixture of big and small bundles occupies 75%-85% of the bulk. The bundles are highly denser at the periphery.

Bhurli :—There are three rows of sub-epidermal cells and 20-25 rows of hexagonal small, very compact rind cells. The vascular bundles 4.5/sq. mm. oval in size. There are four rows of sclerenchyma cells in the bundle sheath with medium to less lignification on both the top and bottom portions of the bundle. The parenchyma occupies 80% of the space of the bulk. The cells are hexagonal small and are more compact in the peripheral region than in the centre. The ratio between the rind and the centre i.e., sclerenchyma is 2:15 showing resemblance to Co. 419.

CONCLUSIONS : " STEAMING QUALITY "

It would appear from these studies that the structure of bagasse differs with different varieties and the steaming quality of bagasse of different varieties is dependent upon the compactness of the bagasse structure. The compactness of bagasse structure is found to be related to the quantity of fibre ' dust' present in the bagasse, the steaming quality being superior in bagasse containing less dust.

As it is the parenchyma that occupies the bulk of the entire tissue, the compactness and thinness of the parenchyma cells appear to have bearing on the degree of disintegration of the bagasse blanket during its passage through the milling train. Co.419 is an example in which the cells are thin and loose and the quantity of fibre dust (18%) much higher than in Co.453 or Co.513 (12%) or CoS.416 (8%).

DISINTEGRATION OF BAGASSE AND PARENCHYMA SCLERENCHYMA RATIO

The parenchyma cells are bigger than the cells in the rind and these cells being thinner and less compact are more easily disintegrated than the rind cells which are small and compact and more lignified. Therefore the ratio parenchyma bears to the sclerenchyma tissue appear to be an important factor determining the degree of ' dust ' in the bagasse. In the case of Co. 419 this ratio is 1 :19 whereas in Co.453 and Co.513 the proportions are 3.5 : 5 and 2 :12 respectively.

The studies also indicate that the proportions of fibre dust in the bagasse mat is also influenced by the length of the parenchyma cells, the longer the cells the greater the proportion of fibre dust present in the bagasse.

CONCLUSIONS : "MILLING QUALITY"

The rind of sugarcane constituting the major bulk of the fibre present in cane, by virtue of its quantity and quality largely determines the milling characteristics of the cane. That rind hardness is closely related to the fibre content of the cane was observed by Ueno (1938) and later studies have confirmed these observations. The factors which contribute either alone or in combination with one another to the hardness of rind were observed by Khanna and Panje (8) and are as follows :—

1. The number of vascular bundles per unit volume in the rind ;
2. The lignification of the cell walls of the vascular sheaths ; and
3. The lignification of the intervascular parenchyma.

It would appear from the observations made in the present investigation that the factors (1) lignification of the bundle sheaths, (2) rows of sub-epidermal cells, (3) compactness and lignification of the parenchyma, (4) space occupied by the parenchyma cells in itself and in relation to the space occupied by sclerenchyma and (5) length of the parenchyma cells, either alone or in combination with one another are responsible for causing one or the other of the two difficulties encountered in milling viz., (1) disintegration of the bagasse into small particles or (b) slippage at the rollers.

The relationship between the structure of the cane and the disintegration of the bagasse and its effect on the steaming quality was discussed above and the factors which may cause slippage and other difficulties at the rollers are given below.

(*1*) *The lignification of the bundle sheath and the quality of the fibre.*

High lignification of the sclerenchyma in the periphery, compact and highly lignified cells of the rind in the lower regions particularly in varieties with smaller number of vascular bundles appear to cause brittleness in the bagasse structure and, with lack of cohesion within the bagasse blanket, are likely to induce slippage at the rollers, as in the case of Bo. 11.

(*2*) *The rows of sub-epidermal cells and the slippage of the cane at the rollers.*

Although Thuljarama Rao 1951 (9) feels that much importance need not be placed in the number of sub-epidermal cells, the present studies indicate the possibility of some relation between the rows of sub-epidermal cells and the slippage of cane at the feed rollers. The indications are that varieties having a greater number of elongate hexagonal sub-epidermal cells may cause slippage, as in the case of Bo. 11.

(*3*) *Slippage at the rollers and the shape and size of cells.*

As the cell walls tend to offer resistance to pressure at every phase of crushing and thus cause slippage at the rollers, it would appear that the greater the cells wall area the greater will be the slippage.

In the case of Bo. 11 and Bo. 24, the cells are squarish and very compact whereas in the case of Co. 453 though the cells are squarish, they are broad, thereby decreasing the number of cell walls per unit volume. The resistance is lesser and hence there is no slippage.

While efforts have been made in the present study to determine the relationship between certain anatomical features of selected varieties of cane and the difficulties experienced in milling these, it may be reasonable to conclude that no single factor can cause any of the troubles to the degree generally found. The troubles experienced in milling a particular variety appear to be due to a combination of the factors stated and the degree to which these factors combine in a variety determines the extent of trouble which may be expected in the milling operation.

On the basis of the relationship between the structure of different varieties of canes and the difficulties experienced in milling these varieties, the varieties may be classified into the following categories :—

1.	Canes causing slippage at the rollers	...Bo.11 and Bo.24
2.	Medium canes causing no slippage at the rollers and no disintegration of bagasse during milling.	Co.453 and Co. 513
3.	Soft canes, the bagasse of which disintegrate	Co. 419

In Bhurli cane the space occupied by rind and sclerenchyma is less and therefore the fibre % cane is less. It can be grouped with Co.419 (although this differs from Co. 419 in compactness, density of vascular bundles and thickness and size of parenchyma) as this variety also gives rise to steam raising difficulties.

ACKNOWLEDGMENTS

Thanks are due to Mr. A. Caws, Director, M/s. Begg. Sutherland & Co. Ltd., for helpful suggestions and to Mr. N. R. Venkataraman for the valuable assistance rendered in the preparation of this paper.

REFERENCES

1. Noel Deerr. Hawaiian Sugar Planters Experiment Station. *Bulletin* 30, 41.
2. Noel Deerr. 1921. *Cane Sugar*, pp. 462.
3. Dymond, G.C. 1942.—Varietal milling results in Natal. *Proceedings of the Sixteenth Congress of the South African SugarTechnologists' Association.* pp. 37-42.
4. Prinsen Geerligs, H. C. 1924. *Cane Sugar and Its Manufacture.* pp. 137.
5. Noel Deerr. 1921. *Cane Sugar*, pp. 463.
6. Heriot, T. H. P. 1920. *The Manufacture of Sugar from the Cane and Beet*, pp. 349.
7. Martin, J. P. 1934. *Hawaiian Planters' Record*, 38 ; pp. 3-31, 95-108.
8. Khanna K.L. and Panje, R. R. Studies in the rind hardness of sugarcane ; *I. J.A.* Series 9, 1.
9. Rao, J.T. Anatomical characters in relation to rind hardness and borer attack in sugarcane, *Second Biennial Conference of the Sugarcane Research Workers.* pp. 41-47.

DISCUSSION

Mr. J. P. Mukherji said that the heating value of dried bagasse of different cane varieties was not the same. He instanced that the bagasse from Co. 419 was approximately 8000 B.T.U. per lb., whereas for other varieties it was normally higher about 8400 B.T.U.

Mr. W. M. Livie considered that different types of bagasse required different methods of control at the furnace, particularly in regard to secondary air introduced at the bridge wall.

Mr. D. H. Foster referred to studies which had been made on high and low fibre canes in Queensland. He pointed out that bagasse from canes having a high proportion of pith cells retained a larger percentage of moisture during milling, and this factor naturally affected the steaming quality.

Mr. G. H. Jenkins was of opinion that the milling property was influenced largely by the degree and nature of the preparation of the cane before crushing, and that this was an important factor in milling quality.

Mr. Ramanujam replied that different types of cane structure correspondingly required different degrees of preparation, and also that mill settings were important. Settings which might be suitable for crushing Co. 513 would not necessarily give good results when crushing Co. 419.

Mr. G. P. Bhargava presented the following paper.

Paper

AN INVESTIGATION INTO THE CAUSES OF EVAPORATOR TUBE FAILURE

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During the course of technical advisory work the authors came across a typical case of evaporator tube failure and this paper deals with the investigations carried out and gives suggestions which may be helpful to Sugar Factory Engineers.

During hydraulic pressure testing of a quadruple effect evaporator 490 ubes were found to be leaking. The evaporator had a heating surface of 6000 sq. ft. with equal bodies 5′—10″ dia. having 603 tubes of 1-15/16″o. d. × 5'-1. 15/16″ ong, 16 S. W. G., the pitch being 2-7/16″. There was a central downtake 1′-3½″ dia. The four incondensable gas outlets were 7/8″ bore-3 connections from the top and one from the bottom in each calandria. The steam inlet to the 1st body was 8″ bore, and the vapour pipes between vessels 14″, 16″, 18″ & 24″ bore respectively.

The quadruple evaporator had been working in parallel with a triple effect evaporator of 5500 sq. ft. heating surface for the past twenty years. The working result for the last season are given in Table I.

TABLE I

. No.		December	January	February	March
1.	Cane crushed mds.	4,04,680	5,80,784	4,54,500	2,99,497
2.	Hours worked	636.9	686.9	563.6	378.7
3.	Cane crushed/hr. mds.	760	845.5	807.0	790.9
4.	Mixed Juice % cane	83.4	86.4	86.3	87.4
5.	Evaporation %	69.32	67.64	65.94	66.31
6.	pH Clear Juice	6.8-6.85	6.8	6.75-6.8	6.7-6.8
7.	Brix Clear Juice	15.32	15.33	15.74	16.22
8.	Brix Syrup	49.47	47.37	46.21	48.15

From the above it will be seen that the pH of the clear juice was maintained closely around 6.8.

At the time of the hydraulic test of the bodies 385 tubes in the 2nd body and 55 tubes in each of the 3rd and 4th vessels were found defective. Leakage of water through the tubes varied from leaf perspiration to fine spray under pressures varying from atmospheric to 40 lbs./sq. in.

Both hand and electric scrapers had been used for cleaning purposes, and an examination of these showed that they were of satisfactory design. The inside surfaces of the tubes did not show any mechanical damage due to scraping.

The defective tubes were taken out from the bodies and weighed. New brass tubes of 70/30 composition taken from the stores were also weighed, the weights differing as indicated in the Table II, and giving an average weight for new 1-15/16″ o. d. tubes of 1.351 lbs. per ft. length. Table III gives the weights of old tubes removed from the evaporator, and the percentage decrease in weights compared with new tubes.

TABLE II

WT. OF NEW TUBES 1-15/16″ O. D. × 5′-2.1/8″ LONG

Tube No.	Weight grams	lbs.	Wt./ft. of length
1.	3145	6.95	1.342 lbs.
2.	3133	6.92	1.337 ,,
3.	3237	7.14	1.378 ,,
4.	3157	6.97	1.347 ,,

Average weight : 1.351 lbs./ft. length.
Weight for length of 5′-1.15/16″=6.95 lbs.

TABLE III

WT. OF OLD TUBES 1.15/16″ O. D. × 5′-1.15/16″LONG

Tube No.	Weight Gms.	Weight lbs.	Wt./ft. length	Difference in wt. taking 1.351 lbs. as standard	%Decrease in weight
1.	2481	5.47	1.08	0.271	20.2
2.	2596	5.72	1.13	0.221	16.4
3.	2524	5.57	1.10	0.251	18.6
4.	2660	5.87	1.16	0.191	14.1
5.	2409	5.32	1.05	0.301	22.2
6.	2498	5.50	1.08	0.264	19.5
7.	2252	4.98	0.985	0.366	26.3
8.	2542	5.62	1.11	0.241	17.8
9.	2778	6.12	1.21	0.141	10.4
10.	2632	5.80	1.146	0.205	15.2
11.	2524	5.57	1.10	0.251	18.6
12.	2687	5.925	1.17	0.181	13.4
13.	2553	5.63	1.11	0.241	17.8
14.	2599	5.72	1.13	0.221	16.3

It was found that in all cases tubes were attacked towards the top ends, particularly below the portion where they were expanded into the top tube plate. The attack extended only a few inches down the tubes, the remainder of the outside surface being free from attack. Test pieces of equal length, cut from corresponding positions in the length of various old tubes, were found to be of equal weight, which showed that the relative wear at different portions of the old tubes was the same.

It appears that the local wastage of the brass tubes was due to the condensate carrying into the calandria appreciable quantities of incondensable gases, principally ammonia and with possibly sulphur dioxide, carbon dioxide, and oxygen in solution. The most dangerous of these gases is ammonia which being light, rises to the top of the steam space, and dissolves in the condensate adhering to the top tube surface, thereby producing a corrosive solution which attacked the tubes. The first body of the evaporator received exhaust steam in the calandria and as this did not contain corrosive gases no tubes in this body were attacked. The intensity of attack was greatest in the second body and less in the third and fourth.

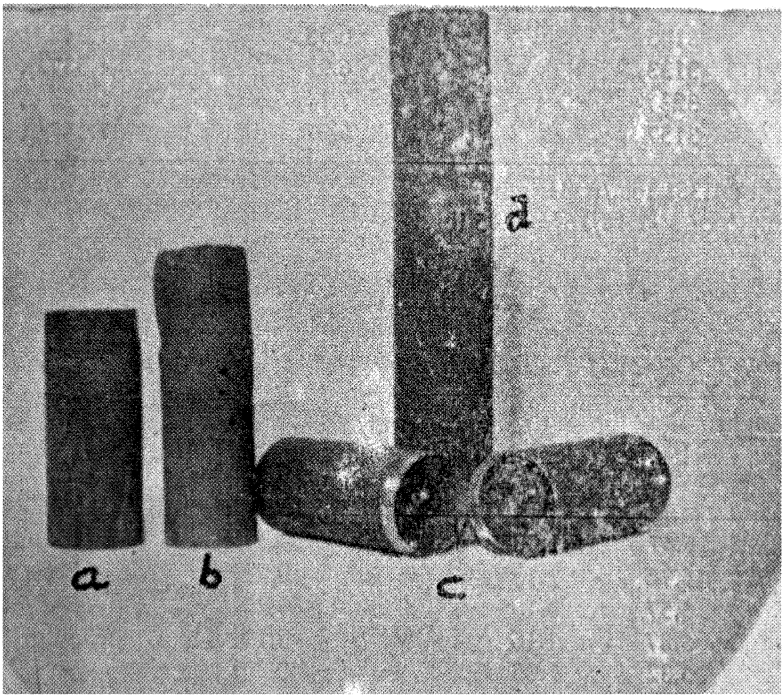

Figure 1.

In Fig. 1 at (a) & (b) are shown cut tube pieces, the fine crack in (a) and the pin holes in (b) in the portion below the top tube plates being clearly visible. After cutting the defective end of some of the tubes it was found under hydraulic pressure test that the remainder of the tube lengths could safely withstand a pressure of 250 lbs./sq. in. In view of this sound condition of the major portions of the tubes it was advised that these could be used again by building them upto their original lengths by the addition of new pieces of tube welded on by means of " Easy Flo " welding rods. The method employed is to turn down the cut ends of the tubes for a distance of 1/8" to 3/16" removing half of the metal thickness so as to produce a sliding fit overlapping joint as shown in Fig. 1 (c). " Easy Flo " rods and flux are then used for gas welding the joint to give a smooth finish inside and outside as shown in Fig. 1 (d). This enables the tubes to be refitted through the holes in the tube plates and avoids any difficulty being experienced later when cleaning with wire brushes or scrapers.

The cost of a new tube of 1-15/16" o. d. × 5'-1.15/16", 16 S. W. G. was about Rs. 12/8/-, while the cost of repairing old tubes by the method suggested was about -/8/-, including material, labour, power, gas, etc. A welder can easily braze 100 tubes in a shift of eight hours and a turner could prepare this number of tubes in the same period. It was found that about two inches of 0.06" dia. " Easy Flo " rod was consumed per joint making the cost of material about two annas.

In order to test that pieces of tube, jointed by the method described, would withstand high pressure, the test arrangement shown in Figure 2 was used. The jointed pieces were subjected to an oil pressure which was steadily raised to 500 lbs./sq. in. without any leakage occurring. After they have been welded, tubes which are to be used again should be tested to 200 lbs./sq. in. before refitting in the evaporator. Fig. 3 shows an apparatus which was designed for this purpose.

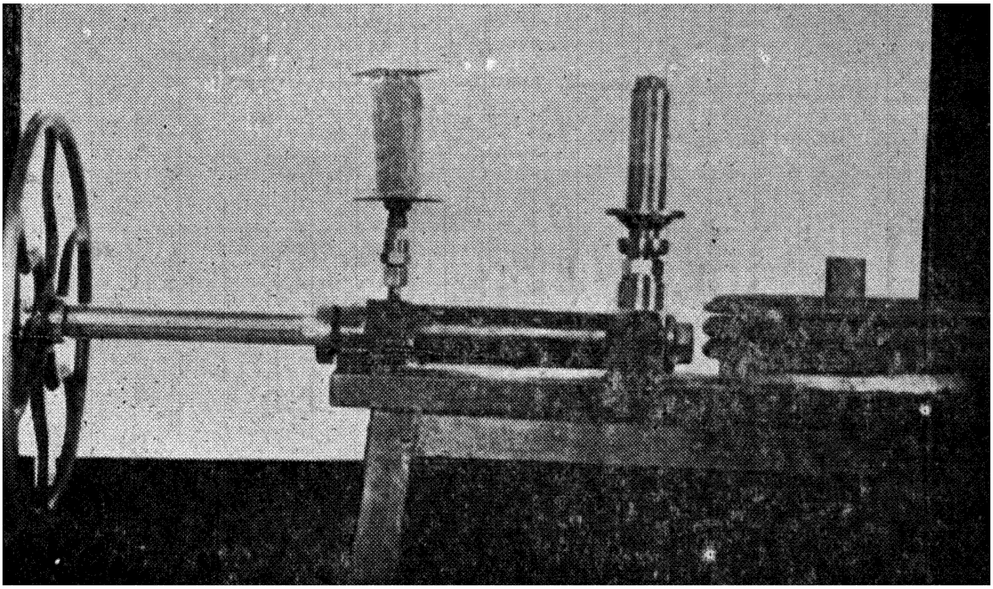

Fig. 2.

As a precaution against further deterioration of the tubes by the action of the incondensable gases it was recommended that two of the gas vent pipes in and from the calandrias be increased from 7/8" bore to 1½" bore and arranged as shown in Fig. 4. It was advised that the third pipe be connected directly to the top tube plate as shown in Fig. 5, so that gases accumulating there could be drawn off directly. Attention was also drawn to the need for cleaning out the

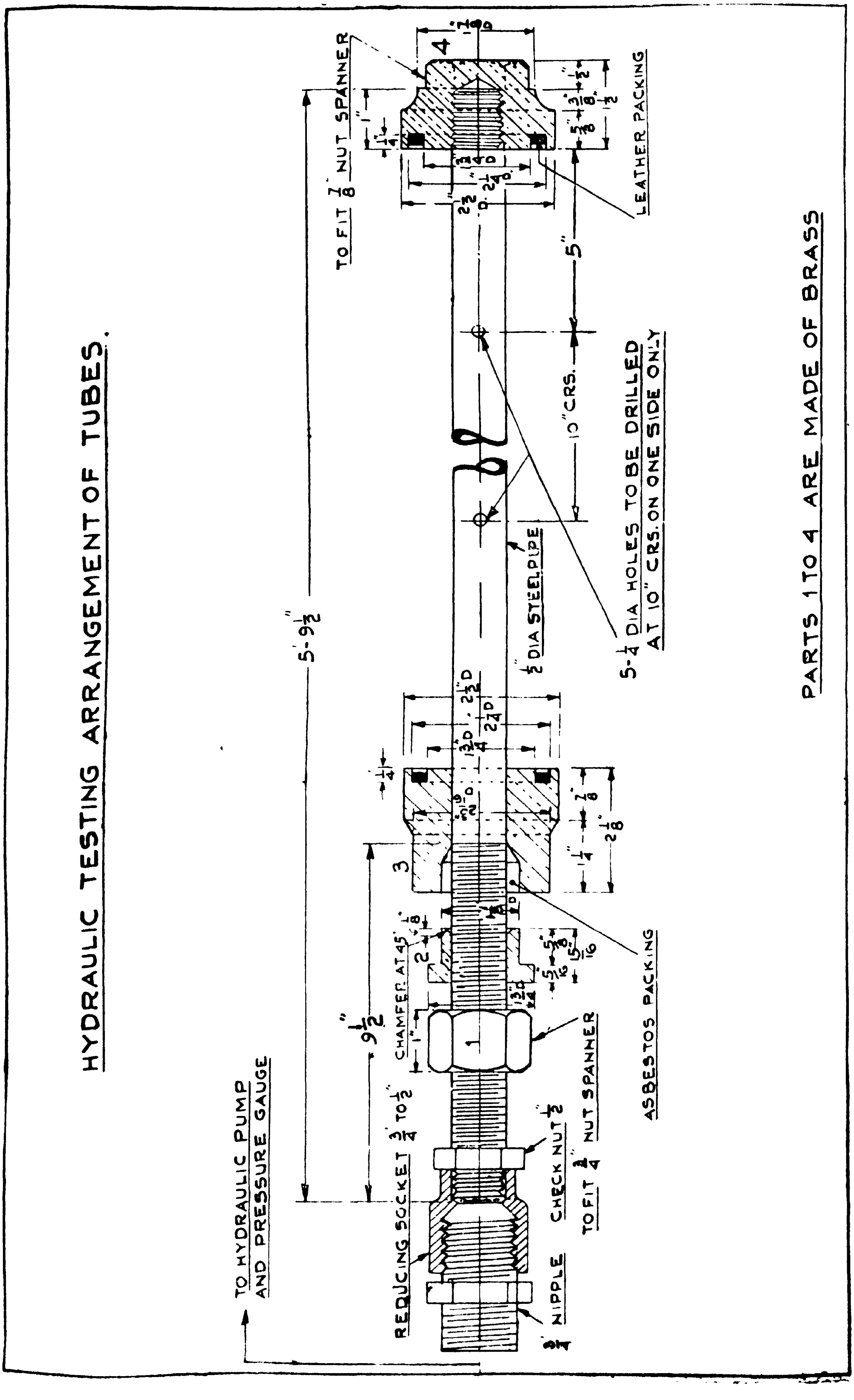
HYDRAULIC TESTING ARRANGEMENT OF TUBES.
TO HYDRAULIC PUMP AND PRESSURE GAUGE
REDUCING SOCKET 3/4" TO 1/2"
NIPPLE
CHECK NUT 1/2"
TO FIT 1/4" NUT SPANNER
CHAMFER AT 45°
ASBESTOS PACKING
1/2" DIA STEEL PIPE
5-1/4" DIA HOLES TO BE DRILLED AT 10" CRS. ON ONE SIDE ONLY
10" CRS.
5"
5'-9 1/2"
9 1/2"
TO FIT 7/8" NUT SPANNER
LEATHER PACKING
PARTS 1 TO 4 ARE MADE OF BRASS
1
2
3
4
1"
1/4"
1/8"
5/8"
5/16"
15/16"
1 1/4"
2 1/8"
7/8"
1/2"
3/8"
2 1/2" D
2 1/4" D
1 3/4" D

Fig. 3.

incondensable gas pipes during the off-season, as these are liable to become choked and thereby lead to tube deterioration if the gases are not adequately drawn off from the calandria.

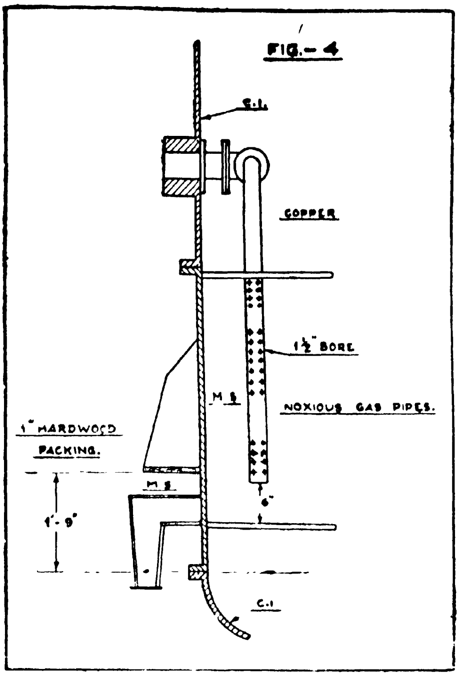

Fig. 4.

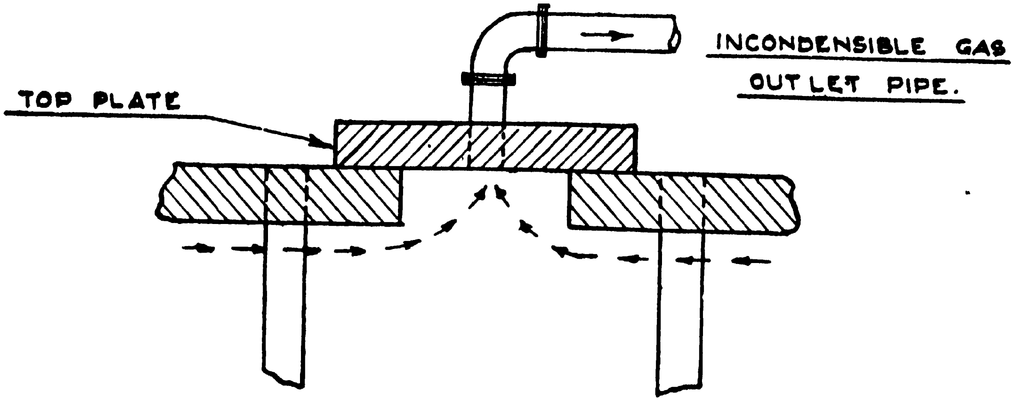

Figure 5.

DISCUSSION

Mr. W. M. Livie expressed the view that 20 years was a good service life for evaporator tubes, and that it was not unreasonable to have to replace them after such a period.

Mr. Bhargava agreed that normally they would have suggested replacing the tubes, but the method or repair was recommended on account of the difficulty of obtaining new tubes during the period of the War.

In the absence of the author Mr. G. H. Jenkins presented the following paper.

Paper

VACUUM PAN DESIGN IN RELATION TO PERFORMANCE

J. HAMILL

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The word " performance " in reference to the operation of vacuum pans is very indefinite and can hardly be otherwise in the present state of our knowledge. To narrow the field as much as possible, we might limit these remarks to the standard type of vacuum pan which has a flat calandria and a superimposed body of either parallel or enlarged type.

Performance is frequently confused with speed of boiling, striking time, or even heat transmission per square foot of heating surface. Unfortunately, except in a particular sense, none of these completely defines " performance ".

Therefore, it would be helpful to the industry if some formula could be devised which would take into account the factors governing the performance of vacuum pans in different situations, or even for the same vacuum pan in different locations, at least for purposes of technical comparison. The factors involved are many and cover such a wide range that the writer has not been able to devise such a formula. It may be that some of our members have attempted to do so and may be encouraged to put forward their views.

The main factors would seem to be the following :

(a) *Temperature of steam in the calandria and the internal arrangements of the calandria for the effective distribution of the steam, combined with removal of incondensable gases and condensate.*

The entering steam temperature may be anywhere between 250°F. and 220° F. in different factories. Obviously, this temperature exerts a direct effect on the boiling rate. The steam distribution within the calandria may also have a direct effect as the steam path must be sufficiently long to give high steam velocity among the tubes and thereby promote heat transmission. The steam must also drive the incondensable gases to one or more suitable points for removal, and do this without marked loss of temperature-usually not more than 2° to 4° F. The removal of condensate is equally important and a calandria which has the lower portion of the tubes submerged in 2″ to 3″ of water at the important part of the pan cycle will operate at a disadvantage.

(b) *Vacuum or temperature of the steam in the vapour space of the pan.*

We have here two opposing conditions. With higher vacuum and, therefore, lower boiling temperature, we tend to increase the heat drop across the heating surface, but at lower temperatures the viscosity of the massecuite increases and tends to slow up the heat transmission. Therefore, the operating vacuum must be specified.

(c) *The degree of submergence of the top tube sheet in the calandria pan.*

Under this heading, we define " submergence " of the heating surface as a percentage of the total strike volume. This is usually referred to as the " graining volume ". A pan in which the heating surface is contained in the lower 25% of the volume of the pan is normally at some disadvantage compared with a pan in which the volume submerged in the heating surface is, say, 45%. The latter would normally boil faster and complete the strike earlier, but the former has a greater ability to build up grain size, thereby reducing the number of cuts when boiling low grade massecuites. This ability reduces the amount of massecuite storage capacity required. Elimination of cuts prolongs the useful boiling time of the pan and renders it more effective, as well as giving the sugar boiler a greater facility in handling.

(d) *The height of the strike above the top tube sheet at the finish of the strike.*

Under this heading, we refer to the actual dimensional height from the top tube sheet to the finished strike level which has the adverse effect of raising the boiling point in the heating zone regardless of the rate of active circulation, although active circulation materially compensates for this disadvantage. "Circulation " is defined as movement of the mass through the tubes to the upper strike level with free and unobstructed return to the bottom of the pan. Zone circulation in the lower part of the pan does not meet this requirement.

(e) *Nature of the initial footing run into the pan to more or less cover the active heating surface.*

This footing may be high purity, filtered syrup as in a refinery, of either high or low density, or it may be evaporator syrup in a raw sugar factory of purity between 70° and 88°. Alternatively, it may consist of a magma of widely varying purity and crystal content. Obviously, a vacuum pan which is presented with a suitable footing containing the proper amount of grain will usually save boiling time as compared with a vacuum pan in which the grain has to be formed from syrup by any of the well known systems of seeding.

(f) *Allowance for cutting-over.*

In some types of pans and systems of boiling, cutting must be resorted to, to arrive at the proper grain size, involving loss of time in the boiling cycle. Putting this another way, a pan which has a high graining volume, requiring more frequent cuts, should be penalized as against a pan designed with a low graining volume,

(g) *The system of feeding the pan and the nature of the feed.*

Continuous feeding tends to speed up the boiling cycle, whereas intermittent feeding, as in hand control, usually leads to loss of time for correction of the boiling condition. High density of feed reduces the steam consumption but low density feed is generally felt to be safer by pan boilers of the older school. However, density and temperature of feed definitely influence pan performance. The introduction of air with the feed may not seriously affect performance but may be the cause of entrainment which is intermittent and hard to detect. Such air usually can be traced to leaky valves or partially empty tanks.

(h) *Location of feed inlet.*

One other important feature should not be forgotten, that is, the place of introduction of feed to the pan. In any standard pan with center feed, the syrup has a strong tendency to rise to the surface of the pan directly up the downtake due to lower density, in opposition to the natural downward flow of the massecuite, and at high levels to remain at the top without proper admixture. The pan designer's object should be to introduce the feed in streams as finely divided as possible and definitely below the heating surface in such a manner that it would be easily dispersed and be well mixed before reaching the upper level of boiling.

STATEMENT OF CONDITIONS

It is, therefore, desirable that the prospective purchaser of a vacuum pan should clearly examine the conditions under which it will operate, both for the nitial condition and the future, and transmit these to the designer. The minimum requirement for such a statement should involve the following information :

Type of sugar to be produced.
Purity and Brix of massecuite.
Purity, Brix and temperature of material to be boiled.
Preferred method of forming grain.
Quantity of massecuite to be produced per unit of time.
System of pan operation so that proper submergence or graining volume can be provided.
Steam pressure available—if not constant give details.
Condenser available—give capacity and vacuum.
If condenser is to be furnished, give quantity and temperature of water available.
Type of vacuum control—manual or automatic.

The designer should thereafter make his own calculations based on not what might be called " test " results, but on what could be reasonably expected under the conditions specified and with the type of personnel available to the user in the country of destination.

Future requirements should be considered. The designer should be given data on the complete operation of the refinery or factory. The installation of a relatively large, fast pan that uses steam intermittently may seriously disturb the entire operation, and it is often desirable to use more pans of smaller size.

The calandria is, of course, the heart of the vacuum pan and upon its efficiency with relation to the conditions within the pan and the liquor itself depends the performance of the apparatus. The designer usually has some general data on the work of his design of calandria under different conditions, and in most cases these are linked to the amount of finished massecuite which can be turned out per square foot of heating surface per unit of time. Pans can be designed for extreme conditions with very high rates of completion per square foot of heating surface, but these conditions usually involve the acceptance of limitations which cannot be met with the usual pan proportions, and may require the acceptance of low Brix strikes with low recovery in the centrifugals. The designer also has to use his standard designs as far as possible for economic reasons, and the purchaser would do well to use these standard designs for the sake of economy and adaptability.

Fortunately, it is possible to design a vacuum pan having all the advantages of an efficient calandria combined with low graining volume and almost universal adaptability to varying conditions due to the introduction of the " low-head " type of pan. This point is illustrated by assuming that the purchaser requires a standard 12 ft. calandria with 25% submerged volume. With the bottom made reasonably small, the volume would be about 456 cubic feet, requiring 1,370 cubic feet above the top tube sheet. A pan with a straight belt would require a height of about 12 feet above the top tube sheet, obviously an impossibility for suitable circulation. Alternatively, with the diameter of the belt divorced from the calandria diameter as in the " low-head " pan, it is possible to reduce this boiling height to 7 feet with a belt 16 feet diameter, which is within experience with the low level design. These may be considered somewhat extreme figures, but experience shows that any height over 7 feet in the conventional pan leads to poor circulation which practically ceases at higher levels.

On the other hand, should the purchaser specify a similar straight-sided 12 ft. calandria pan with 45% submerged volume and a total volume of about 1,000 cubic feet, the boiling height would be of the order of 5 feet—a very reasonable figure. Once installed for such a condition, the user would find himself limited in the use of such a pan except for some grades of refined sugar. However, should the pan be installed as in the former case with 25% or 30% submergence, the pan could very well be operated at a strike volume of 1,100 to 1,200 cubic feet without sacrifice of efficiency, and at a moderate increase in cost over the other type of pan, since the calandria cost would be the same in either case.

The disadvantage of the parallel belt pan is that, without some sort of structure surrounding the " invisible downtake " above the calandria downtake, the expanding massecuite rising to the surface encroaches on the space required for downward flow. When the rising steam bubbles and massecuite expand into the downcoming massecuite, a definite path for circulation is destroyed. As a result, the circulation is " short circuited " at some height below the upper surface of the massecuite. At this point good circulation ceases to exist. The point of " no return " flow may be 4-1/2 feet to 6 feet, depending upon the downtake diameter. However, with some form of protecting structure, the diameter of downtake may be reasonably small and the boiling height raised.

Various structures of this were designed, but finally in 1939 the management of Ingenio Manuelita in the Cauca Valle, Colombia, consented to such a trial and installed one of the simpler designs in an 8 ft. pan with a sloping calandria, producing white sulphitation sugar direct from evaporator syrup.

The capacity of the pan was increased by a combination of striking time and raising of strike level. A second pan 9 feet diameter with 30″ downtake producing crystallizer strikes was similarly fitted, and the strike time was reduced from 12 to 13 hours to 8 to 9 hours with improved density and recovery.

Having proved that the " invisible downtake " could be properly protected by louvres, the management of Manuelita installed the first true " low-head " pan in 1940, of all welded steel construction. This pan, with a 9 ft. calandria and an 11 ft. belt in association with the circulating louvres, demonstrated that active circulation resulted over the entire strike level area, even at the end of a 101 Brix low grade strike. This was clearly seen through the illuminated dome sight glasses.

Since that time, pans with belts from 7 ft. to 17′6″ diameter have been installed at boiling levels of 5 ft. to 8 ft. above the top tube sheet. No practical limits have been met but there are limits to boiling height, if not to diameter, since the submerged heating surface tends to approach simple heating conditions the deeper the submergence. In established experience, however, no loss of performance or output has been observed in pans up to 2,400 cubic feet capacity.

It is suggested that pan users fit their pans with efficient dome lights well above the finished strike level and examine the boiling surface with a view to correcting faulty steam distribution in their calandrias and the detection of bottom to top circulation.

The upper surface should be of the same colour as the massecuite and have a visible movement towards the downtake and should give indication of even boiling around the shell. If the surface is a smooth reflective molasses colour, with random ebullition, the circulation is not rising to the top and displacing the surface molasses.

Freeboard above the finish strike level is important, especially on pans having boiling rates or strike times as fast as 1 to 2 hours on liquor, as in sugar refineries or others making white sugar. Generally speaking, it is found that 3 feet vertical height below the dome is not too much with 15 pounds calandria pressure, although with care 1½ to 2 feet will serve.

The natural circulation in such a pan of the " low-head " type with circulating louvres is particularly violent to the end of the strike and, by inspection through the dome, can be observed obviously to be in no need of any assistance from outside power. The use of power has some other functions, but should not be relied upon to give complete bottom to top circulation nor to move heavy massecuites which cannot be moved by natural circulation.

In conclusion, technologists and factory owners sending out inquiries for vacuum pans should specify the main features of performance, such as volume, steam pressure, vacuum, type of sugar, especially graining volume, and generally give the pan designer the conditions to be met in regard to the product to be produced. All too often the only figures given are strike volume and heating surface, and for economic and competitive reasons manufacturers are forced by these conditions to offer the most competitive design price-wise—not necessarily the most useful unit for the purpose intended, not the most economical per unit of massecuite produced.

In comparing pans of various designs, other details such as efficiency of save-all, volume and free discharging of pan bottoms, and design of discharge gate are of major importance. The thickness and type of pan construction material are also important, since they affect both initial cost and life. Other minor details requiring consideration are suitable type and design of proofstick, washbox, sight glasses—both as to type and number—boiling-out connections, safety valves, entrance manholes and instruments. All of these add to the ease of operation and control of the vacuum pan.

A vacuum pan is essentially an apparatus to be used by the sugar boiler for crystallizing sucrose from the mother liquor. The object of the designer should be to produce the most convenient and efficient apparatus for the purpose. To do this, the fullest co-operation and assistance of the factory superintendent and his sugar boilers are necessary if the best design is to be achieved.

DISCUSSION

Mr. Chandrasekran said that from his experience in the operation of a 15 ft. diameter pan, the rate of boiling fell off considerably when the massecuite level was more than 5 ft. above the top tube plate.

Mr. G. H. Jenkins considered that pans should not be designed for a strike capacity requiring a massecuite level of more than 6 ft. above the top tube plate. He also considered the central downtake should be 50% of the pan diameter, and the ratio of the area through the tubes to the downtake area, 3 to 1.

Mr. F. L. Stewart stated that he considered large pans should be provided with two or more steam inlets spaced around the calandria, these being connected together and supplied by one steam valve only.

Mr. J. O. Sason considered that the design of the pan bottom had an influence on circulation, and that a central conical insert was beneficial.

Mr. Vander Meyden asked for information on the performance of mechanical circulators.

Mr. J. P. Mukherji gave comparative boiling times for a 35-ton streamlined pan fitted with a mechanical circulator. He stated that with " C " massecuite the boiling time could be reduced from 7/8 hours to around 3½/4 hours by the use of mechanical circulators with similar reductions on other massecuites. The rating of the electric motor driving the circulator was 75 B.H.P. He also stated that circulation was further improved if stationary louvres were fitted above the downtake in a pan already fitted with a mechanical circulator.

Dr. K. Douwes-Dekker stated that the horse power required for circulating massecuite was high. He mentioned the case of a 50 B.H.P. motor fitted to a pan which had to be replaced by one of 70 B.H.P.

Mr. A. Constandse considered that mechanical circulators were only of assistance to massecuite circulation towards the end of a strike and in a pan which suffered from poor circulation.

In the absence of the author the paper was taken as read.

Paper

NOTES ON CONDENSING PLANT FOR CANE SUGAR FACTORIES

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INTRODUCTION

In the early stages of boiling and evaporating under reduced pressure, each vacuum apparatus was equipped with its own condenser and wet-air pump. As the through-puts of the sugar factories became larger. the size and the number of vacuum units increased as did the size and the number of wet-air pumps. Eventually the size and number of latter became too cumbersome and new factories were no longer equipped with individual condensers with wet-air pumps, but more usually with one central condenser evacuated by a dry-air pump.

Although it is obvious that one central condensing plant requires less supervision, maintenance and floor space than a number of individual condensing units, the transition to centralized condensation was a backward move from a processing point of view. It is well known that when a number of vacuum apparatuses is served by a joint vacuum pump, the vacua mutually affect each other, the resulting vacuum fluctuations impairing boiling operations and promoting entrainment.

The steady increase in facory through-put resulted in the factories eventually outgrowing the size of the central condensing plant and two or more of such plants had to be installed in the larger factories. This fact, in addition to the preference for the individual condensing system from the processing side, has resulted in a return to the individual system. It is, however, not the wet-air pump which has returned, but other self-contained units such as :

(a) individual barometric condensers, each with its own vacuum pump.
(b) individual multi-jet condensers.
(c) special equipment of the Rees Roturbo, Westinghouse-Leblanc and other condensing pump types.

Regarding (a), the vacuum pump concerned can be of the ordinary reciprocating or piston type, but it can also be a rotary pump, either of the dry or the water-ring type. The air can also be removed with the aid of a water-jet, or by a steam-jet air pump.

Of all the systems the combination " individual barometric condenser with reciprocating or rotary dry-air pump " consumes the least power. Other system, either multi-jets or evacuating with the aid of a water or steam jet require, more energy. The systems with a barometric condenser are less sensitive with regard to cooling water temperature than the multi-jet condenser. The latter operates as the wet-air pump with condenser according to the parallel or concurrent principle and is therefore less suitable in cases where the cooling water temperatuce is rather high.

A system introduced in Java in the thirties consists of individual barometric condensers equipped with one or two individual water-jet air pumps, instead of individual reciprocating or rotary vacuum pumps. The water-jet air pumps are bolted to the barometric condensers and operate with water under pressure of 1-1½ kg./cm^2. (gauge). The tail-water of each jet is collected in a special tank placed about 15 feet under each condenser, on the pan stage. Since the condensers are only 15 feet above the tanks, the tailwater of the air-jets can be drawn from the tanks into the condensers with the aid of their vacuum, no separate injection-water pump being required. The condensers are drained in the usual manner by barometric tail-pipes. By this arrangement the water is used twice ; firstly to draw off the air, and secondly to condense the vapour.

In Central and South America the use of steam-jet air pump is gaining popularity due to their simplicity.

It should be mentioned that the original central condensing system with one central condenser has developed in some cases into a system with individual condensers but still centralized air removal. Sometimes an auxiliary or secondary condenser is placed between the individual condensers and the joint vacuum pump, or group of vacuum pumps, in order to cool all vapour-air mixtures from the individual condensers to the same temperature. Since these condensers are still served by a joint vacuum pump or pumps, the drawback, i.e., mutual affecting of the vacua, is still present.

A further improvement is the introduction of the booster vacuum pumps for pre-evacuating the vacuum pans before they are connected to the system. When the booster pump is properly used, vacuum fluctuations can to a great extent be ironed out.

OPERATIONAL PRINCIPLE OF THE COUNTER-CURRENT CONDENSER

Since the barometric condenser is the most used condenser in sugarhouse work, further discussions will be confined to this type of condenser.

The barometric condenser is a counter-current jet or injection condenser because injection water and vapour enter the condenser at opposite ends. Since the air leaves the condenser at the side where the water enters, the air is drawn off by the dry-air pumps at about the same temperature as the entering water, while in the case of the co-current condenser the air has the same temperature as the waste water, waste water and air leaving at the same side.

In order to expose as large a surface as possible to the vapour flow for condensation, different arrangements are in use. The flow of injection water can be distributed over the condenser cross section by a number of spray nozzles spaced symmetrically around the top part of the condenser, or the water surface exposed to the vapour is enlarged by arranging for the water ro cascade over trays. Almost invariably the water curtains are formed by water cascading alternatively over annular weirs arranged at different heights around the wall of the condenser, and over circular trays at inter-spacing heights in the centre of the condenser. The water overflowing the first weir falls as a tubular curtain on the first tray, where it is re-directed as another tubular curtain and falls on the second annular weir, and so on. The curtains are seldom really continuous, but even so, there is a definite resistance to the vapour flow as the vapour and the air must break through the curtains. There is a slightly higher vacuum at the top of the condenser than at the vapour inlet side.

Apart from water and vapour, incondensable gas also enters the condenser. Injection water always contains air in the dissolved state and sometimes air bubbles, as well and the vapour carries along air originating from leaks and gases freed from juices as a result of boiling and concentrating. The air which has to be expelled when restoring the vacuum in a pan after a strike has been made, is dealt with under a separate section.

All incondensable gases will collect finally at the top of the condenser where they are drawn off by the vacuum pump. Since the gases are saturated with vapour, it is more correct to refer to them as vapour-gas mixtures. In colloquial language, however, the mixture is called " air " and this notation is followed except in those cases where the partial pressures of the vapour and gas are concerned. It is also customary in sugar factory practice to refer to "vacuum" and not to " pressure " where vacuum apparatuses, vacuum pumps and condensers are concerned. This practice will be followed again with exception where partia pressures of the vapour-gas mixture are concerned. When referring of vacua the vacua will be indicated in mm. of mercury, a barometric reading of 760 mm Hg being assumed.

Since the air has to be removed by a pump, the volume of the air at the top of the condenser should be as small as possible, and it is therefore essentia that the air arrives at the top of the condenser with as low a temperature as possible with regard to available quantity and temperature of the injection water. Hence in addition to condensing the vapour, the task of the condenser is to cool the air Moreover, from an economic point of view the condenser should perform its dual task as efficiently as possible so that with the least amount of injection water and the smallest capacity of vacuum pump the highest vacuum is obtained.

An ideal condenser, that is, one performing with 100% efficiency, should be characterised by the following qualities :

(a) the water should leave the condenser at the same temperature as the vapour entering the condenser, because then the water requirement of the condenser will be minimum,

(b) the air should leave the condenser at the same temperature as the wate enters, because then the air volume will be minimum,

(c) the vacuum at the vapour inlet side should be equal to the vacuum a the air outlet side, because then the vacuum will be maximum unde prevailing conditions.

In practice there are, however, always differences in temperatures and vacua, which differences will now be considered.

TEMPERATURE DIFFERENCE BETWEEN VAPOUR AND WASTE WATER

If t_v denotes the temperature of the vapour where it enters the condenser and t_w denotes the temperature of the waste water leaving the condenser, then the temperature difference will be denoted by

$$y = t_v - t_w \quad \text{..} \quad (1)$$

There are two reasons for this difference in temperature. Firstly, owing to the limited area of contact between vapour and water, the water can never be heated to the same temperature as the vapour. Only in the case of an infinitely large area of contact would the temperature difference be infinitely small. Secondly—and this reason is of minor importance—due to the presence of air the temperature of the vapour-gas mixture entering the condenser does not correspond completely with the temperature of saturated steam at the pressure at the vapour branch of the condenser. In practice, however, the concentration of air where the vapour enters the condenser is so small that it may be assumed that the temperature of the vapour at the vapour inlet branch corresponds with that of saturated steam at the same pressure.

Weiss (1) assumes that $y=2$°C. in the case of efficient, and $y=4$°C. in the case of poor performance. In both cases Weiss is referring to central condensers which, due to their greater height, can accommodate more trays than individual condensers ; hence the area of contact is relatively larger in the case of the former.

Hugo (2) gives the following formula for y :

$$y = (0.1 + 0.02a)/(t_v - t_i) \text{ °C} \quad \text{..............................} \quad (2)$$

in which formula t_v and t_i denote the temperatures of vapour and injection water respectively, and *a* indicates the percentage by weight of air present in the vapour. This formula refers also to central condensers.

Hugo postulates that in all cases where the result obtained by the formula is smaller than 3°C. the value of 3°C. should be used.

Lyle (6) considers that the condenser is of reasonably good design when y is not more than 2°C. Webre has found in practice that y varies from 5°F. to 25°F. ; a fair average in the case of good equipment being 15°F. (8°C.).

Summarising, it is proposed to use $y=2$°C. where central condensers are concerned, and $y=3$°C. for individual condensers.

Before continuing the discussion of the differences in temperature between vapour and waste water, and between air and injection water, discussion on the proportion of injection water required is dealt with as this follows logically.

QUANTITY OF INJECTION WATER

The proportion between the required quantity of injection water and the quantity of vapour depends on :

(a) the required vacuum,

(b) the temperature of the available injection water,
(c) the load on the condenser and the condenser design.

Item (c) determines the magnitude of y, and causes the vacuum difference between top and bottom of the condenser.

Neglecting the loss of heat due to rediation, the heat present in the entering vapour and water must be equal to the heat present in the waste water and air. Neglecting the heat present in the air we can write per 1 kg. of vapour to be condensed :

$$(1 \times h) + (r \times t_i) = (1 + r)\, t_w$$

or $$r = (h - t_w)/(t_w - t_i) \quad \text{......} (3)$$

In this formula r denotes kg. (or litres) injection water per kg. of vapour, and h the total heat of the vapour in kcal./kg.

The different values of h, i.e., the total heat of saturated steam for steam of temperatures from 20°C. to 60°C. are to be found in Table I (see Appendix). The table shows also other properties ; the heat of evaporation, the specific volume, the corresponding pressure in kg./cm². and the ditto vacuum in mm. Hg; all data in metric system and in imperial measure. The table is based on values derived from tables published in "Handbook of Chemistry and Physics" (14). Substituting the average value of 620 kcal./kg. for h in formula (3) this becomes :

$$r = (620 - t_w)/(t_w - t_i) \quad \text{......} (3a)$$

In this form the formula is used to compute the magnitude of the ratio for different values of t_i and t_w shown in Table II (see Appendix).

TEMPERATURE DIFFERENCE BETWEEN AIR AND WATER AT THE TOP OF THE CONDENSER

As explained, the air arriving at the top of the condenser is not completely cooled to the temperature of the entering cooling water ; the air temperature being always slightly higher than that of the water. Weiss (1) gives the following formula for this difference :

$$(t_a - t_i) = 0.1\,(t_w - t_i) + 4°C. \quad \text{......} (4)$$

This formula says that the difference between air temperature (t_a) and water temperature (t_i) is 4°C. more than 1/10 of the difference between waste (t_w) and injection water temperature (t_i). Webre (3) assumes an average value of 6°C. and Hausbrand (4) of 5°C. Tromp (5) and Hugo (2), both say that there is no difference ; t_a and t_i being equal. Hugo adds that although t_a may be slightly higher when measured at the top of the condenser, when the air travels from the top to the vacuum pump it will cool and arrive at the pump with the same temperature as the injection water.

It is proposed, particularly in view of the less efficient cooling in individual condensers, to accept Weiss's formula for the estimation of the air temperature at the top of the condenser :

$$t_a = 0.09 t_i + 0.1 t_w + 4°C. \quad \text{......} (4a)$$

VACUUM DIFFERENCE BETWEEN TOP AND BOTTOM OF CONDENSER

Literature on this subject is far from enlightening. According to the author's experience a well designed and adequately loaded condenser should not show more than 5 mm. Hg difference in vacuum between vapour and air branches. However, overloaded and flooded condensers show far larger differences.

AIR IN INJECTION WATER AND IN VAPOUR

Weiss (1) gives a formula which can be used invariably where injection condensers are concerned for indicating the volumes of air present in water and in vapour :

$$L_{vol} = (0.02W + \mu D)/1000 \text{ m}^3 \quad \ldots\ldots (5)$$

In this formula W and D are the water and vapour quantities in kg. respectively, and μ denotes the degree of leakiness of the system concerned, L_{vol} is the volume of air in cubic metres (N.T.P.). For sugar factories Weiss recommends $\mu = 8$ and Weiss's special formula for sugar factory practice therefore reads :

$$L_{vol} = (0.02W + 8D)/1000 \text{ m}^3 \quad \ldots\ldots (6)$$

Assuming that the proportion between water and vapour is 40 to 1, the formula becomes ;

$$L_{vol} = (0.80D + 8D)/1000 \text{ m}^3, \quad \ldots\ldots (6a)$$

which shows that in this case there is ten times as much air present in vapour as in the water.

In technical literature other data are given and in order to compare these data (which sometimes refer to vapour, and the other times are given as percentages of the volume of water) the volume ratios will be all converted to weight ratios. Since the weight ratios are small, it is proposed to indicate the air concentrations as grammes of air per metric ton of water or of vapour.

Since the greatest part of the incondensable gases is air, it is proposed to assume that the specific gravity at 760 mm. Hg and 0°C. is equal to that of air or = 1.2929. By multiplying formula (6) by 1.2929, the formula is converted into a weight ratio formula :

$$L_w = (0.026W + 10.34D)/1000 \text{ kg.} \quad \ldots\ldots (7)$$

which shows that there is 26 grammes of air in 1000kg. of water and 10343 grammes of air in 1000 kg. of vapour.

QUANTITIES OF AIR PRESENT IN INJECTION WATER ACCORDING TO . DIFFERENT AUTHORITIES

Since only 26 grammes per 1000 kg. of water can be dissolved in water under atmospheric conditions, any quantity in excess of this concentration must be present in the form of air bubbles. An assumption, for example, of 36 grammes implies that 10 grammes are present as air bubbles and 26 grammes in the dissolved state.

Authority	*Grammes of air present in 1000 kg. of injection water*
Weiss (1)	26 g./1000 kg.
Hausbrand (2)	30 in general ; in the case of a river with swift current or with cascades the ratio can go up to 145g./1000 kg.
Badger (10)	13.26 g./1000 kg.
Webre (4)	39 g./1000 kg.
Corner (12)	100 g./1000 kg.
Hugo (2)	20-30 g./1000 kg. when originating from a lake or slowly running river ; from a spray pond 30-40 g./1000 kg. ; from a swift running river or a river with rapids 50-150 g./1000 kg.

Hugo's ratios show the greatest differentiation with respect to the source of the water and agree with Hausbrand's figures. The other authorities with the exception of Corner, refer obviously to water derived from a lake or slow running river. It is proposed to use Hugo's ratios according to circumstances.

QUANTITIES OF AIR PRESENT IN VAPOUR ACCORDING TO DIFFERENT AUTHORITIES

The following amounts of air are present in vapour according to the following authorities.

Authority	*Grammes of air in 1000 kg. of vapour*
Weiss (1)	10.34 kg. or 10340 g./1000 kg.
Hausbrand (2)	About 8800g./1000 kg.
Badger (10)	4000g./1000 kg. for a triple effect.
Coxen (11)	From 5000g. to 7000g./1000 kg. for evaporators.
Corner (12)	6000g. for a triple ; 7400g. for a quadruple and 7800g. per 1000 kg. of vapour from the last vessel of a quintuple effect.
Webre (3)	936g./1000 kg. for evaporators.
Horton (13)	6000g./1000kg. in the case of a quadruple effect.
Tromp (5)	7300g./1000kg.
Hugo (2)	10500g./1000kg.

The above quantities are not always stated as such by the authorities, but can be calculated from data given by them. For example, Webre states that the quantity of air due to vapour is equal to the quantity of air from the cooling water and, since he gives the amount of air in water and the ratio of water and vapour, the air in vapour can be calculated. Horton gives figures as the volumetric effect and piston displacement of the vacuum pump ; evaporation rate and water/vapour ratio. Badger gives only a figure for a triple effect, and adds that each case should be considered on it merits.

For the total quantity of gases to be removed by the vacuum pump of a central condensation system Hugo gives empirically 12000g. per 1000kg. of vapour, which is based on a water/vapour ratio of 40 : 1 and 40g. of air per 1000 kg. of water. In addition to this general figure, Hugo gives also values for air due to leaking and air or gas originating from juice, syrup or molasses. With regard to the amount of air due to leaking of the plant, Hugo differentiates between new installations with short and air-tight mains and old installations with a large number of flanges.

Summarizing it is proposed to adopt the following proportions for air present in water or vapour :

Air present in Water.

24g. per 1000 kg. of water when the water originates from a lake or a slowly flowing river.

34g. per 1000 kg. of water when the water is returned from a cooling tower or spray pond.

Air present in Vapour.

750 g. per 1000 kg. of vapour when the vapour originates from the last vessel of a quadruple effect.

900 g. per 1000 kg. of vapour in the case of vapour from a quintuple effect.

960 g. per 1000 kg. of vapour for vapour from vacuum pans.

When dealing with the air content of water, water temperature of 25-30°C. has been assumed for water from lakes or slow flowing rivers. 34g./1000 kg. for re-cooled water is based on a temperature of 30-35°C.

The air content of vapour from vacuum pans has been fixed rather high to allow for leakage of discharge valves.

In connection with these proportions it is proposed to adopt the following formula :

$$L = (aW \times bD)/10^6 \text{ kg.}, \quad \ldots\ldots(8)$$

where a denotes the grammes of air present in 1000 kg. water and b the grammes of air present in 1000 kg. vapour.

With the aid of this formula, and assuming $a=24$ and $b=960$, the total weight of air to be removed is calculated for injection water of 25°C., of 27½°C. and of 30°C. The results of these calculations are given in column 10 of the Tables IV-A ; IV-B and IV-C. Table IV-B, for example, shows that to maintain a vacuum of 672 mm. Hg, 31m^3 of water of 27½°C. are required, and 10.34 kg. of air have to be removed, per 1000 kg. of vapour condensed.

Although the proportions by weight are more convenient (a) when comparing the proportions as shown in literature, and (b) when assessing the total quantity of air to be removed, the weight quanitity has to be converted into volume, when the capacity of the vacuum pump is considered. For the conversion from weight to volume, however, the density of the air at the top of the condenser must be known.

THE DENSITY OF THE AIR AND THE VOLUME OF AIR TO BE REMOVED FROM THE TOP OF THE CONDENSER

It has been pointed out that what is colloquially referred to as " air ", is actually a gas-vapour mixture. According to Dalton's Laws, the pressure of the vapour in a mixture depends on the temperature of the mixture only, and it is not affected by the presence of any other gaseous substance in the same space. This makes it possible to assess the partial pressure of the gas, when total pressure and temperature are known. From the partial pressure of the gas and the temperature of the mixture, the specific volume of the gas can be calculated, provided the specific gravity of the gas at N.T.P. is known.

With the aid of the specific volume and the weight of the gas the volume of the gas can be calculated which volume is equal to the volume of the vapour gas mixture, again according to Dalton's Laws.

For example, when the total pressure at the top of the condenser is 80 mm. Hg and the temperature 35°C., the partial pressure of the gas (air) will be 80-42.2=37.8 mm. Hg, where 42.2 mm. is the pressure of saturated steam (vapour) at 35°C. Assuming that the gas is pure air, the specific gravity at N.T.P. is 1.2929. The specific gravity of the air at 35°C. and 37.8 mm. Hg will be :

$$\frac{273}{273+35} \times \frac{37.8}{763} \times 1.2929 = 0.0570 \text{ kg./m}^3$$

Hence the specific volume of the air at the top of the condenser is :

$1/0.0570 = 17.54$ m^3/kg.

In this manner the specific volumes of the air at different circumstances are calculated. These are given in column 8 of the Tables IV-A ; IV-B and IV-C (see Appendix). By multiplying the weights of air shown in column 10 by the specific volumes according to column 8, the volumes of air to be expelled per 1000 kg. of vapour are calculated ; the results are given in column 11-A. Column 11-B gives the results indicated in English measure, viz., in cubic ft. of air per 2000 lbs. or short ton of vapour.

Finally column 12 shows the ratio between the volume of cooling water and the volume of air. For vacua ranging from 685 mm. to 665 mm. this ratio varies from 6 : 1 to 5 : 1, on the assumption that :

(a) the air content of the water is 24 g./1000 kg.,

(b) the air content of the vapour is 960 g./1000 kg.,

(c) the difference in vacuum between top and bottom of condenser is (5) mm. Hg,

(d) the difference in temperature between vapour and waste water is 3°C., and

(e) the difference in temperature between air and cooling water is equal to 0.1 $(t_w - t_i) + 4°$ C.

In order to use Tables IV-A, IV-B and IV—C, the weight of vapour to be condensed must be known. The quantity of vapour to be expected under different circumstances is now considered.

ASSESSMENT OF THE QUANTITIES OF VAPOUR TO BE CONDENSED

The quantities of vapour to be condensed by individual condensing units serving evaporators and vacuum pans is first considered. Table III gives the percentages of water evaporated in each vessel of a straight quadruple effect and of a straight quintuple effect for two cases. The columns (a) represent the case where the condensate of each vessel is drawn off separately. The columns (b) show the percentages of water evaporated in the case where only the condensate of the first vessel is drawn off separately ; the other condensates being drawn off jointly after the flash of each condensate has been led to the following calandria.

TABLE III

AMOUNTS OF WATER EVAPORATED IN EACH VESSEL OF A STRAIGHT QUADRUPLE AND QUINTUPLE EFFECT INDICATED AS PERCENTAGES OF THE TOTAL QUANTITY ; (a) FOR SEPARATE DISCHARGE OF THE CONDENSATES AND (b) FOR COMBINED DISCHARGE

	QUADRUPLE EFFECT		QUINTUPLE EFFECT	
	(a)	(b)	(a)	(b)
1st Vessel	22.53%	22.13%	17.20%	17.18%
2nd „	24.13%	23.70%	18.17%	18.15%
3rd „	25.81%	25.70%	19.30%	19.47%
4th „	27.53%	28.47%	20.54%	21.19%
5th „	—	—	22.19%	24.01%
Total	100.00%	100.00%	100.00%	100.00%

Having calculated the total quantity of water evaporated from the clarified juice, by using the percentages shown in this Table the weight of the vapour to be condensed can be assessed for straight evaporators. When, however, vapour bleeding is practised, no empirical rule can be used, and each case must be computed taking into account the quantities of vapours bled from the different vessels.

In the case of vacuum pans, differentiation has to be made between pans boiling high, medium and low purity strikes. The highest evaporation can be obtained when boiling high purity and the lowest when boiling low purity strikes. For example, a pan boiling an A-massecuite by developing a footing of C-sugar magma with the aid of syrup will evaporate about 65 kg. *per Hl. of strike volume*. Assuming an actual boiling time of three hours, the average evaporation rate will be 65/3=22 kg./hr. of water *per Hl. strike volume* of the pan. Hence in the case of 500 Hl. pan the average vapour flow rate will be 500 x 22=11,000 kg. per hour.

Assuming that a B-massecuite—also in the case of raw sugar manufacture—takes four hours to develop from footing to completed strike, and that during this operation 56 kg. of water *per Hl. strike volume* is evaporated, the average evaporation rate is 56/4=14 kg./hr. *per Hl. of strike volume* of the pan. Again, in the case of a 500 Hl. pan boiling B-massecuite, the average vapour flow rate will be 500 x 14= 7,000 kg./hr.

By the same reasoning it is found that the evaporation rate *per Hl. of strike volume* of a pan boiling C-massecuite is 50/8=6¼ kg./hr. In the case of a pan with a strike volume of 500 Hl. the average flow rate of the vapour will be 500 x 6¼= 3125 kg./hr.

The average vapour flow rate is not based on area of the heating surface of the pan, because this is of minor importance. The boiling rate is mainly controlled by the nature of strike and the boiling properties of the pan, e.g., circulation rate. Large heating surfaces often impair good boiling properties.

The average vapour flow rates are considered as the capacities of condenser and pumps ought to be based on the average, and not on the maximum rates. Basing capacities on maximum flow would result in condensers and pumps being too large which will be for 75% of the time only partly loaded. Condensers and pumps based on the average rate will give during 75% of the time the required vacuum, and only in the beginning of the boiling cycle will the vacuum be below normal. This is an advantage and not a drawback. Fast boiling requires a lower vacuum as it reduces the viscosity and the tendency to entrainment.

Although a large number of new central condensing plants are not now designed, the request is often made to check up existing plant in order to determine if it can cope with a higher crushing rate. For this purpose—as in the case of a new design—the aggregate vapour flow rate of all vacuum has to be estimated, which can then be compared with the capacities of condenser and pumps. In such a case, the aggregate flow rate would be estimated as follows.

CRUSHING RATE 100 METRIC TONS OF CANE PER HOUR

(a) Vapour from last vessel of quadruple =
28% of 75% of 100 metr. tons =21,000 kg./hr.
(b) Vapour from A-m.c. pans=
95 Hl./hr. A-m.c. a 65 kg./Hl. =6,175 kg./hr.
(c) Vapour from B-m.c. pans=
45 Hl./hr. B-m.c. a 56 kg./Hl. =2,520 kg./hr.
(d) Vapour from C-m.c. pan=
35 Hl./hr. C-m.c. a 50 kg./Hl. =1,750 kg./hr.
Average Vapour Production (per hour)=31,445 kg./hr.

According to Table IV-C (Appendix) 41.1 m^3 water of 30°C. are required and 229 m^3 of air have to be removed, per 1000 kg. of vapour to be condensed when a vacuum of 681 mm, Hg has to be maintained. Therefore, a vapour flow rate of 31, 445 kg./hr. requires $21\frac{1}{2}$ m^3 injection water of 30°C. per minute (360 /sec.) and capacity of the vacuum pump must be such that it can remove 120 m^3 of air per minute.

THE VOLUME OF AIR TO BE REMOVED FROM A VACUUM PAN TO RESTORE THE VACUUM

The volume of air to be removed in order to restore the vacuum in a pan after striking is sometimes required as for example, when calculating the capacity for a booster pump or, in the case of individual condensing units, to ascertain whether the vacuum pump can quickly restore the required vacuum.

Weiss has provided the formula for calculating the volume to be removed to restore the vacuum. According to Weiss, the total volume V_1 which has to be removed by the vacuum pump to bring the pressure in a vessel with a capacity V_g from atmospheric pressure to a pressure P_e amount to :

$$V_1 = V_g \quad (-l_n P_e)$$

For a vessel with a capacity of 1000 Hl. the following values of V_1, adjusted to P_e result :

Final pressure	0.30	0.25	0.20	0.15	0.10 atm.
Final Vacuum	532	570	608	646	684mm. Hg
V_1	1204	1385	1610	1900	2344 Hl.

To evacuate, for example, a vacuum pan of 500 Hl. strike volume, and with 750 Hl. total volume including the condenser, from atmospheric pressure to 646 mm. Hg vacuum, htc vacuum pump has to remove a total volume of air of 1900 x 750/1000 = 1425 Hl.
If the pump is to perform this evacuation in five minutes, the capacity of the pump will be 1425/5=285 Hl./min. or 28½ m³/min.

In the previous section it was estimated that a 500 Hl. pan when boiling a C-massecuite will produce an average of 3,125 kg./hr. of vapour. Hence, when a vacuum of 681 mm. Hg has to be maintained, (3,125 x 229)/(1000 x 60) = 12m³ of air has to be removed per minute. According to the previous calculation a pump of a capacity of 12 m³/min. would require 142.5/12 = 12 minutes to evacuate a 500 Hl. pan from atmospheric pressure to a vacuum of 646 mm. Hg. In practice the time will be shorter, because the pan will not be filled only with air, but with a mixture of steam and air, and the steam will condense the moment the vacuum is high enough for the cooling water to reach the condenser. But, on the other hand, it shows that when the vacuum pump is based on conditions-prevailing when a C-massecuite is boiled, the capacity of the pump will be cut very fine with respect to restoring the vacuum after striking.

In the case of a 500 Hl. pan boiling B-massecuite, the average flow rate of vapour would be 7,000 kg./hr. and accordingly the vacuum pump will have to remove (7,000 x 229)/(1000 x 60) = 26.7 m³ of air per minute. A pump of such capacity will re-evacuate the pan in about 5 minutes time.

PISTON DISPLACEMENT AND VOLUMETRIC EFFICIENCY OF VACUUM PUMPS

Of the different devices for removing air from the top of a barometric condenser only the reciprocating dry-air pump will be considered.

Values for the volumetric efficiency range between even wider limits than the already mentioned variations in quantities of air present vapour ; from technical literature the figures range from 50 to 94%.

The volumetric efficiency of a reciprocating dry-air pump depends on different factors, but firstly on the volume of the dead space (i.e., the space between piston and top and bottom covers when the piston is at the end of its stroke) relative to the piston displacement volume. This dead space is always indicated as a percentage-ratio of the piston stroke, the ratios ranging from 1 to 6%. The lowest values are obtained with long stroke air pumps with Hoerbiger valves fitted in the top and bottom covers of the air cylinder ; slide-valve pumps showing the highest figures. Secondly, the volumetric efficiency varies with the vacuum; the higher the vacuum the lower the efficiency.

Thirdly, the volumetric efficiency is affected by the cooling of the air during the compression stroke ; the better the cooling the higher the efficiency. In this respect small pumps are better than large, slow running better than fast running, and pumps with valves placed sideways better than pumps with valves in the cylinder covers, (valves placed sideways enable the cylinder covers also to be water cooled). The compression curve $pv^n = c$ shows an exponent nearly equal to 1.41 (which implies that the compression is practically adiabatic) in the case of large pumps with valves in the cylinder covers. Small pumps—provided they do not run too fast—show lower exponents in particular when the covers are also water cooled (valves placed sideways).

Fourthly, the resistance experienced by the air when flowing through the valves affects the volumetric efficiency. With respect to reducing the resistance at the suction side, it is good practice to instal an air-vessel at this side. This is usually a vertical cylindrical vessel of capacity equal to two or three times the stroke volume of the pump, and placed as near the suction branch of the pump as possible. In addition to ironing out the pulses in the connecting line between condenser and pump, this vessel collects rust, scale and dirt which is liable to come down the suction pipe line at the beginning of the season.

At the end of each stroke the dead space will be filled with air of a slightly higher pressure than the atmosphere. On the return stroke this volume of air has first to be expanded to a pressure slightly lower than that at the top of the condenser before air from the condenser will flow into the pump cylinder. When the dead space is large compared to the stroke volume and the vacuum is high, the piston has to travel a considerable part of its stroke before the air inside is sufficiently expanded to allow the outside air to flow into the cylinder. Hence only a relatively small part of the stroke volume remains to be filled with outside air from the condenser. When, however, at the end of the compression stroke this side of the cylinder is connected with the other side, where at this moment high vacuum prevails, then the remaining air from the compression stroke will flow to the other side of the piston so that the piston starts on its return stroke with a vacuum instead of atmospheric pressure.

Such compensation devices, either effectuated by the slide-valve or by the piston, are popular on pumps with a high dead-space ratio and are largely a necessity. Modern pumps with Hoerbiger—, Roeder—, or other feather—, or ring valves fitted in the bottom and top covers do not require such devices, as they obtain high volumetric efficiency due to their small dead-space ratio.

Brouwer (17) investigated a vacuum pump of 1000 mm. dia. by 800 mm.

stroke, running from 65 to 85 r.p.m. The pump had Hoerbiger valves in the cylinder covers. At a vacuum of 650 mm. Hg the volumetric efficiency was 95% and at 695 mm. 92%.

Hugo (2) referring to pumps with slide and Corliss valves gives the following figures for volumetric efficiency :

(a) With compensation : 55-80 percent.

(b) Without compensation : 40-60 percent.

Horton (13) mentions a volumetric efficiency of 55 percent at 685 mm. Hg and 60 percent at 660 mm. Hg vacuum, as referring to " normal dry vacuum pumps with feather (no slide) valves."

The modern trend is fast running pumps, operating from 180 to 360 r.p.m. with relatively short stroke. A short stroke results in a larger percentage dead space than a long stroke. Fast running pumps have smaller dimensions than slow running pumps, and it is therefore not always possible to obtain the required valve area when fitting the valves in the top and bottom covers. Valves placed sideways leave the whole surface of the top and bottom covers free for water cooling but, on the other hand, result in a larger dead space proportion than when the valves are placed in the cylinder covers.

With pumps for individual condensing units, the dimensions of the cylinder will be smaller than is the case with large capacity pumps as used for central condensing plants. Hence a lower volumetric efficiency is to be expected in the case of the former. It is proposed therefore to assume 65-75% as the volumetric efficiency for fast running dry-air pumps of individual condensing units, and 70-80% for slow running pumps, depending on the efficiency of the cooling system ; properly maintained pumps being tacitly understood. In the case of larger pumps as used for central condensing plants the efficiency may be rated higher. A pump with Hoerbiger valves in the cylinder covers may be taken as high as 90% ; other pumps 85% volumetric efficiency. Of course, when the pump cylinder or the slide-valve is worn the efficiency may be extremely low due to leakage.

The volume of air to be removed as shown in Tables IV-A, IV-B and IV-C have to be divided by the volumetric efficiency of the pump concerned in order to arrive at the required piston displacement of the pump.

To obtain an idea on the dead-space percentage and the condition of a pump a good practice is to run the pump with closed inlet stop valve, and note the highest vacuum obtained (18). The pump investigated by Brouwer (17) gave in this manner maximum vacuum of 750 mm. ; the dead-space being 1·% of the stroke volume.

According to von Ihering the maximum vacuum which a pump can obtain after an infinite number of strokes is :

$$p_{\infty} = \frac{p \times a}{1+a}$$

in which formula " a " denotes the proportion between dead-space volumet stroke volume and " p " the atmospheric pressure. This formula gives for a pump with 1% dead-space a $p\infty$ of 752.5 mm. Hg when the barometric pressure is 760 mm. Hg.

Hausbrand (4) gives the following table of maximum vacua obtainable after infinite strokes, adjusted to dead-space percentages :

	Dead-Space Percentages						
	1%	2%	3%	4%	5%	6%	7%
Maximum Vacuum in mm. Hg	752.5	745.1	737.9	730.8	723.8	716.8	710.3

	Dead-Space Percentages							
	8%	9%	10%	11%	12½%	13½%	15%	16½%
Maximum Vacuum in mm. Hg	703.7	697.2	691.0	684.7	675.6	668.8	660.0	652.4

When we have a new pump and do not know the dead-space percentage we run the pump with air inlet stop-valve closed and the vacuum obtained will indicate what the percentage is, approximate. However, when we have an old pump with known dead-space percentage and we run the pump with closed valve, the attained vacuum will give an insight in the condition of piston and valves, when comparing the attained vacuum with the obtainable according to the table, for the given dead-space percentage.

The author always carries out the above test when complaints are made regarding vacuum. When the test shows that the condition of the pump is satisfactory, then there must be other reasons for low vacuum, viz., air leaks, too small capacity of air pump, too hot or not sufficient cooling water etc.

THE DESIGN OF CONDENSERS

In order to obtain a small temperature difference between

(a) discharging waste water and entering vapour, and

(b) discharging air and entering cooling water, the transit time of the water and the area of contact between vapour air and water should be as large as possible.

It takes only 0.91 sec. for water to fall 4 metres when not interrupted during its fall. If the fall is interrupted four times by placing trays at 1 metre intervals, the time transit of the water will be 4 x 0.46 = 1.84 sec. or twice as long.

Increasing the area of contact can be achieved by distributing the water such that it falls like rain over the whole cross-section of the condenser. However, such a distribution is not practical. The fine perforations required to distribute the water in small jets or drops would soon clog up. Moreover, a perforated sheet can only be fitted at the top of the condenser, and not a second or a third further down. This means that the transit time of the water will be short if the condenser is not made with greater height. In order not to disturb the even distribution of the water, the vapour velocity must be kept low. This means a condenser of greater diameter as well as greater height.

The common form of condenser does not allow the falling water to accelerate too much, but breaks its fall several times by collecting the water on circular trays and annular weirs at successive heights. When there are four cataracts, the aggregate lengths of these cataracts should be from 3,200 mm. (small condensers) up to 3,600 mm. and more for larger individual condensers.

In addition to a suitable height for providing correct transit time for the water, the diameter of the condenser must be adequate to ensure that the water curtains are not too thick, or the vapour velocity too high. When the water curtains are too thick, not only will the resistance of the condenser be too high, but the water requirements will also be too great. This is because in the short time available the heat cannot penetrate through the whole thickness of the water curtains.

Condenser design is largely the art of cramming into a limited space as much contact area as possible. Data on condenser design are given in Hausbrand's book " Evaporating, Condensing and Cooling Apparatus."

SUMMARY

Data available in technical literature regarding the volume of air present in cooling water of condensers in cane sugar factories, and the percentage of air present in vapour from vacuum apparatus, are quoted and discussed, the formula of Weiss being, in particular, considered.

The volumes of cooling water required and volumes of air which have to be removed by the vacuum pump under different conditions are derived, and the results tabulated for reference in a series of tables. Piston displacement required for reciprocating vacuum pumps and the design of injection condensers are briefly discussed.

Note : At the conclusion of the 3rd Congress of the I S. S. C. T., a resolution was passed which read :—

" Whereas the metric system is based entirely on the decimal system of numbers, relates logically measures of volume to measures of mass, has been legally adopted by most countries, and is in universal use throughout the scientific world.

Be it therefore resolved that the cane sugar industries of the countries represented by this Society be urged gradually to introduce the metric system, and that until that is accomplished, they publish all field and factory results in metric units, either exclusively or along with the customary units."

In accordance with this resolution the metric system has been used in this paper.

TABLE I
PROPERTIES OF SATURATED WATER VAPOUR

Temperature		Vacuum		Total Pressure			Heat of Evaporisation		Total Heat		Specific Volume	
°C.	°F.	mm. Hg	inches Hg	mm. Hg	kg./cm²	p.s.i.a.	kcal./kg.	B.T.U./lb.	kcal./kg.	B.T.U./lb.	m³/kg.	cu.ft./lb.
20	68,0	742.5	29.23	17.5	0.0238	0.339	584.9	1053	605.0	1089	57.8	926
21	69.8	741.4	29.14	18.6	0.0253	0.360	584.4	1052	605.5	1090	54.5	873
22	71.6	740.2	29.14	19.8	0.0269	0.383	583.9	1051	606.0	1091	51.5	824
23	73.4	738.9	29.09	21.1	0.0286	0.406	593.3	1050	606.4	1091	48.60	778
24	75.2	737.6	29.04	22.4	0.0304	0.432	582.8	1049	606.9	1092	45.92	735
25	77.0	736.2	28.98	23.8	0.0322	0.458	582.3	1048	607.4	1093	43.40	695
26	78.8	734.8	28.93	25.2	0.0342	0.486	581.3	1047	607.8	1094	41.05	657
27	80.6	733.3	28.87	26.7	0.0362	0.515	581.2	1046	608.2	1095	38.83	622
28	82.4	731.7	28.81	28.3	0.0384	0.546	580.7	1045	608.8	1096	36.74	589
29	84.2	730.0	28.74	30.0	0.0407	0.579	580.2	1044	609.2	1097	34.78	557
30	86.0	728.2	28.67	31.8	0.0431	0.613	579.6	1043	609.6	1097	32.95	528
31	87.8	726.3	28.59	33.7	0.0456	0.649	579.1	1042	610.1	1098	31.24	501
32	89.6	724.3	28.52	35.7	0.0483	0.687	578.6	1041	610.6	1099	29.62	475
33	91.4	722.3	28.44	37.7	0.0511	0.727	578.0	1040	611.0	1100	28.08	450
34	93.2	720.1	28.35	39.9	0.0540	0.769	577.4	1039	611.4	1101	29.62	426
35	95.0	717.8	28.26	42.2	0.0571	0.813	576.9	1038	611.9	1102	25.25	405
36	96.8	715.4	28.16	44.6	0.0604	0.859	576.4	1037	612.4	1102	23.98	384
37	98.6	712.9	28.07	47.1	0.0638	0.907	575.8	1036	612.8	1103	22.78	365
38	100.4	710.3	27.96	49.7	0.0673	0.957	575.3	1035	613.8	1104	21.65	347
39	102.3	707.6	27.86	52.4	0.0710	1.010	574.7	1034	613.7	1105	20.58	330
40	104	704.7	27.74	55.3	0.0750	1.066	574.2	1033	614.2	1106	19.57	314
41	106	702	27.6	58	0.079	1.12	573.6	1032	614.6	1106	18.61	298
42	108	699	27.5	61	0.083	1.18	573.1	1030	615.1	1107	17.69	283
43	109	695	27.4	65	0.087	1.24	572.5	1031	615.5	1108	16.82	270
44	111	692	27.2	68	0.092	1.32	571.9	1029	615.9	1109	16.01	256
45	113	688	27.1	72	0.097	1.39	571.3	1028	616.3	1109	15.25	244
46	115	685	27.0	75	0.103	1.46	570.8	1027	616.8	1110	14.54	233
47	117	681	26.8	79	0.108	1.54	570.2	1026	617.2	1111	13.86	222
48	118	676	26.6	84	0.114	1.61	569.6	1025	617.6	1112	13.21	212
49	120	672	26.45	88	0.119	1.70	569.0	1024	618.0	1112	12.60	201
50	122	668	26.3	92	0.125	1.78	568.4	1023	618.4	1113	12.02	193
51	124	663	26.1	97	0.132	1.88	567.8	1022	618.8	1114	11.47	184
52	126	658	25.9	102	0.138	1.97	567.3	1021	619.3	1115	10.96	176
53	127	653	25.7	107	0.145	2.07	566.8	1020	619.8	1116	10.47	168
54	129	648	25.5	112	0.153	2.17	566.2	1019	620.2	1116	10.00	160
55	131	642	25.3	118	0.160	2.28	565.6	1018	620.6	1117	9.56	153
56	133	636	25.0	124	0.168	2.39	565.1	1017	621.1	1118	9.14	146
57	135	630	24.8	130	0.176	2.51	564.5	1016	621.5	1119	8.74	140
58	136	624	24.6	136	0.185	2.63	563.9	1015	621.9	1120	8.36	134
59	138	618	24.3	142	0.194	2.75	563.4	1014	622.4	1120	8.00	128
60	140	611	24.0	149	0.203	2.88	562.8	1013	622.8	1121.1	7.66	123

TABLE II

RATIO INJECTION WATER TO VAPOUR

REQUIRED LITRES (OR Kg.) OF INJECTION WATER PER Kg. OF VAPOUR, ADJUSTED TO INJECTION AND WATER TEMPERATURES

Temperature of Injection Water	Temperature (t_w) of Waste Water in degrees Celsius																				
	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	51°	52°	53°	54°	55°
20°	39.0	36.5	34.3	32.3	30.6	29.0	27.6	26.3	25.1	24.0	23.0	...	...	...	...	...	...	...	...	...	...
21°	41.8	38.9	36.4	34.2	32.3	30.5	29.0	27.5	26.2	25.0	23.9	23.0	...	...	...	...	...	...	...	...	...
22°	45.0	41.7	38.9	36.4	34.2	32.2	30.5	28.9	27.5	26.2	25.0	23.9	22.9	...	...	...	...	...	...	...	...
23°	48.8	44.9	41.6	38.8	36.3	34.1	32.2	30.4	28.8	27.4	26.1	25.0	23.9	22.9	...	...	...	...	...	...	...
24°	53.2	48.7	44.8	41.6	38.7	36.2	34.0	32.1	30.4	28.8	27.4	26.1	24.9	23.8	22.8	...	...	...	...	...	...
25°	58.5	53.1	48.6	44.8	41.5	38.7	36.2	34.0	32.0	30.3	28.8	27.3	26.0	24.9	23.8	22.8	...	...	...	...	...
26°	65.0	58.4	53.0	48.5	44.7	41.4	38.6	36.1	33.9	32.0	30.2	28.7	27.3	26.0	24.8	23.8	22.8	...	...	...	...
27°	73.1	64.9	58.3	52.9	48.4	44.6	41.4	38.5	36.1	33.9	31.9	30.2	28.6	27.2	26.0	24.8	23.7	22.7	...	...	...
28°	...	37.0	64.8	58.2	52 8	48.3	44.5	41.2	38.5	36.0	33.8	31.9	30.2	28.6	27.2	25.9	24.7	23.7	22.7	...	...
29°	...	...	72.9	64.7	58.1	52.7	48.2	44.4	41.2	38.4	35.9	33.8	31.8	30.1	28.6	27.1	25.9	24.7	23.6	22.6	...
30°	...	...	...	72.8	64.6	58.0	52.6	48.1	44.4	41.1	38.4	35.9	33.7	31.8	30.0	28.5	27.1	25.8	24.6	23.6	22.6
31°	...	...	...	...	72.6	64.4	57 9	52.5	48.1	44.3	41.1	38.3	35.8	33.6	31.7	30.0	28.4	27.0	25.8	29.6	23.5
32°	...	...	...	...	...	72.5	64.3	57.8	52.5	48.0	44.2	41.0	38.2	35.8	33.6	31.7	29.9	28.4	27.0	25.7	24.6
33°	...	...	...	...	...	...	72.4	64.2	57.7	52.4	47.9	44.2	40.9	38.1	35.7	33.5	31.6	29.9	28.4	27.0	25.7
34°	...	...	...	...	...	...	...	72.2	64.1	57.6	52.3	47.8	44.1	40.8	38.1	35.6	35.5	31.6	29.8	28.3	26.9
35°	...	...	...	...	...	...	...	...	72.1	64.0	57.5	52.2	47.8	44.0	40.8	58.0	35.6	35.0	31.5	29.8	28.2

TABLE IV-A

VOLUMES OF GASES (AIR) PER 1000 Kg. AND PER 2000 Lbs. OF VAPOUR CONDENSED, ADJUSTED TO VACUUM FOR AN INJECTION WATER TEMPERATURE OF 25°C. (77°F.)

Conditions prevailing at Lower part of Condenser				Conditions prevailing at Top Part of Condenser					Per 1000 kg. of Vapour condensed			Cu. ft. of Air per 2000 lbs. of Vapour Condensed.	Ratio between Air and Injection Water Volume
Vacuum		Temperatures		Tempe-rature	Total Pressure	Vapour Pressure	Air Pressure	Spec. Vol. of Air	m³ of water required	kg of Air	m³ of Air	Cu. ft / 2000 lbs.	
mm. Hg 1—A	ins. Hg 1—B	Vapour °C. 2	Waste Water °C. 3	°C. 4	mm. Hg 5	mm Hg 6	mm. Hg 7	m³/kg. 8	m³ 9	kg. 10	m³ 11—A	11—B	m³/m³ 12
718	28.3	35	32	30.0	37.2	31.8	5.4	120.82	84.0	11.62	1404	44,978	16.7:1
715	28.2	36	33	30.1	39.6	32.0	7.6	85.87	73.4	11.36	975	31,253	13.3:1
713	28.1	37	34	30.2	42.1	32.2	9.9	65.95	65.1	11.16	736	23,580	11.3:1
710	28.0	38	35	30.3	44.7	32.4	12.3	53.09	58.5	11.00	584	18,711	10.0:1
708	27.9	39	36	30.4	47.4	32.6	14.8	44.14	53.1	10.87	480	15,372	9.0:1
705	27.7	40	37	30.5	50.3	32.7	17.6	37.13	48.6	10.77	400	12,815	8.2:1
702	27.6	41	38	30.6	53.3	32.9	20.4	32.04	44.8	10.68	342	10,964	7.6:1
699	27.5	42	39	30.7	56.5	33.1	23.4	27.94	41.5	10.60	296	9,490	7.1:1
695	27.4	43	40	30.8	59.8	33.3	26.5	24.68	38.7	10.53	260	8,330	6.7:1
692	27.2	44	41	30.9	63.3	33.5	29.8	21.95	36.2	10.47	230	7,369	6.3:1
688	27.1	45	42	31.0	66.9	33.7	34.2	19.14	34.0	10.42	200	6,408	5.9:1
685	27.0	46	43	31.1	70.7	33.9	36.8	17.79	32.0	10.37	184	5,910	5.8:1
681	26.8	47	44	31.2	74.6	34.1	40.5	16.17	30.3	10.33	167	5,350	5.5:1
676	26.6	48	45	31.3	78.7	34.3	43.6	15.03	28.8	10.29	155	4,954	5.4:1
672	26.45	49	46	31.4	83.0	34.5	48.5	13.51	27.3	10.26	139	4,442	5.1:1
668	26.3	50	47	31.5	87.5	34.7	52.8	12.42	26.0	10.22	127	4,066	4.9:1
663	26.1	51	48	31.6	92.2	34.9	57.3	11.44	24.9	10.20	117	3,740	4.7:1
658	25.9	52	49	31.7	97.1	35.1	62.0	10.58	23.8	10.17	108	3,448	4.5:1
653	25.7	53	50	31.8	102.2	35.3	66.9	9.81	22.8	10.15	100	3,190	4.4:1
648	25.5	54	51	31.9	107.5	35.5	72.0	9.12	21.9	10.12	92	2,956	4.2:1
642	25.3	55	52	32.0	113.0	35.7	77.3	8.50	21.0	10.10	86	2,749	4.1:1

TABLE IV-B

VOLUMES OF GASES (AIR) PER 1000 Kg. AND PER 2000 Lbs. OF VAPOUR CONDENSED, ADJUSTED TO VACUUM, FOR AN INJECTION WATER TEMPERATURE OF 27½ °C. (81½°F.)

Conditions prevailing at Lower Part of Condenser				Conditions prevailing at Top Part of Condenser					Per 1000 Kg. of Vapour condensed			Cu. ft. of Air per 2000 lbs. of vapour condensed	Ratio between Volumes of air and water
Vacuum		Temperatures											
mm. Hg 1-A	ins. Hg 1-B	Vapour °C. 2	Waste Water °C. 3	Temperature °C. 4	Total pressure mm. Hg 5	Vapour pressure mm Hg 6	Air pressure mm. Hg 7	Specific volume of air m³/kg. 8	m³ of Water required m³ 9	kg of Air kg. 10	m³ of Air m³ 11-A	Cu ft./2000 lbs. 11-B	m³/m³ 12
710	28.0	38	35	32.5	44.7	36.7	8.0	82.22	78.0	11.47	943	30,219	12.1:1
708	27.9	39	36	32.6	47.4	36.9	10.5	62.67	68.7	11.25	705	22,587	10.3:1
705	27.7	40	37	32.7	50.3	37.1	13.2	49.87	61.4	11.07	552	17,691	9.0:1
702	27.6	41	38	32.8	53.3	37.3	16.0	41.15	55.4	10.93	450	14,410	8.1:1
699	27.5	42	39	32.9	56.5	37.5	19.0	34.64	50.5	10.81	375	12,000	7.4:1
695	27.4	43	40	33.0	59.8	37.7	22.1	29.81	46.4	10.71	319	10,232	6.9:1
692	27.2	44	41	33.1	63.3	38.0	25.3	86.05	42.9	10.63	277	8,871	6.5:1
688	27.1	45	42	33.2	66.9	38.2	28.7	22.97	39.9	10.56	242	7,759	6.1:1
685	27.0	46	43	33.3	70.7	38.4	32.2	20.42	37.2	10.49	214	6,865	5.8:1
681	26.8	47	44	33.4	74.6	38.6	36.0	18.33	34.9	10.44	191	6,130	5.5:1
676	26.6	48	45	33.5	78.7	38.8	39.9	16.54	32.9	10.39	172	5,505	5.2:1
672	26.45	49	46	33.6	83.0	39.0	44.0	15.00	31.0	10.34	155	4,712	5.0:1
668	26.3	50	47	33.7	87.5	39.3	48.2	13.79	29.4	10.30	141	4,523	4.8:1
663	26.1	51	48	33.8	92.2	39.5	52.7	12.53	27.9	10.27	129	4,123	4.6:1
658	25.9	52	49	33.9	97.1	39.7	57.4	11.51	26.6	10.24	118	3,775	4.4:1
653	25.7	53	50	34.0	102.2	39.9	62.3	10.61	25.3	10.21	108	3,470	4.3:1
648	25.5	54	51	34.1	107.5	40.1	67.4	9.81	24.2	10.18	100	3,200	4.1:1
642	25.3	55	52	34.2	113.0	40.3	73.7	8.98	23.2	10.16	91	2,922	3.9:1
636	25.0	56	53	34.3	118.8	40.6	78.2	8.46	22.2	10.13	86	2,747	3.8:1
630	24.8	57	54	34.4	124.8	40.8	84.0	7.88	21.4	10.11	80	2,553	3.7:1
624	24.6	58	55	34.5	132.1	41.0	91.1	7.29	20.5	10.09	74	2,357	3.6:1

TABLE IV—C

VOLUMES OF GASES (AIR) PER 1000 Kg. AND PER 2000 Lbs. OF VAPOUR CONDENSED, ADJUSTED TO VACUUM, FOR AN INJECTION WATER TEMPERATURE OF 30°C. (86°F.)

Conditions prevailing at Lower Part of Condenser				Conditions prevailing at Top Part of condenser						Per 1000 kg. of Vapour Condensed		Cu. ft. of Air per 2000 lbs. of Vapour condensed	Ratio between Volumes of Air and of Injection Water
Vacuum		Temperature Vapour	Temperature Waste Water	Temperature	Total Pressure	Vapour Pressure	Air Pressure	Spec. Vol. of Air	m^3 of Water	kg. of Air	m^3 of Air		
mm. Hg 1-A	ins. Hg 1-B	°C. 2	°C. 3	°C. 4	mm. Hg 5	mm. Hg 6	mm Hg 7	m^3/kg. 8	m^3. 9	kg. 10	m^3 11-A	Cu. ft./2000 lbs. 11-B	m^3/m^3 12
705	27.7	40	37	35.0	50.3	42.2	8.1	81.87	83.3	11.60	950	30,426	11.4 : 1
702	27.6	41	38	35.1	53.3	42.4	10.9	60.88	72.8	11.35	691	22,138	9.5 : 1
699	27.5	42	39	35.2	56.5	42.6	13.9	47.74	64.6	11.15	532	17,054	8.2 : 1
695	27.4	43	40	35.3	59.8	42.9	16.9	39.28	58.0	10.99	432	13,830	7.4 : 1
692	27.2	44	41	35.4	63.3	43.1	20.2	32.87	52.6	10.86	357	11,438	6.8 : 1
688	27.1	45	42	35.5	66.9	43.4	23.5	28.33	48.2	10.76	305	9,762	6.3 : 1
685	27.0	46	43	35.6	70.7	43.6	27.1	24.52	44.4	10.67	262	8,378	5.9 : 1
681	26.8	47	44	35.7	74.6	43.9	30.7	21.65	41.1	10.59	229	7,345	5.6 : 1
676	26.6	48	45	35.8	78.7	44.1	34.6	19.22	38.3	10.52	202	6,477	5.3 : 1
672	26.45	49	46	35.9	83.0	44.4	38.6	17.23	35.9	10.46	180	5,774	5.0 : 1
668	26.3	50	47	36.0	87.5	44.6	42.9	15.51	33.7	10.41	161	5,173	4.8 : 1
663	26.1	51	48	36.1	92.2	44.9	47.3	14.07	31.8	10.36	146	4,670	4.6 : 1
658	25.9	52	49	36.2	97.1	45.1	52.0	12.80	30.0	10.32	132	4,232	4.4 : 1
653	25.7	53	50	36.3	102.2	45.4	56.8	11.72	28.5	10.28	120	3,860	4.2 : 1
648	25.5	54	51	36.4	107.5	45.5	62.0	10.74	27.1	10.25	110	3,525	4.1 : 1
642	25.3	55	52	36.5	113.0	45.8	67.2	9.92	25.8	10.22	101	3.248	3.9 : 1
636	25.0	56	53	36.6	118.8	46.0	72.8	9.16	24.6	10.19	93	2,990	3.8 : 1
630	24.8	57	54	36.7	124.8	46.3	78.5	8.49	23.6	10.17	86	2,766	3.7 : 1
624	24.6	58	55	36.8	132.1	46.6	85.5	7.80	22.6	10.14	79	2,534	3.5 : 1
618	24.3	59	56	36.9	137.6	46.9	90.7	7.36	21.7	10.12	74	2,386	3.4 : 1
611	24.0	60	57	37.0	144.4	47.1	97.3	6.86	20.8	10.10	69	2,220	3.3 : 1

REFERENCES

1. Weiss, F. J. 1910. Die Kondensation ; Julius Springer ; Berlin.
2. Hugo, E. 1950. La Sucrerie de Cannes ; Dunod ; Paris.
3. Webre, A. L. and Robinson, C. S. 1926. Evaporation ; *Chem. Cat. Co.* ; New York.
4. Hausbrand, E. 1933. Evaporating, Condensing and Cooling Apparatus ; Ernest Bennet, London.
5. Tromp, L. A. 1946. Machinery of the Cane Sugar Factory ; Norman Rodger ; London.
6. Lyle, O. 1950. Technology for Sugar Refinery Workers ; Chapman and Hall ; London.
7. Lyle, O. 1947. The Efficient Use of Steam ; H. M. Stationery Office ; London.
8. Horsin-Deon, P. 1900. Fabrication du Sucre ; E. Bernard ; Paris.
9. Noel Deerr. 1921. Cane Sugar ; Norman Rodger ; London.
10. Badger, W. L. 1926. Heat Transfers and Evaporation ; *Chem. Cat. Co* ; New York.
11. Coxon, F. 1917. *Int. Sugar Journal* p. 19.
12. Cornor, O. 1920. *Engineering*, p. 74.
13. Horton, H. 1935. *Int. Sugar Journal*, p. 357.
14. Handbook of Chemistry and Physics 1939. Chemical Rubber Publishing Co. ; Cleveland, Ohio, U.S.A.
15. E. C. von Pritzelwitz vander Horst. 1929. *Proc. 3rd Congress I. S. S. C T.*
16. Archief voor de Java Suikerindustrie. 1929. III p. 920.
17. Brouwer, G. Zuigerstoomwerktuigen.
18. Perk, C. G. M.. 1952. " Machinery and Steam Engine Tests " ; *S. A. Sugar Journal* March.

Mr. Crawford presented the following paper.

Paper

HEAT TRANSFER IN JUICE HEATERS

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INTRODUCTION

Although the literature on heat transfer is very extensive, few of the published data relate to heat transfer from condensing steam to sugar juices, as occurs in the type of juice heater used in the raw sugar industry.

It is, of course, the overall heat transfer, and the manner in which it changes with progressive scaling of the heating surfaces, juice velocity, and other factors such as fouling of the vapour side, which are of direct interest to the engineer and sugar technologist, and because of this a study of heat transfer and scaling in juice heaters has been adopted as a research project of the Sugar Research Institute.

To carry out this work an experimental juice heater, on pilot plant scale, was designed and constructed. Briefly it is a 12 pass single tube, horizontal heater, using 1″ o.d., 16 s.w.g., brass tubes, six arranged on each of two concentric pitch circles of $3\frac{1}{2}''$ and $7\frac{1}{4}''$ p.c.d. respectively. The tube assembly is $7'-4\frac{7}{8}''$

between tube plates and is housed in a steel casing of 10′ internal diameter. Juice enters the heater on one of the inner ring of tubes and leaves at the outer ring. The total effective tube length is thus 88′-10½″.

The heater is arranged to operate with mixed and limed juice from the supply to the heaters in a raw sugar factory, and the test equipment includes recording pressure gauges on juice inlet and outlet, automatic control of the steam pressure on the outside of the tubes, a juice pump and measuring tank, and an orifice type weir for measurement of condensate.

EXPERIMENTAL PROCEDURE

To obtain realistic data relating to heat transfer in a juice heater operating under factory conditions, tests must be made continually during the period between successive de-scalings. In the present instance, the duration of each operational run was between 100 and 140 hours, and the results reported are of 11 operational runs, five during the 1953 season, and the remainder during the 1954 season, all being carried out at Racecourse Mill in the Mackay district of Queensland. Each operational run was carried out at a predetermined juice velocity, and at regular intervals during each run normal operation was interrupted, for a short period, to permit the determination of heat transfer data at a series of juice velocities.

At the conclusion of an operational run, the heater tubes were flushed with water, drained, and headers removed. The scale was then baked for a period of 3—4 hours, using steam at about 2 p.s.i.g. on the outside of the tubes. The scale was then removed, and collected individually from each of the twelve passes, using a rubber stopper on the end of a steel rod. This technique left an apparently clean metal surface, but before commencing a new run, the inner tube surface was wire-brushed and blown through with compressed air. Scales were stored in airtight containers and subsequently analysed and used for determination of scale thickness. In all tests, the vapour side pressure was maintained very close to 1½″ Hg above atmospheric pressure.

HEAT TRANSFER AND JUICE VELOCITY

The influence of juice velocity on heat transfer cannot be completely dissociated from the effects of scaling, because even during the short time required to carry out tests at various velocities, the scale deposit is itself increasing. However, the testing technique has permitted a reasonable degree of separation and the scaling effect may be considered of secondary importance.

The graphical method of analysis of overall coefficients of heat transfer, published by Wilson (1) in 1915, has been utilised. This method makes use of the known fact that the total resistance to heat flow is the sum of the individual resistances, and is also equal to the reciprocal of the overall coefficient, thus ;

$$\frac{1}{U} = R_v + R_w + R_s + R_j, \text{ where}$$

U = overall heat transfer coefficient, (B.T.U./sq. ft./hr./°F.).
R_v = resistance of vapour side,
R_w = resistance of wall,
R_s = resistance of scale,
R_j = resistance of juice film.

Except where very high juice velocities are used, the resistance of the liquid side R_j is usually the major resistance, and with test conditions reasonably steady, no serious error is introduced by assuming that $(R_v + R_w + R_s)$ is approximately constant during short period testing at different velocities. Also it is well known that the liquid side resistance, in heaters of the type concerned, is an inverse function of the liquid velocity V, and so, following Wilson, a plot of 1/U vs. $1/\phi$ (V) should give a straight line with normal rectangular co-ordinates. For water and other liquids in turbulent flow $\phi(V)$ may be taken as "b. $V^{0.8}$" where "b" is a constant. Flow in the present instance is turbulent over the test range and it has been found the index 0.8 applies equally well to raw juice. Fig. 1 shows the Wilson plot for tests during a typical operational run carried out during an operational run at an average velocity of 7.4 ft./sec.

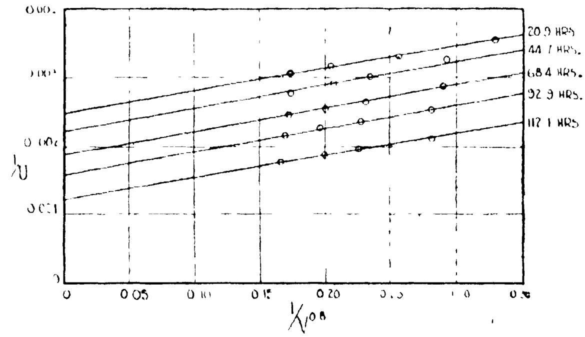

FIG. 1 WILSON PLOT FOR TYPICAL OPERATIONAL RUN

The general relationship between U and V for all tests carried out is :—

$$\frac{1}{U} = a + \frac{1}{b.\ V^{0.8}}$$

where " a " is the combined resistance of steam side, tube wall and scale. The reciprocal of the constant "b" is the slope of the lines in Figs. 1, 2 and 3, and "b" may be interpreted as the apparent coefficient of heat transfer from scaled tube to juice, based on the mean tube diameter, at unit juice velocity. It was found that this slope varied somewhat between different operational runs, but an average value for "b" in these experiments is 256, so that the appropriate empirical equation for this heater and Central Queensland juice is,

$$\frac{1}{U} = a + \frac{1}{256\ V^{0.8}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1$$

Experimental data of Orrok (2), plotted by McAdams (3), give $b=268$ for water, and since the viscosity and density of raw juice and water are little different, the agreement may be considered good.

The factor, "a", in the empirical equation changes with the state of scaling of the tubes, increasing continuously from start to finish of an operational period.

HEAT TRANSFER AND SCALING

The intercept on the $1/U$ axis of the lines of Fig. 1, and similar diagrams, gives the combined resistance of steam side, tube wall and scale deposit at the time of testing. If these intercepts are plotted on a base of duration of operational run, curves such as those of Fig. 2 are obtained. These give the value of the factor " a " in Equation (1) at any time after commencement of operation.

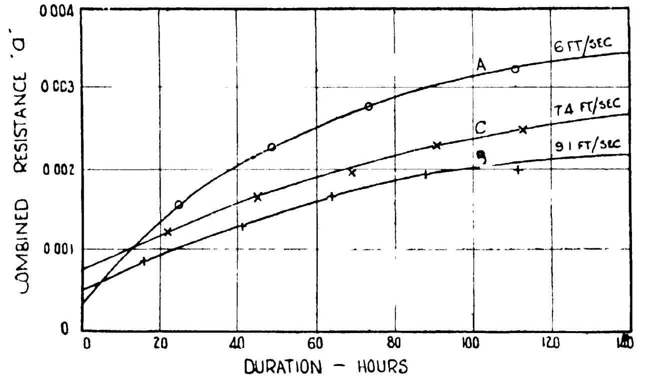

FIG 2 CHANGE IN OVERALL RESISTANCE "a" $(= R_{v+w+s})$

They are of particular interest in suggesting that the rate of scaling in the earlier period of operation is appreciably influenced by juice velocity, so that high juice velocities will not only increase heat transfer through the juice film, in accordance with Equation (1), but may reduce the total amount of scale deposited in a given time.

In considering this possibility, the juice temperature must be considered as it must strongly influence the deposition of scale. In the tests represented by Curves A and B, the mean juice temperature was higher for B than for A for the greater part of the operational period, i.e., the higher juice velocity also had the higher juice temperatures. It is to be expected that the effect of this would be to increase the scaling rate, but the opposing influence of velocity has clearly outweighed this effect.

The initial value of the combined resistance, "a", is not easily determined when the rate of increase of resistance is high, as occurs with low velocities and very clean tube surfaces. Curve A of Fig. 2 is an example of this, the tubes in this instance being in the new condition. The resistance lines may sometimes be successfully extrapolated to give these initial values, and another useful method is to extrapolate from plots of $1/U^2$ against time of operation. The initial values in Fig. 2 have been fixed in this manner. It is clear that tube cleaning in the cases of Curves B and C did not bring the initial resistance back to its value for the new tubes. Nevertheless this fact serves to emphasize still further the influence of velocity on scale deposition. Apart from the temperature effect discussed above, Curves A and B may be compared directly. The operational runs from which they are derived were identical in all other practical respects, except for juice velocities, and as they were carried out in successive weeks, late in the 1953 season, the cane constituents would be unlikely to have materially changed. Curve C is for tests considerably later in the season, and although it shows a similar velocity influence the values of resistance may have been affected by seasonal variations in the composition of the cane.

To test this the resistance curves of Fig. 3 have been prepared from operational runs in the 1954 season. Juice velocities and other test conditions were identical. Curve X is for the week commencing 14th September, and Curve Y is for the week commencing 16th November, 1954. Allowing for the difference in initial values of resistance it is seen that the rate of scaling was appreciably greater in the early part of the crushing season than towards its close. The fact that the initial resistance of the X Curve was greater than that for the Y Curve, confirms this view, because this means that the temperature difference for Curve X would be greater than that for Curve Y. Despite this deposition of scale was greater in the former case. Actual weighing of the scales showed that the scale deposited during the run represented by Curve Y, was only 45% of that deposited during the earlier run. Although many interesting data on scale formation have been obtained in this experimental heater, they cannot be commented on at any length in this paper.

The analyses of the scales formed during the runs represented by Curves X and Y are, however, given in Tables I and II respectively, to enable members of this Society to compare the scales with those with which they normally deal. These analyses are typical of the juice handled at Racecourse Mill during the 1953 and 1954 seasons, and it may be said that the experimental heater has proved to be very useful in the study of the influence of time and temperature on the composition of the scales deposited, in relation to the tube length. Attention is drawn for example, to the progressive increase in the organic content of the scale from the first pass to the last.

For the heater designer and factory engineer, the important factor is not the initial value of the scale resistance, but rather the time which may elapse before the resistance builds up to such an extent that the heater becomes ineffective. The factory engineer must select a suitable time interval between de-scalings, and the heater should be designed on the basis of resistance at the end of this time interval.

Table III gives suggested values of the combined resistance " a " at 72 and 144 hours of operation respectively, together with overall coefficients of heat transfer, calculated by inserting the appropriate values of " a " in Equation (1). In using these, it would be necessary to ensure a reasonable state of tube cleanliness after de-scaling.

TABLE I

HEATER SCALE ANALYSIS CURVE X

Pass No.	2	4	6	8	10	12
Scale Wt. (gm.)	27.29	27.75	25.20	35.09	25.97	23.10
% L. O. I.	43.53	47.95	50.87	55.53	67.54	82.24
% Ash	56.47	52.05	49.43	44.47	32.46	17.76
Ash Analysis %						
SiO_2	0.25	0.29	0.43	0.32	0.43	1.37
Al_2O_3	0.36	0.38	0.50	0.51	0.65	1.59
Fe_2O_3	1.63	1.69	2.02	2.36	3.59	7.21
P_2O_5	41.35	41.33	41.23	40.69	38.71	32.51
CaO	38.81	39.44	39.39	39.29	38.24	37.65
MgO	10.85	10.73	10.83	10.69	9.84	9.44
SO_3	1.30	1.39	1.36	1.21	1.77	3.41

TABLE II

HEATER SCALE ANALYSIS CURVE Y

Pass No.	2	4	6	8	10	12
Scale Wt. (gm.)	18.77	17.49	9.08	10.20	14.99	17.09
% L. O. I	49.93	59.73	77.07	87.48	89.83	90.15
% Ash	50.07	40.27	22.93	12.52	10.17	9.85
Ash Analysis %						
SiO_2	0.22	0.43	1.83	16.26	15.54	20.29
Al_2O_3	0.86	1.37	2.52	4.08	5.69	5.82
Fe_2O_3	2.45	3.33	8.59	16.26	22.44	22.50
P_2O_5	39.53	37.44	28.19	8.69	2.94	2.38
CaO	39.53	39.62	36.53	27.83	23.44	17.65
MgO	10.58	12.73	8.09	9.00	9.84	9.43
SO_3	1.88	2.19	5.51	9.19	12.35	11.72

TABLE III

SUGGESTED DESIGN VALUES

Juice Velocity	Combined resistance " a "		Overall Heat Trans. Coeff. U	
ft./sec	72 hrs.	144 hrs.	72 hrs.	144 hrs.
6.0	0.0027	0.0043	275.5	231.0
7.5	0.0021	0.0026	350.0	298.0
9.0	0.0017	0.0022	422.0	348.0

The overall heat transfer coefficients corresponding to Curves X and Y, and the empirical Equation (1) are also shown in Fig. 3.

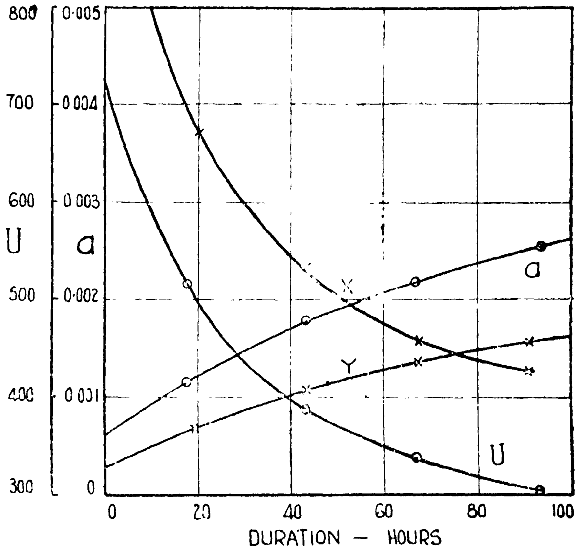

FIG 3 EFFECT OF SEASONAL VARIATION ON OVERALL RESISTANCE & HEAT TRANSFER COEFF

THERMAL CONDUCTIVITY OF HEATER SCALE

If the initial value of the combined resistance of vapour side and tube can be determined with reasonable accuracy for any operational run then it is possible to estimate the thermal conductivity of the heater scale.

Thus applying the resistance concept, if U_1 is the overall coefficient at the commencement of a run, and U_2 that at termination, then the resistance of the scale deposited is given by-

$$R_s \quad (1/U_2 - 1/U_1)$$

The reciprocal of R_s is the individual heat transfer coefficient for the scale formed, referred to the logarithmic mean diameter of the tube. Corrected for reference to the internal diameter, a coefficient, h_s, is obtained which is related to the scale conductivity by the simple equation,

$$h_s = \frac{k}{x}$$

Where k is the scale conductivity, and x the scale thickness. If U_1 and U_2 are in B.T.U./sq. ft./hr./°F., and x is in ft. then the unit of k is B.T.U./sq. ft./hr./°F./ft.

To determine scale thickness, two methods were employed, and it is pointed out that only average thicknesses for the total tube length were so determined. The first method was by determination of the bulk specific gravity of the scale, and hence from the weight of scale per pass, the thickness was calculated. The second method was direct measurement by micrometer of a very large number of samples. The former yielded results 15 to 20% lower than the second, and because of doubts of the accuracy of the bulk density measurement, due to porosity, the method of direct measurement was adopted.

Table IV gives details of initial and final values of heat transfer coefficients, average scale thickness and thermal conductivity for a series of operational runs during the 1954 season.

It is of interest to note how the conductivity of the scale decreased as the crushing season progressed, and it should be pointed out that this is not at variance with the earlier finding that scale resistance also decreased as the season progressed, because as will be seen from Table IV, the amount of scale deposited in a given time decreased steeply, after run No. 4, during the remainder of the crushing season.

TABLE IV

THERMAL CONDUCTIVITY OF SCALES

Run No.	Commencing Date	Total Wt. of scale (gm.)	Scale Thickness (mm.)	h_s	k
1	20.7.54	290	5.6	660	0.31
2	27.7.54	270	5.3	636	0.28
3	17.8.54	342	6.6	562	0.31
4	14.9.54	382	7.3	530	0.32
5	19.10.54	266	4.9	624	0.25
6	29.10.54	219	4.2	660	0.23
7	2.11.54	223	4.3	649	0.23
8	9.11.54	214	4.1	715	0.24
9	16.11.54	172	3.4	784	0·22

The average value of k, from Table IV is 0.27 B.T.U./sq. ft./hr./°F./ft., and it will be seen that this is much lower than the conductivity of other types of scales listed for comparison in Table V.

TABLE V

Type of Scale	Reference	k
General	Oliver Lyle (4)	0.08 — 1.00
Boiler Scale	McAdams (3)	1.3
Boiler Scale	Badger (5)	0.5 — 1.50
Calcium Sulphate	Badger (5)	0.4 — 0.75
Crystallizer element scale (massecuite side)	Honig* (6)	0.67

* Calculated from data in this paper.

CONCLUSIONS

This paper does not purport to deal with all aspects of heat transfer in juice heaters. It does indicate, however, two ways in which heat transfer is influenced by juice velocity. Firstly, the heat transfer through the juice film increases with increased velocity in the manner defined by the empirical Equation (1), and secondly an increase in velocity apparently reduces the rate of scale deposition. This may be due to the time factor in the chemical reactions, or to the establishment of an appropriate carrying velocity for precipitated matter, or to a combination of both.

The resistance of scales has received attention and it has been shown that for this Central Queensland juice, the rate of scaling decreased appreciably as the season progressed. Finally, the conductivity of the scale formed has been estimated and its value compared with that of scales of other types.

REFERENCES

1. Wilson, E. E. 1915. *Trans. Am. Soc. Mech. Engrs.*, Vol. 37 p. 47.
2. Orrok, G. A. 1910. *Trans. Am. Soc. Mech. Engrs.*, Vol. 32 p. 1773 & p. 1139.
3. McAdams, W. H. 1942. " *Heat Transmission* ".
4. Lyle, Oliver. 1947. " *The Efficient Use of Steam* ". Table XIX.
5. Badger, W. L. 1926. " *Heat Transfer and Evaporation* ".
6. Honig, P. 1953. " *The Technology of Crystallizers*". *Sugar Journal*, Vol. 16. No. 6.

Session—Saturday, 28th January, 9.15 A.M.

Mr. K. S. Arnold, *Chairman*

The author presented the following paper. This was discussed with the next paper presented by Mr. J. P. Mukherji.

Paper

AUTOMATIC CANE CARRIER CONTROL

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INTRODUCTION

The paper describes the steps taken to improve cane carrier operation in Queensland culminating in the decision by at least one factory to dispense entirely with the carrier driver and use fully automatic control.

Crushing Rate and Cane Supply. The average crushing rate for the 1954 season of the thirty-one factories operating in Queensland was between 90 and 100 long tons of cane per hour. Approximately 80 percent of the crop is handled by 2′-0″ gauge private tramways and the balance by 3′-6″ gauge government railways and motor trucks. In nearly all cases tracks run across the carrier at right angles. The cane is removed from the rail and motor trucks by rakes while for the tram trucks—which have an average capacity of about 2¼ long tons tipping is the general method adopted. Only two factories use a feeder carrier, and only one has a double milling tandem.

Preparatory Devices. For cane preparation all factories use two sets of revolving knives. The average clearance of the knife tips above the carriers is 15½″ and 1¼″ for the bottom and top knives respectively. In a number of cases Searby type shredders are used in addition to knives.

The majority of knives are driven by direct coupled electric motors. Powers up to 400 B.H.P. are used, and the popular speed is 585 r.p.m.

Load taken by preparatory devices. If cane could be loaded evenly on a carrier which ran at constant speed, the power required by any preparatory device at a crushing rate of 125 long tons per hour, and fibre in cane of 12½ percent would probably never exceed 200 B.H.P. Such ideal conditions however cannot be realised in practice ; even with rake unloading, the depth of cane varies from place to place, while with tipping there must be a succession of humps any one of which could overload a preparatory drive motor sufficiently to trip it off the line and perhaps cause a choke.

Conditions are rendered worse by the fact that the job of the carrier driver is to keep a constant depth of feed in the hopper of No. 1 mill. At the moment a hump of cane is passing through a set of knives he may decide that more feed is needed and accordingly speed up the carrier. The motor might already be working at full load and, with the sudden increase in speed, it could easily be subjected to an overload of over 200 percent.

Signalling Devices. To assist in preventing overloads and chokes an ammeter for each preparatory drive motor was mounted close to and in full view of the carrier driver. A red line on the face of the instrument showed the danger point and gave warning that the carrier speed should be reduced when the current reached that point. As a further precaution relays were arranged in the motor circuits which came into operation at a certain overload and caused a red light to flash and/or an alarm bell to ring.

Simple Automatic Device. The simple signalling devices described were found to be of considerable assistance towards smoother operation but their effectiveness was entirely dependant on the vigilance of the carrier driver. As a safeguard, therefore, relays were introduced into the circuits of the preparatory drive motors and adjusted to operate at a certain overload. On the occurrence of an overload on any of the motors a solenoid valve was energised which cut off the steam supply to the carrier engine and stopped the carrier. The feed to the first mill was hardly affected as only a few seconds were required to bring the load back to normal, open the relay contacts, and restore the steam supply to start the carrier again under the driver's control.

The Slip Resistor. In spite of the "carrier stopping" precaution, peak loads on the preparation drive motors, although considerably reduced, were at times still found to be severe. Resistance connected permanently in the rotor circuit of the slip-ring motors helped considerably in flattening out these peaks.

The inertia of revolving knives plus that of the motor will give out energy when there is a reduction in speed. A typical slip-ring motor running under full-load with short-circuited slip-rings at 97 percent synchronous speed might have characteristics such that, when overloaded sufficiently to cause the speed to drop to 96 percent synchronous, the torque would increase from normal full-load to 200 percent full-load. At the same time the current would increase by approximately the same percentage value. By connecting a suitable resistance in the rotor circuit of the motor the characteristics could be altered so that the full-load speed would be approximately 93 percent synchronous with a drop to 86 percent synchronous at 200 percent full-load torque. The large increase in the speed drop allows more use to be made of the stored kinetic energy, and thus reduces the amount of electrical energy which must be drawn from the mains to overcome a particular load peak.

Increasing the available kinetic energy by the addition of a flywheel or flywheels to the knife shafts still further reduces peak loads, but it is doubtful whether the gain justifies the extra expense and mechanical difficulties involved. It is important to note that full benefit from a flywheel can only be obtained when the motor which it is assisting is of the high slip type.

Improved Automatic Device. A further improvement was effected in the case of electrically-driven carriers by using two relays instead of one in each preparatory motor circuit. The first relay operates at say, 110 percent motor load and, by introducing resistance into the rotor circuit of the slip-ring motor driving the carrier, slows the carrier down to one third maximum speed. This slowing down of the carrier is generally sufficient to prevent further overloading at the knives but should the current continue to rise the second relay comes into operation at about 150 percent load and stops the carrier. With load conditions restored to normal the carrier speed returns to that corresponding to the setting of the manual controller which is operated by the driver. It should be noted that the relays in the preparatory motor circuits have no effect on carrier speed until an overload occurs. They then take full control, and the driver cannot increase speed until normal conditions again prevail.

Another safeguard which is generally fitted to electrically driven carriers is that of interlocks to prevent the carrier being started before all the preparatory drive motors are running. The same interlocks also ensure that, if any one of the large motors trip out, the carrier is automatically stopped.

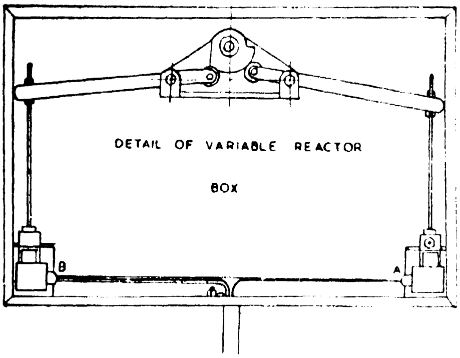
Fully Automatic Scheme. In this scheme the overload relays mentioned above have over-riding control, but in addition there is a feeler plate in the hopper to the first mill which fixes the speed of the carrier by the position it is constrained to occupy by the flow of prepared cane to the mill. With no cane in the hopper (which should be of sufficient depth to allow the feeler plate to be mounted about 6 feet above the top of the feed roller) the carrier runs at maximum speed. As the supply of cane builds up in the hopper it eventually reaches the feeler plate and starts to force it outwards. This action is transmitted to a device for opening contactors which introduce resistance into the rotor circuit of the carrier motor thereby reducing the carrier speed. The overall result is the maintenance of a uniform height of feed in the hopper in spite of appreciable variation in the depth of cane on the carrier. An installation fitted to the hopper at the Mulgrave Central Mill, Queensland, is shown in the figure. The oil dashpot is essential for smooth operation, as the cane often falls into the hopper in large masses, which, in the absence of some damping device, would cause bouncing of the feeler plate and hunting of the carrier motor.

The relays which give the desired carrier speed are voltage operated devices. Alternating current is rectified after passing through the two variable reactors and then passes through four relay coils. With both reactor cores down, the voltage is choked back to a value which is not sufficient to operate any of the relays. Under this condition all the resistance units in the rotor circuit of the carrier motor are shorted out and speed is a maximum. As the feeler plate is forced outwards the cane starts to lift the right hand reactor core and so increase the voltage applied to the relays. The first relay operates when the core has been lifted ½ inch, and the second when the lift is the maximum of 1 inch. The cane then starts to lift the left hand reactor core and causes the third and fourth relays to operate. As each of the first three relays operates a unit of resistance is brought into the rotor circuit of the carrier motor which runs progressively slower. The fourth relay opens the stator circuit and stops the carrier. The reverse operation naturally takes place when the supply of cane decreases allowing the feeler plate to move back.

Should it be desired to revert to hand control, a small change-over switch is thrown from the " automatic " to " manual " position, and the carrier motor speed can then be varied by a hand controller from the driver's platform. This change to manual control does not affect the operation of the overload relays in the preparation motor circuits which still have over-riding control.

Mulgrave Mill decided to dispense with carrier drivers at the start of the 1955 crushing season. A few initial operational difficulties were experienced but these were successfully overcome. All members of the staff are now quite satisfied that the " robot " is the most efficient carrier driver employed over the fifty odd years of existence of the Mill.

Scale 4" = 1' 0"



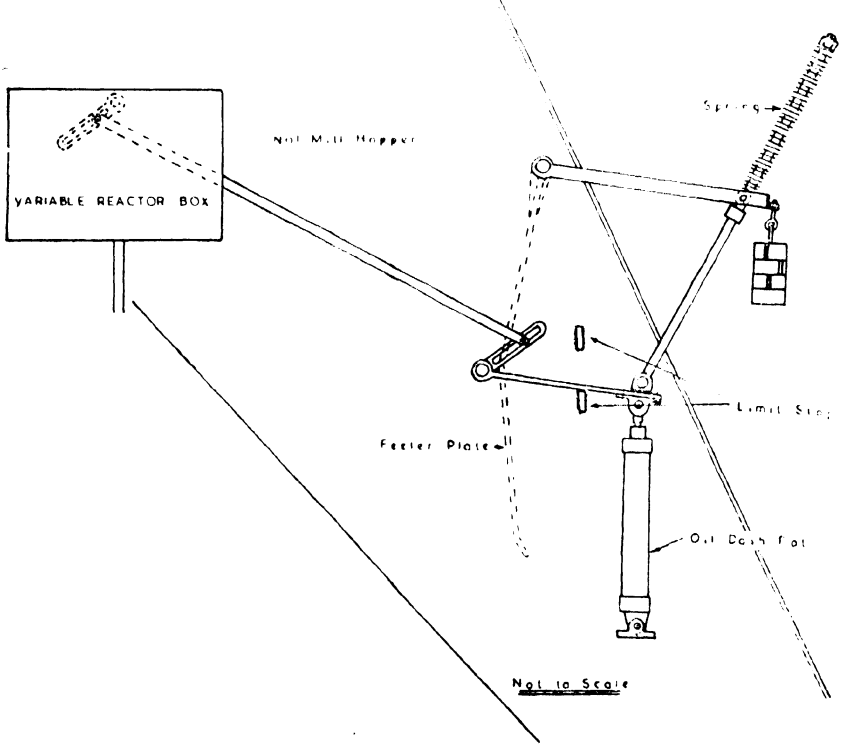
Top Speed A&B Down

1st Reduction - A up 1/4"

2nd " - A up 1"

3rd " - A up 1" + B up 1/4"

Stop - A up 1" + B up 1"



Not to Scale

In the absence of the author Mr. J. P. Mukherji presented the following paper.

Paper

ELECTRIFICATION OF CANE CARRIER AND EQUIPMENT WITH APPLICATION OF WARD-LEONARD DRIVE TO CARRIER.

A Johnson
Millaquin Sugar Company, Queensland

INTRODUCTION

During the recent expansion programme in the Queensland sugar industry, the Millaquin Mill increased its crushing rate from 76 tons per hour to 110 tons per hour. In doing so it was necessary to increase the horsepower on the cane preparation equipment, and the opportunity was therefore taken to change over from steam engine to electric motor drive. Certain difficulties were encountered in the early stages of the change over, particularly as regards control over the cane carrier speed to maintain a satisfactory feed to the milling train. The equipment used is described, and also the modifications—in the form of a Ward Leonard control on the cane carrier speed—which were made to overcome the difficulties.

EQUIPMENT

The carrier installed is 78″ wide and was driven by a twin cylinder 9″ x 12″ steam winch. A set of leveller knives is situated just obove the point where the carrier changes from the horizontal to the slope, and is driven by a 180 B.H.P., 585 r.p.m. slip-ring motor. A second set of leveller knives, also driven by a 180 B.H.P., 585 r.p.m., slip-ring motor is installed at the top of the carrier. The carrier delivers the cut cane to the feed chute of a 78″ Searby Shredder driven by a 250 H.P., 960 r.p.m., slip-ring motor. The shredded cane is delivered to a chute feeding the first mill which has rollers 38½″ x 84″. The rollers of the second and third mills are 35″ x 72″, and of the fourth mill 38½″ x 84″.

The cane supply to the mill is by the three following methods :—

(1) By 2 ft. gauge tram trucks of 2½ tons capacity from which the cane is mechanically tipped on to the carrier. In Queensland such tipping devices are normally placed to deliver the cane down a chute at the lower end of the carrier, which breaks up the masses. At Millaquin, however, the yard layout precludes this arrangement, and the trucks are discharged just ahead of the lower set of leveller knives, resulting in the cane feed on the carrier being in a compact mass.

(2) By motor lorry from which the cane is raked on to the carrier by Davids' rakes. By this method the feed on to the carrier is far from being compact, and

is in a loose tangled state forming an excellent feed for the leveller knives.

(3) By 3′ 6″ gauge rail wagons. These wagons are also discharged by Davids' rakes and the feed is similar to that for lorry cane. It is difficult to maintain a crushing rate of over 100 tons per hour by raked cane alone, particularly in Queensland where a large number of suppliers are delivering at the same time, and individual analyses are required at the rate of one sample for approximately 10 tons of cane.

Jamming relays were fitted to each of the knife motors acting on an A.C. solenoid valve, which was installed in the 2″ steam line to the steam carrier winch. This solenoid valve was actuated as the load on either set of knives reached a predetermined value of approximately 150% of the full-load rating of each motor.

OPERATIONAL RESULTS

The first days of operation of the 1953 season showed that unexpectedly high ammeter readings were occurring on the knife and shredder motors. These showed peaks up to 1200 amps. for the shredder motor, and about 600 amps. on the knife motors, the full-load ratings being 310 and 255 amps. respectively. These severe fluctutations with fairly lengthy overloads caused some concern.

The jamming relays on each knife motor, operating on the solenoid valve on the carrier winch, helped to protect these motors and to avoid carrier chokes. However, with the variation in the type of feed to the carrier, the frequent operation of the jamming relays tended to hinder an even feed being presented to No. 1 Mill, with detrimental effect on the milling results. Further, the overload peaks on the knife and shredder motors reacted on the governors of the turbine and on the voltage regulator of the alternator.

To improve on this state of affairs, slip resistors were inserted in the rotors of each knife motor and of the shredder motor. The value of the slip resistor was 0.09 ohm per phase on each motor. The inclusion of these slip resistors gave the motors a slip in speed of approximately 25% at 50% overload. This was sufficient to compensate for the heavy overload on the motor at the time a heavy feed was in the carrier at the knives set of the particular motor. The improvement in operation was reflected in reduced ammeter readings. Graphs 1 and 2 show a comparison of the readings with slip resistors, and without, the readings being obtained by a recording watt-meter under normal operating conditions.

With the operation of the jamming relays the solenoid valve on the winch caused stopping and starting of the carrier and this tended to feed the knives some what unevenly, and had undesirable effects on the feeding of No. 1 mill.

WARD-LEONARD DRIVE FOR CARRIER

Because of these difficulties it was decided for the 1955 season to drive the carrier with a variable speed D.C. motor under Ward-Leonard control as shown diagrammatically in Fig. 3.

The Millaquin Mill had D.C. electric supply available as well as A.C. supply, and use was made of existing machines. A 35 B.H.P., 960 r.p.m. slip-ring motor is the prime mover and is directly coupled to a 60 B.H.P., 480 Volt D.C. machine used as a D.C. generator. A 40 B.H.P., 300 to 900 r.p.m. D.C. motor was available

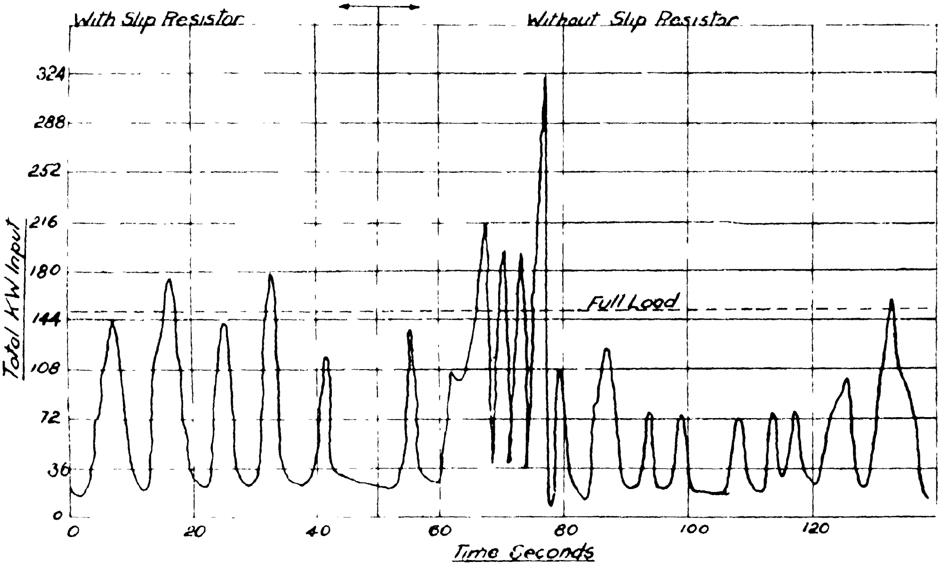


FIG 1 Showing the effect of a slip resistor on a bottom knife motor load

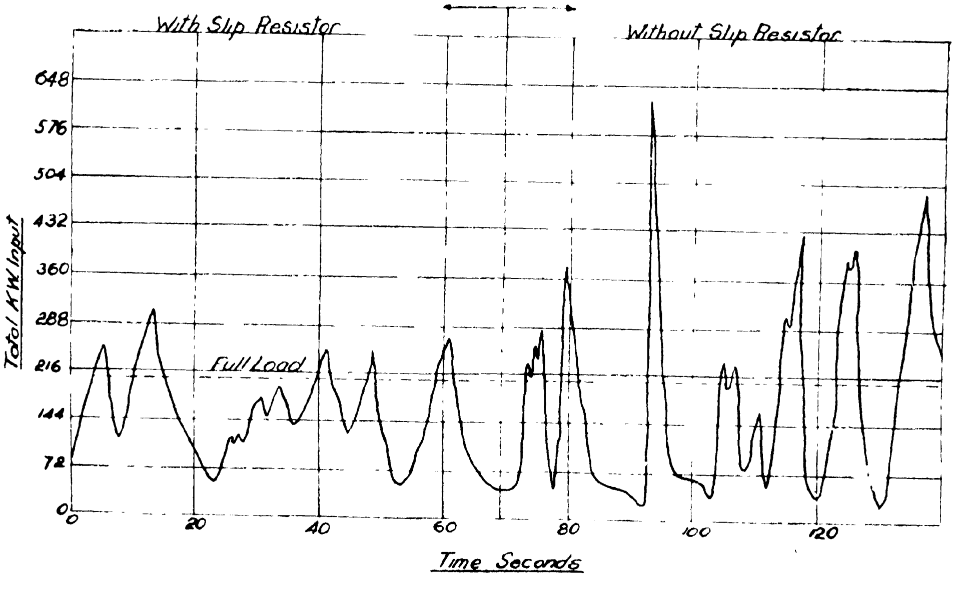


FIG 2 Showing effect of slip resistor on a shredder motor load

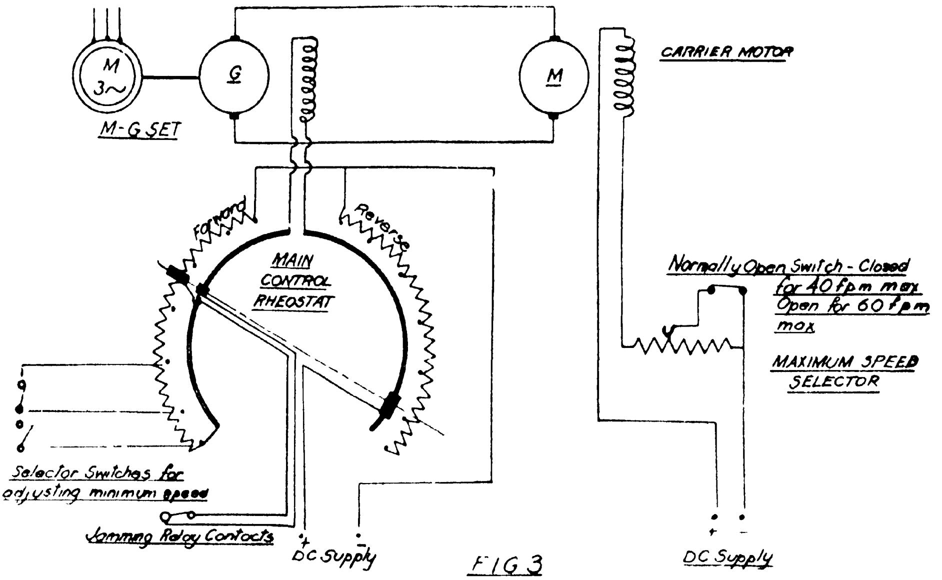


FIG 3

MAIN CONNECTIONS - WARD LEONARD CONTROL FOR CARRIER MOTOR

and was fitted up to drive the carrier in place of the steam winch. This motor is excited by a separate 500 Volt D.C. supply and was set for a normal full speed of 600 r.p.m. The Ward-Leonard control unit operated on this carrier drive motor.

With the above arrangement a variable carrier speed from 0 to 40 ft. per minute was obtained with a 38 step controller. The jamming relays on the knife motors, which previously operated the solenoid valve on the steam supply to this carrier winch, now automatically reduce the carrier speed to 8 feet per minute by suitably lowering the voltage developed by the Ward-Leonard Generator. This slow speed is not sufficient to prolong unduly any severe load on the knife motors and yet gives a continuous feed to the mills.

Under occasional conditions, arising from difficulties in unloading rail trucks at the carrier, a greater speed than 40 feet per minute is sometimes required. At such times the density of feed in the carrier is much less than with tipped cane, and there may be patches of extremely light feed. The speed of the motor driving the carrier can then be increased by alteration of the motor field to 900 r.p.m., which increases the carrier speed from 40 to 60 feet per minute.

In addition to the remarkable improvement in the steadiness of all operations associated with the preparation of the cane, it has also been noticed that the pol %bagasse of the last mill is more uniform than previously. Due to the smoothness in changes of carrier speed, the loadings on the knives and shredder are more even, and peaks in the ammeter readings relatively low.

The installed horse powers of the motors are adequate for crushing rates atleast up to 120 tons per hour. The present crushing rate of 100—112 tons per hour is being obtained with an average carrier speed of about 20 feet per minute with carrier motor input varying from 5-25 B.H.P. and averaging 10-12 B.H.P.

Graph 4 shows typical loadings on the knife motors since the Ward-Leonard control has been introduced, and Graph 5 the corresponding conditions on the shredder motor. As a further development, it is hoped eventually to operate this carrier automatically by means of a feed indicator on the feed chute to No. 1 mill.

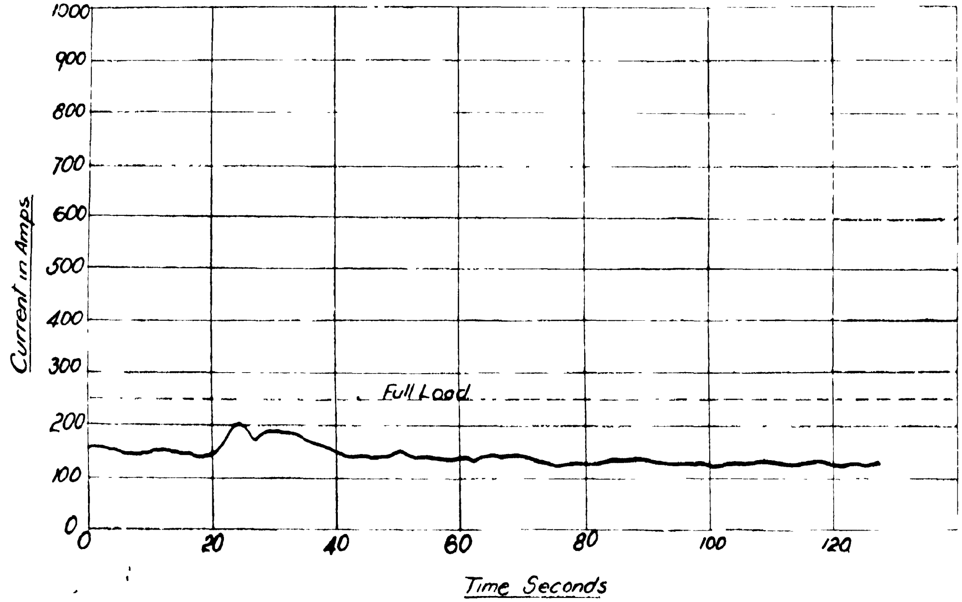


FIG 4 Current readings on bottom knife motor showing effect of slip resistor plus Ward Leonard Control

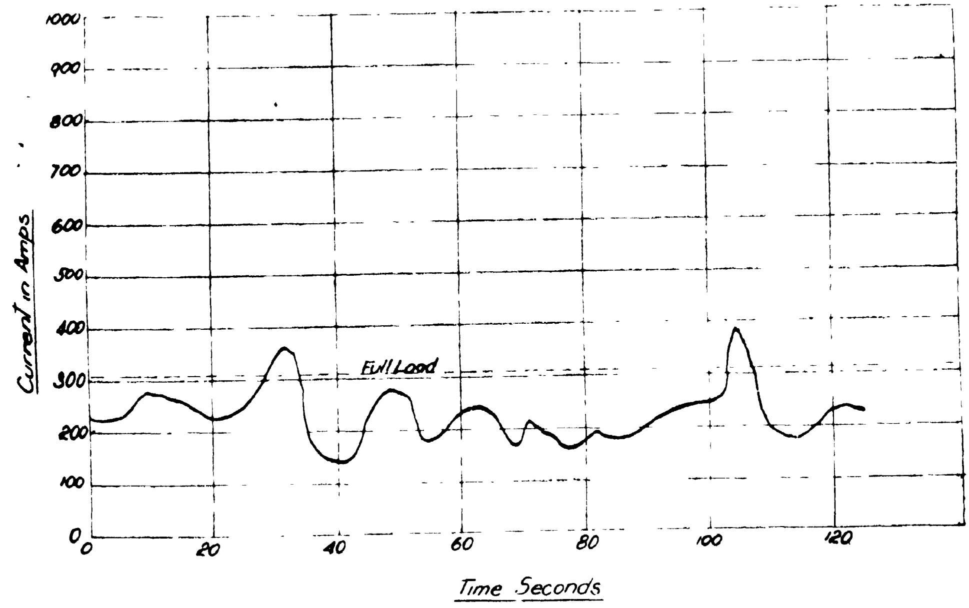


FIG 5 Current readings on Shredder motor showing effect of slip resistor plus Ward Leonard Control

DISCUSSION

Dr. Crawford considered that, apart from automatic devices and special electric equipment for driving cane carriers, the feed to the mills could be greatly improved by giving more attention to such matters as methods of loading on to the carrier, length of carrier, and design of feed chutes. He considered that the cane carriers would provide a better feed if made longer, and he also advocated that they be divided into two sections and be driven individually.

Mr. Mukherji described various equipments which he had tried for producing a more continuous feed to the mills. He stressed the need for adequate preparation by knives, and advocated the use of two sets. He also described the smoother running obtained by fitting additional flywheels to the knive shafts. For the electric driving of cane carriers he preferred to use the V.S.G. hydraulic system in conjunction with an electric motor, rather than adopt the Ward-Leonard system.

Mr. Heggie described the use of two carriers for receiving cane from bullock carts and railway wagons. He had not experienced any difficulty in ensuring an even feed to mills using electric motor drive with manual control.

Mr. W. M. Livie considered that the work of the authors provided valuable contributions to the operation of cane carriers. He asked to what extent mill extraction and crushing rate were improved by the special equipment described. He commented that, with automatic control, there would be no safeguard at the mill for preventing a large stone or piece of metal entering the mill with the cane.

In the absence of the author Mr. C. McNicol presented the following paper.

Paper

RECIRCULATING OF JUICE IN THE MODERN MILL

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The conventional form of strainer fitted to milling plants is the drag or scraper type. In this the unstrained juice flows on to a long narrow screen through which the screened juice passes and along which scrapers and sometimes brushes drag the fibrous matter off the screen and up an incline to deliver it to a conveyor. This conveyor discharges the fibrous matter or cush-cush to the blanket of bagasse between the first and second mills or, where the three-roller crusher is used, between the crusher and first mill.

With this conventional arrangement, juice from each mill is strained, the combined juice from the crusher and first mill, and separately the juice from each of the succeeding mills, being delivered at different points on the screen and the strained juice kept separate by means of compartments in a long tank under the screen. All the cush-cush accumulates on top of the screen and is dragged along together and deposited at one place on the milling train. In very large trains there may be two cush-cush strainers but, in any case, the principle is the same namely that the cush-cush from several mills is deposited on one place.

The obvious disadvantages of the above arrangement are :—

1. The cush-cush from the last mill which has passed through all the preceding mills and has had the greater part of the sucrose extracted from it—is dragged through a stream of richer juice from the earlier mills on the screen. Re-absorption of a portion of this juice takes place, which has to be re-extracted so that work is done over again on fibrous matter already almost exhausted.
2. As all the fine and sloppy cush-cush is fed in front of one mill, difficulties may occur. The author has noted on numerous mill trains that the second mill, in front of which cush-cush was being deposited, gave trouble in feeding and in many cases the hydraulic load on this mill was kept low to reduce the feeding difficulties. Many engineers have minimised this trouble by close attention to the mill settings and are thereby able to maintain good extraction by the mill taking the cush-cush, but there is no doubt that this is not accomplished without difficulty and extra attention.
3. The long cush-cush strainer with chains, scrapers and occasionally brushes exposed to the juice, and carrying a certain proportion of juice round in a closed circuit, encourages propagation of bacteria which causes inversion. There is also the possibility of leuconostoc growth which luckily may be killed by means of steam jets. Under certain conditions, favourable to its growth, however, it is possible to fill whole ranges of the piping system of the factory solid with this organism.

Only the mixed juice going to the boiling house must be strained. It is not necessary to strain juice from the later mills, because, in the compound imbibition process, this is returned to dilute the blanket of bagasse in the earlier mills and, provided the mixture of juice and cush-cush can be pumped, this is the logical method of operating. The pumping system has the additional advantage of spreading the cush-cush over the whole train and preventing re-absorption of richer juice as mentioned above.

Sugar technologists and engineers have been fully aware of the above for many years and a number of attempts were made to pump unstrained juice, but until the advent of the centrifugal chokeless pump, these had very limited or no success. Even after the chokeless pump was demonstrated as a means of pumping unstrained juice successfully, a considerable amount of experimentation had to be done and experience gained in the method of admission of the unstrained juice to the pumps and in the distribution of the mixture of juice and cush-cush on the mills. This development took some years, and it is only since World War II that the chokeless return system has been extensively adopted. The problems which had to be solved were :

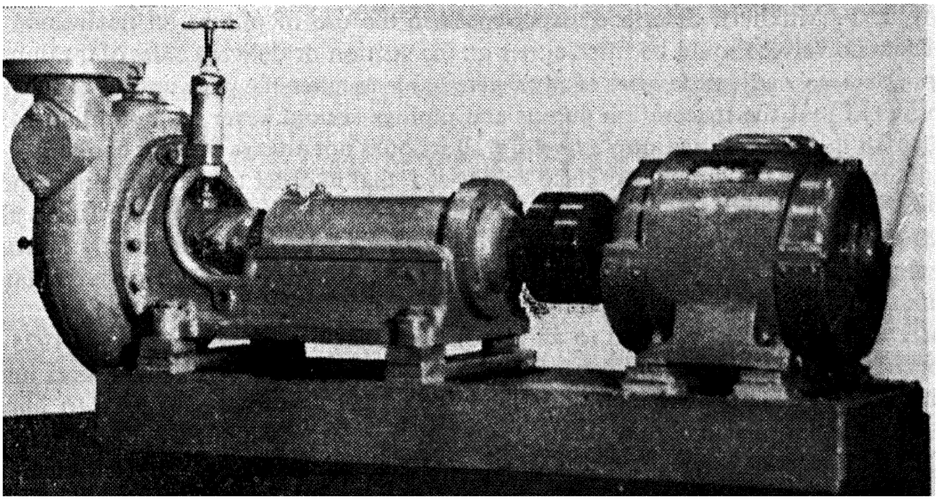
1. Type and location of gutters to allow free flow of cush-cush and liquid without undue frothing.
2. Method of feeding unstrained juice to the chokeless pumps so that uniform pumping is maintained and, should the supply of juice

temporarily fail, the pump would not be left dry and possibly plug the discharge pipes with cush-cush. In the successful arrangement, as th level of juice falls in the suction gutter, air is drawn into the pumpe which slows down pumping.

3. Arrangement of gutters so that, if a pump cuts out temporarily, juice will flow forward to the next preceding mill, and not over-flow on to floor.

In certain circumstances, it is possible to dispense with the drag type strainer and elevator completely. Mixed juice containing the cush-cush is pumped by means of a chokeless pump to a strainer, which is located above the mills at a height to allow discharge of the cush-cush strained from the juice on to the blanket of cane between the first and second three-roller units. The strainer may be of the vibrating type or of the rotating type, and the cush-cush may be dropped directly or conveyed on to the blanket of cane by means of a conveyor or carried by return juice, which is also unstrained, along a simple gutter discharging on to a spreader plate. This simplification of the straining end of the plant has resulted in a reduction in running costs by eliminating the maintenance of the screens, chains, etc., of the drag type strainer. Some mills report an improvement in the purity drop across the mills which is particularly important where large tonnages are being handled.

A modern chokeless pump for dealing with mill juice is shown in the illustration.



Limits of Operation : Any pump with an inlet and discharge under 3″ is not really chokeless when handling juice from mills, so that normally, there is not enough liquid in circulation on mills grinding much under 1000 tons per day to allow the operation of a really chokeless system. A number of operators, however, are running the chokeless system on mills grinding 600 to 700 tons of cane per day, but the system in this case has to be carefully watched. It is normally trouble-free on trains grinding from 1000 tons per day upward, provided the amount of imbibition water is not too low.

In studying the chokeless system of returning juice in mill trains, particularly on mills grinding high capacity at high surface speeds such as may be seen operating in Puerto Rico and Cuba, the author has observed that the tonnage in a given tandem can grind with high extraction seems to be governed by the amount of liquid, which can be drained from the mills. In long trains, say of 21 rollers, it would be ideal if the last mill could take all the imbibition water required and produce bagasse of reasonable dryness and low sucrose content. Where high tonnages are ground, however, the imbibition water has usually to be spread over two, and sometimes three, of the later mills in order to obtain adequate drainage and bagasse sufficiently dry for burning.

It would be of great interest if data could be accumulated on how much liquid is being drained off mills of different sizes running at high capacity. From the data available to the author, it appears that the maximum amount of liquid at present being drained off an 84″ mill, irrespective of the speed at which it is running, is somewhere between 50 and 55 tons per hour on the last mill.

DISCUSSION

Mr. J.O. Sason asked whether, when using unchokable pumps, it would be necessary to interconnect the juice gutter below the mills.

Mr. McNicol replied that it was advisable to do so in case a pump failed so that, instead of overflowing to waste, the juice could temporarily be passed over to the next pump. This could be arranged either by weirs between the gutters, or partition which could be removed when required.

Mr. J. P. Mukherji described experiences in the use of pumps on unstrained juice. He stressed that no valves should be fitted either on the suction or delivery sides of the pumps. Where mills are not closely adjusted pieces of cane were liable to enter the juice and to choke the pumps. He considered that the maceration pumps and pipings should never be less than 4″ bore. A controlled air inlet on the suction was helpful, but could not always prevent choking. Due to the large fluctuations in the quantity of juice he advised that in order to avoid choking and overflow, the capacity of the pump installed should be much in excess of the average calculated juice flow.

Mr. McNicol stated that the operation of the juice system was frequently faulty, and that pumps could not cope with conditions where workers allowed cush-cush to accumulate and only raked it down at intervals into the pumps.

Mr. O. M. Henzell referred to an installation made in the West Indies in 1925 which was still working satisfactorily. He knew of about 18 more factories where unstrained juice pumping had subsequently been installed, and in no case had it been necessary to revert to juice straining. He emphasised that to operate the system satisfactorily, mills had to be maintained in good condition and be closely adjusted so as to reduce to a minimum the amount of cush-cush carried down with the juice. He considered that with small plants of less than 1000 tons per day crushing capacity, the juice quantity was generally insufficient to maintain proper pumping of unstrained juice.

Mr. R. S. Soni described his experience on a 2000 tons per day plant with maceration up to 18% on which unchokable pumps installed five years ago were still working satisfactorily. One problem experienced was the distribution of the unstrained juice on to the mills, which had required considerable experimenting before a satisfactory arrangement was evolved.

Mr. McNicol confirmed that where the quantity of juice was relatively small—as in the case of mills below 1000 tons per day capacity—trouble was liable to be experienced with unchokable pumps. With an adequate juice supply carrying only a normal quantity of cush-cush the system was, however, entirely satisfactory and had distinct advantages.

Mr. D. K. Brahma, *Chairman*

Mr. K. S. Arnold presented the following paper.

Paper

STEAM TURBINE DRIVE FOR SUGARCANE MILLS

K. S. Arnold
Duncan Stewart & Co. Ltd., Glasgow

Until recent years sugar cane mills have almost exclusively been driven by horizontal single-cylinder steam engines. In a few cases electric motor drive has been employed, but has never been extensively adopted. Soon after the last World War some large milling plants were installed in South Africa with vertical high-speed steam engines driving the individual mills. The steam turbine has also now been introduced, and gives promise of becoming the most popular form of mill drive.

The first steam turbine installation on a cane mill was made in 1947 at the Lula Factory in Louisiana. A Corliss steam engine was replaced by a 350 B.H.P. multi-stage turbine and gearing for driving the last mill of a four-mill 34½" x 60" tandem, crushing around 85 tons of cane per hour. This conversion proved so satisfactory that many other turbine drive installations have been made on mills in Louisiana. Subsequently the application of the steam turbine has been extended to other countries and, in addition to many conversions made on existing mills, most large new plants installed over recent years have been provided with this form of drive.

In this paper the advantages of the steam turbine for cane mill drive are mentioned, and suitable types of turbine briefly described. The steam consumption and horse power characteristics relative to the steam engine are discussed, and reference made to the gearing aspect of the drive. Information is also given on various arrangements of turbine drive which can be selected when replacing steam engines and gearing on existing mills, or when installing new milling plants.

INCREASED POWER DEMAND OF MILLS

The desire in recent years to enlarge the sugar output of factories naturally requires increases in the crushing rates of existing milling plants. This is being achieved generally by increasing roller surface speeds, and by design improvements on the mills and their ancillary equipment. It frequently transpires, however, that the steam engines—installed initially on mills for dealing with a specified crushing rate—now impose a limitation on the increase in factory output, due to being inadequate in horse power for the higher cane tonnage required.

In the above circumstance the only solution is to replace the steam engines by driving units designed for the higher power demand. Replacement may be effected by installing larger steam engines, or by introducing steam turbines with the necessary additional reduction gearing. In the overall picture the latter method is the more convenient, and also appreciably cheaper, as the price of the turbine and gearing will be lower than that of a new engine, and installation costs less than the construction of new foundations and the erection of larger engines. But these are not the only considerations, as other advantages are to be gained when replacing steam engines by steam turbines, advantages which also apply when this form of drive is adopted on a new milling plant.

SOME ADVANTAGES OF STEAM TURBINE DRIVE

Clean exhaust steam. When steam engines are employed for driving mills the exhaust steam, passed out to the factory for process work, carries over a proportion of atomised cylinder oil. Despite the use of separators this oil is liable to be deposited on the tube heating surfaces of juice heaters, first vessels of evaporators, and vacuum pans, thereby retarding heat transfer and seriously reducing the working rates of these vessels. This detrimental situation does not arise when turbines are employed, as there is no oil contamination of the exhaust steam.

Smoother running. With the slow-speed steam engine the pulsations of the heavy reciprocating parts may be transmitted through the gearing to the mills and, augmented by cyclic variations in speed, are liable to cause irregular running of the mills with adverse effect on capacity and extraction. The steam turbine, on the other hand, transmits a steady torque and can also readily be governed to maintain speed within close limits. The operation of the gearing and mills is thus appreciably smoother when driven by steam turbine, and chokes are less liable to occur. In consequence a higher average crushing rate can be maintained, wear on gears and bearings is reduced, and breakages are less liable to occur.

Speed Control and Emergency Stopping. While it is not impossible to arrange for steam engines to be regulated for speed and stopped in an emergency by means of remote control, the nature of the governors and valves to be operated does not readily allow control gear to be fitted. Remote control is thus extremely rare on steam engines driving mills, the almost universal practice being to have speed adjustment and stopping carried out by attendants on duty at the individual engines.

Steam turbines lend themselves readily to the application of remote control, and on milling plants driven by turbines it is customary to have a central control desk situated at a vantage point on or near the mill platform. Control devices and tachometers fitted in this desk connect by electric wiring to servomotors and solenoids on the governors of the individual turbines. By merely pressing push buttons one attendant at the desk —having a full view of all the mills—can maintain strict control over the speeds of the various turbines, accurately adjusting each machine so as to maintain steady crushing at the related mill or mills. In an emergency this attendant can also instantly stop one particular turbine or, if need arises, can stop all simultaneously. Apart from reducing the number of attendants required, these facilities contribute substantially to the smooth operation of a milling plant, and assist in achieving a high average crushing rate. They also provide a safeguard against serious accident which might otherwise result from a delayed shutting-down of the plant in an emergency.

Higher Operating Steam Pressure. When single-cylinder steam engines are employed for driving the mills, cylinder strength considerations normally restrict the inlet steam pressure to around 150 p.s.i.g. Some sugar factories generate steam at pressures above this figure and, when installing new factories or replacing boiler plant there is now a tendency to adopt pressures around 250 p.s.i.g., and even higher. Although passing upwards of 40% of the total steam generated, mill engines cannot benefit in efficiency by these higher pressures, as the boiler steam has to be reduced before entering the engine stop-valve, which is obviously an uneconomical arrangement. As steam turbines can operate on steam at the highest pressures, the above restriction does not exist when they are employed for driving mills and, irrespective of boiler pressure, the steam can thus be supplied directly to the turbines with resulting improvements in convenience and operating efficiency.

TYPES OF STEAM TURBINE FOR MILL DRIVE

For cane crushing mills the power requirement for individual driving units is generally within the range of 200 to 1,000 B.H.P., the particular power depending on the crushing rate, and whether the mills are driven independently or are coupled together by gearing in groups of two, three or four. Normally it is only with small mills that more than two are coupled for driving together. With large mills individual drive is more usual, particularly when steam turbines are employed.

The inlet steam pressure available for turbines in the cane sugar factory seldomly exceeds 150 p.s.i.g., 100°F. superheat, with a back-pressure normally between 8 and 15 p.s.i.g. For operating under these steam conditions, and for any higher inlet pressures, two types of turbine are suitable—the simple single-wheel type and the multi-stage type. For the relatively small horse powers required the machines will normally have wheels between 18″ and 30″ diameter.

The section of a typical *Single-wheel Turbine* is shown in Fig. 1. This is an impulse machine having one pressure and two velocity stages. The turbine is shown incorporated on a common bedplate with a single-stage reduction gear, which gives an output speed of around 1300 r.p.m. with the turbine running at 500 r.p.m. This combined arrangement is particularly suitable for the driving of mills, as it provides an initial speed reduction in extremely compact form.

In the case of the single-wheel turbine there is a particular speed which, relative to wheel diameter, will give the highest efficiency and correspondingly the lowest steam consumption. For a 24″ dia. wheel this optimum speed is around 5500 r.p.m., and for a 30″ wheel around 4500 r.p.m. These speeds can be taken as applying for inlet steam pressures up to 250 p.s.i.g. and will thus cover the large majority of cases in sugar factories.

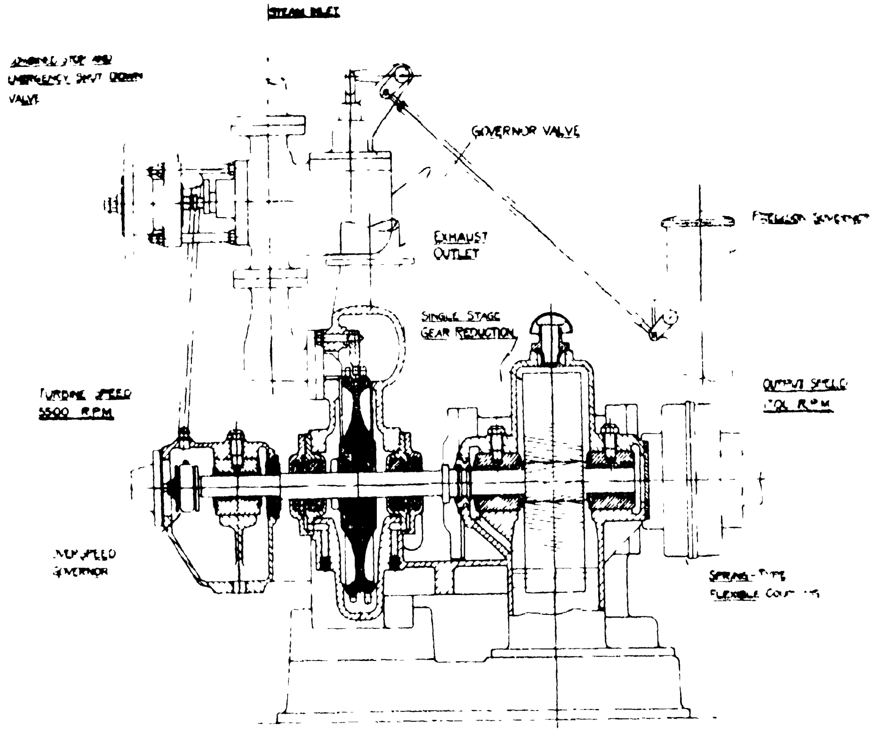


Fig. 1. Single-wheel steam turbine with combined single stage reduction gear.

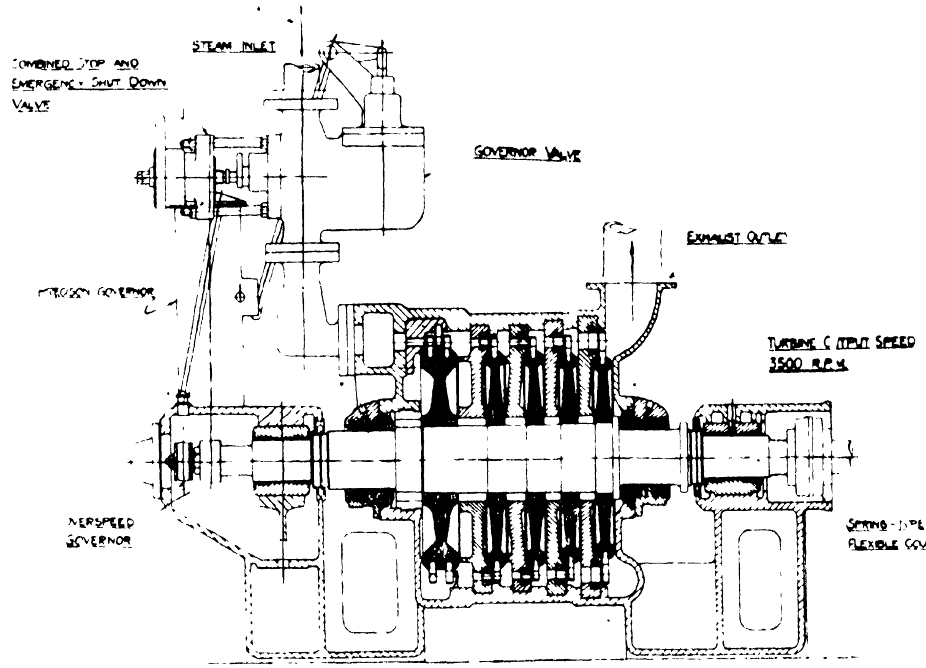


Fig. 2. Multi-stage Steam Turbine.

A cross-section of a typical *Multi-stage Turbine* is shown in Fig. 2. This type normally incorporates a two-row impulse wheel similar to that in the single-wheel machine, followed by a number of single-row impluse wheels usually four or five. The highest efficiency on this turbine can be obtained at lower speeds than for the single-wheel type—around 3500 r.p.m. for 24″ wheels, and 3000 r.p.m. for 30″ wheels. Under the same steam conditions the consumption of the multi-stage turbine is from 15 to 20% lower than that of the single-wheel type.

As will be seen by a comparison of the two cross-sectional arrangements, the greater number of wheels in the multi-stage turbine results in a larger and more complicated machine which, for the same power output, is approximately twice the cost of the single-wheel turbine with combined gear. While the steam consumption of the multi-stage turbine is lower, its direct output speed is in the region of three times that of the geared single-wheel turbine combination. (Due to the long rotor shaft of the multi-stage machine it is not normally practical to incorporate a reduction gear). The multi-stage turbine also demands more careful operational attention, involves extra work in maintenance, and the stocking of more expensive spares. For these reasons it is always preferable to install single-wheel turbines for mill drive, and it is only necessary to consider the multi-stage type when low steam consumption is an important factor in a particular installation

STEAM CONSUMPTION AND HORSE POWER CHARACTERISTICS

A criticism commonly levelled against the turbine is that the steam consumption is much higher than for the horizontal steam engine and that as a result, when used for driving the mills, turbines are liable to disturb the steam balance of the sugar factory. As a generalisation this is not true, and would only apply in certain unfavourable circumstances. The relative steam consumption and power characteristics of the steam engine and steam turbine are entirely different, but in many respects the turbine is the more versatile machine for the driving of mills.

The steam turbine is better suited to the higher steam pressures, and where the inlet pressure available for the turbine is low-say 110 p.s.i.g. or less—the steam consumption will generally be higher than for the engine. Above that pressure, however,—and depending on type, speed, and correct application the single-wheel turbine can generally hold its own, while the multi-stage type will normally have a lower consumption than the steam engine.

Steam Engine. For a particular steam consumption an engine, working within a prescribed pressure range, will develop a fixed maximum horse power. If more horse power is required from the engine, this can only be obtained by arranging for a later cut-off, which will increase the steam consumption. This will be seen by reference to Fig. 3, where a curve shows the relationship of horse power, cut-off, and steam consumption for a typical drop-valve steam engine

24″ bore × 48″ stroke running at 55 r.p.m., and operating under the steam conditions 150/10 p.s.i.g., 100°F. superheat. Taking the practical range of cut-off for a mill engine to be between 0.40 and 0.75 of the stroke, the horse power developed by this engine at the two extremes will be respectively 415 and 550 B.H.P., with corresponding steam consumptions of 30 and 39 lbs. per B.H.P. hour. The steam consumption curve for the same steam engine at 120 p.s.i.g. inlet pressure is also given for comparison purposes.

Although some steam engines may have been installed originally to provide the initial horse power requirement at a cut-off of 0.40, it is extremely unlikely that with subsequent increases in power demand they will now be able to operate at such an early point. It will not be unreasonable, therefore, to assume that the cut-off today will in general be at least 0.6 which, for the above engine, will give a steam consumption of 35 lbs. B.H.P.-hour at the corresponding full-load horse power. With an inlet steam pressure of 120 p.s.i.g. the figure will be 38 lbs. These steam consumptions may be regarded as the most favourable for existing mill engines of the Corliss or drop-valve type, governed by cut-off. For existing throttled-governed engines of the piston-valve type the consumptions will be appreciably higher.

Steam Turbine. For a particular size of turbine the horse power range is extremely wide, and depends essentially on the number of steam nozzles fitted in the steam chest. Also, as the steam consumption per B.H.P. is independent of the number of nozzles, this consumption will be constant for the same size of turbine over a wide range of horse powers, provided the particular outputs are obtained by fitting the appropriate number of nozzles.

By way of example, a particular *Single-wheel Turbine* having a 24″ dia. wheel, can be fitted with nozzles varying in number from 5 to 15. Under the steam conditions of 150/10 p.s.i.g. 100°F. superheat, the corresponding range of powers developed will be 175 to 550 B.H.P. when running at 5500 r.p.m. At the various full-loads between these figures corresponding to the appropriate number of nozzles fitted, the steam consumption will be almost constant at 31 lbs. per B.H.P.-hour, and at ¾ load—obtained by throttle governing—the consumption will be 34 lbs. as shown by curve in Fig. 3. It will be seen that the above figures compare favourably with those obtained on a steam engine of similar horse power operating under the same steam conditions.

Also shown on Fig. 3 is the consumption curve for the same 24″ turbine running at 4000 r.p.m., but otherwise under conditions as above. This curve shows the appreciably higher resulting steam consumption, and serves to emphasise the importance of arranging that steam turbines should operate for their normal duty at around the most economical speed for their size and type.

The steam consumption and power characteristics of the *Multi-stage Turbine* are identical to those of the single-wheel type but, by dividing the pressure drop between a larger number of stages, lower steam consumptions are obtained, and the most economical speeds relative to wheel diameter are slower. The consumption curve for a 24″ multi-stage turbine operating with steam at 150/10 p.s.i.g., 100°F. superheat, and running at 3500 r.p.m., is given in Fig.3, from which it will be seen that the full-load figure is 27 lbs. per B.H.P.-hour and for $\frac{3}{4}$ load is 29 lbs.

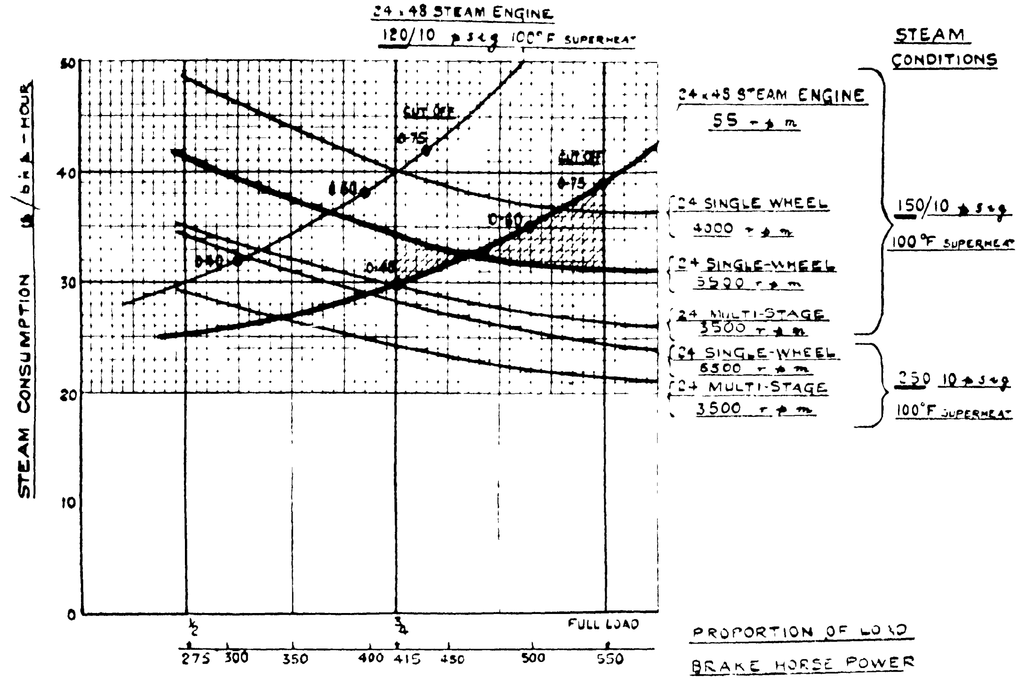


Fig. 3. Relative Horse Powers and Steam consumptions of Steam Engines and Turbines.

Also given in Fig. 3 are the two consumption curves for 24″ single-wheel and multi-stage turbines respectively, operating as above but with inlet steam pressure raised to 250 p.s.i.g. It will be seen that this increase introduces a marked improvement in steam economy, both turbines being then appreciably better in consumption than the drop-valve steam engine.

The above comparative aspects of the steam consumptions of steam engines and turbines are summarised in Table I.

It will be seen from the curves that with increasing horse power the B.H.P.-hour steam consumption of the turbine decreases, whereas with the engine the reverse is the case. Under the steam conditions taken, the consumption of the 24″ single-wheel turbine at $\frac{3}{4}$ load is higher than that of the engine, but at full-load is appreciably lower.

Advantages of Steam Turbine Characteristics. The variable horse power characteristic of the steam turbine has advantages when this machine is applied to the driving of mills. For instance, different powers are often required on a milling plant for driving the various units, such as cane knives, 2-roller crusher, and 3-roller mills. When steam engines are employed for these varying duties they will be of different type and size, and will require the stocking of different

TABLE 1

STEAM CONSUMPTIONS OF ENGINES AND TURBINES FULL-LOAD 550 B.H.P.

Steam conditions			24″×48″ Drop-valve Steam Engine		24″ Turbine			
					Single-wheel 5500 r.p.m.		Multi-stage 3500 r.p.m.	
Inlet Pressure p.s.i.g.	Superheat °F	Exhaust Pressure p.s.i.g.	Full-load	¾-load	Full-load	¾-load	Full-load	¾-load
250	100	10	—	—	24	28	21	24
150	100	10	39	30	31	34	27	29
120	100	10	42	32	35	41	29	35

spare parts. With the steam turbine, however, it is possible to standardise on one type and size of machine, as the respective horse power outputs required can be provided for in the individual turbines merely by fitting the required number of nozzles, and the B.H.P-hour steam consumption will be practically the same on each turbine.

Again, when installing steam turbines, flexibility can be permitted in assessing the horse power demand of the mill—provided of course that the full available power of the turbine is above the maximum estimated power requirement. Should it be found after the turbine is in service that the power demand has been over-estimated, then the position can readily be adjusted at the factory by plugging nozzles in the steam chest so that only those necessary for developing the actual power are in operation, which will thereby ensure the most economical steam consumption. Correspondingly, if the power has been under-estimated, then the required number of additional nozzles can be fitted—still without affecting the B.H.P.-hour steam consumption of the turbine.

Turbines are generally fitted with a number of nozzles under the manual control of valves, which under normal running conditions are kept closed. These valves can be opened to provide additional power should this be required for a particular purpose, and are also available for temporary use in the maintaining power during a spell of low boiler pressure, as may occasionally occur in a cane sugar factory.

It will be obvious that the steam turbine can also be installed to provide for future increases in power demand more readily and economically than the steam engine. In the normal way when a particular machine is supplied it will possess an available horse power in excess of the immediate demand. If in later years the development of additional power becomes necessary for coping with increases in crushing rate, the turbines can then be fitted as required with additional nozzles up to the maximum designed accommodation of the steam chest, these additions with their corresponding increases in horse power again having little effect on the B.H.P.-hour steam consumption. If such an increase in power were to be required from a steam engine it could only be obtained at the expense of an appreciable increase in the B.H.P.-hour steam consumption.

TURBINE SPEED AND REDUCTION GEARING

In the case of steam engine drive a reduction in speed from 55 r.p.m. at the engine to around 4 r.p.m. at the mill is an average condition, representing a reduction ratio of 14 to 1. As mentioned above, for efficient operation on small steam turbines they will require to be run at speeds between 3000 r.p.m. and 5500 r.p.m.—depending on type and wheel diameter—in order to give the lowest steam consumption. This will necessitate the introduction of intermediate gearing having a high overall reduction ratio of 800/1400 to 1—probably the highest employed in any industrial application.

It is possible by one or both of the expedients of running the turbine at a relatively low speed and increasing the reduction ratio of the individual stages of gearing, to effect the large overall reduction between turbine and mill in three stages only. This, however, appears generally an undesirable arrangement, as the turbine will have an uneconomical consumption, and the individual gearing stage reduction ratios will be high, resulting in small diameter pinions which will be detrimental to good wearing conditions, gear life and silent running. If the individual reductions are limited to ratios consistant with good gear operating conditions, then it appears necessary to incorporate four stages with a turbine running at the lower speed of about 3000 r.p.m., and five stages with one running at the higher speed of 5500 r.p.m. In borderline cases it appears preferable also to introduce an extra stage of gearing so that for the steam consumption requirements a single-wheel turbine can be employed, rather than to use a multi-stage turbine by reason of its lower operational speed in order to eliminate one gear reduction stage.

TURBINE DRIVE APPLICATION AND LAYOUT

With the large horizontal single-cylinder steam engine and gearing there are restrictions in the layouts which can be devised for driving mills. The weight of the engine and its heavy flywheel, coupled with the external forces transmitted by the reciprocating parts, necessitate heavy and extensive foundations. The engine must also of necessity be situated at ground level driving through two—and in some instances three—horizontally-disposed stages of reduction gearing, generally according to the arrangement shown in Fig. 4. With the steam turbine—due to its relatively light weight and the absence of externally transmitted forces—such limitations do not exist, and the turbine can be installed on a small foundation or be placed on a relatively light structural platform. Furthermore, the larger number of stages of gearing between the turbine and the mill provide latitude in design for locating the turbine in various positions relative to the mill, and advantage can be taken of this feature to provide more convenient overall arrangements than are possible with steam engine drive.

Three general choices exist in the application of turbine drive to existing milling plants :—

(a) Replacement of the steam engine only.

(b) Replacement of the steam engine and existing first-motion gearing.

(c) Replacement of the steam engine and all existing gearing.

The arrangements of turbine drive which can be adopted in the above instances are equally suitable for new milling plants, and the layouts shown in Figs. 4 to 8 apply to both cases.

(a) *Replacement of the Steam Engine only.* When replacing the steam engine only, for the purpose of providing more power for the mill, it is to be presumed that the existing gearing is not unduly worn and that it is also of adequate strength for transmitting the increased horse power. The conversion is simple, and merely entails removing the existing engine and placing the new turbine with its reduction gearing on the old foundation, according to the arrangement shown in Fig. 5. The connection to the existing gearing will normally be made

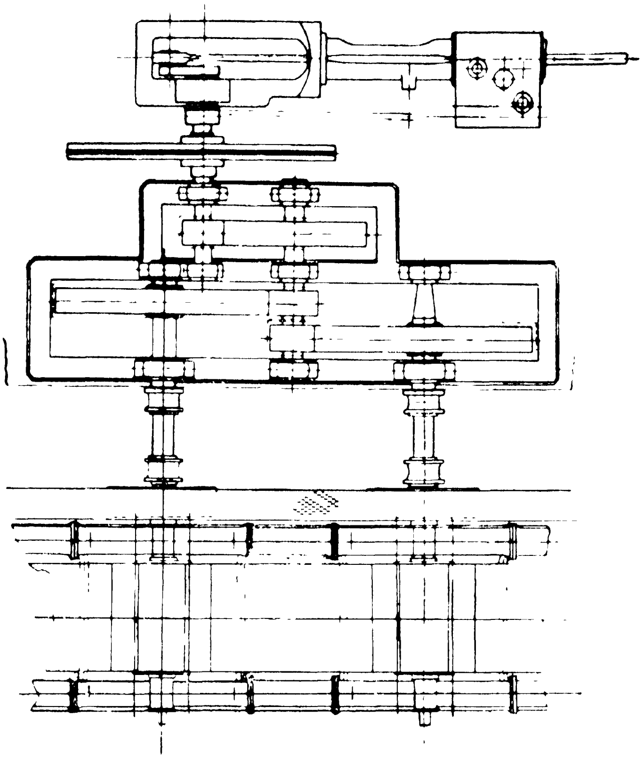


Fig. 4. Conventional Steam Engines layout.

by cutting the engine crankshaft and fitting a gear-type flexible coupling for connecting to the turbine gear-box. If an increase in roller surface speed is required, then the output speed from the gear-box of the turbine can be made appropriately higher than the former speed of the engine.

(b) *Replacement of the Steam Engine and existing first-motion Gearing.* This second case arises where the first-motion gearing may be worn and/or is of inadequate strength for the increased horse power. Two layouts are possible. The first will be similar to Fig. 5, but with the turbine gear-box having an additional reduction stage incorporated, and the output shaft coupled to the pinion shaft of the existing second-motion gearing. The second layout is shown in Fig. 6, provides a more convenient and compact arrangement. Here a vertical-type of gear-box is employed, which brings the input shaft for coupling to the turbine into such a position that the turbine can be located at mill platform level, and on the inside of the gear-box facing towards the mills. The turbine thus occupies a more accessible position and can—if remote control is not employed—be operated by an attendant having a full view of the mills driven by the particular turbine. The overall space occupied by this arrangement is appreciably less than that taken up by an existing steam engine drive and offers a solution in those cases where—due to space limitations—the flat arrangement of turbine layout shown in Fig. 5 cannot be installed within the width of the existing mill house.

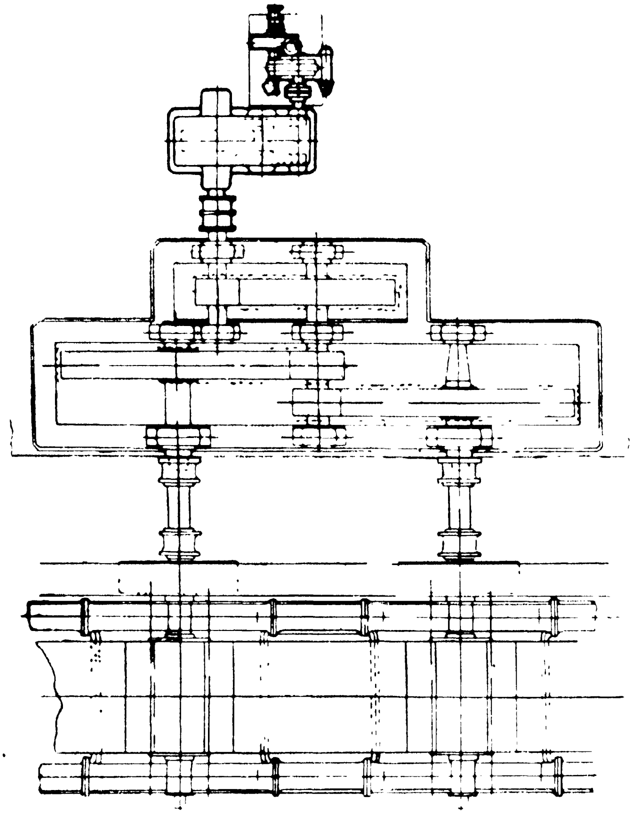


Fig. 5. Steam Engine replaced by Turbine and Gear-Box.

(c) *Replacement of the Steam Engine and all existing Gearing.* While the layouts already described can be adopted for this case, another—and even more compact—arrangement is shown in Fig. 7. Here all gearing is assembled in one gear-box and is so disposed that the turbine is situated between the gearing and the mill at platform level, and immediately adjacent to the mill platform. Fig. 7 shows this arrangement when driving two mills together, and Fig.8 the arrangement for individual drive as adopted on larger mills. The advantage to be gained by this layout in new installations will be apparent. The much narrower over all width of the milling plant will allow of the mill house being reduced in span by upwards of one quarter of that necessary with steam engine or flat turbine drive layouts, with corresponding reduction in the span of the overhead cranes, and in the width of foundations.

It is hoped that the information given in this paper will stimulate among sugar factory engineers an interest in steam turbine drive as applied to mills, and that it will provide some initial guidance for considering installation for replacing steam engines, or for applications to new milling plants.

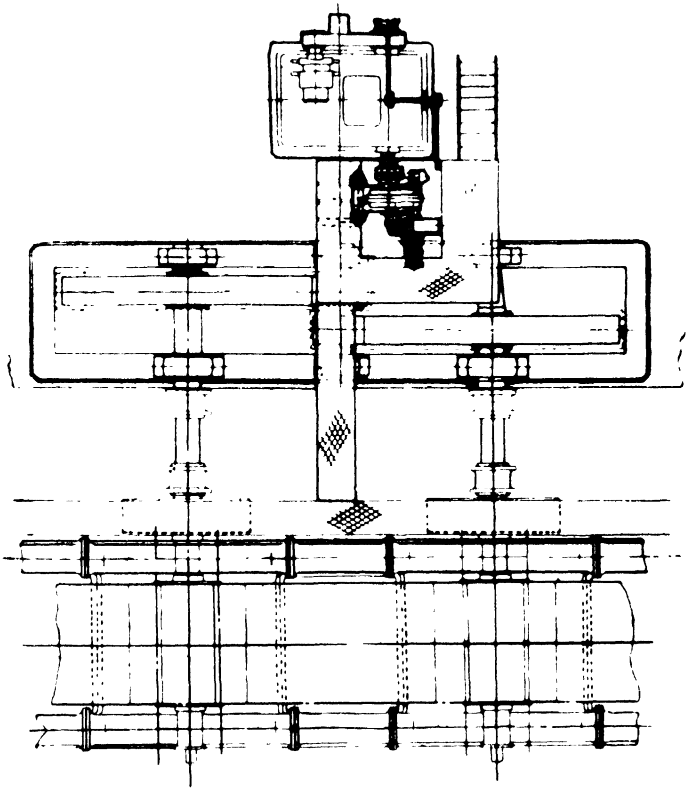


Fig. 6. Engine and First-Motion Gears replaced by Vertical Gear-Box and Turbine (British Patent No. 699, 432).

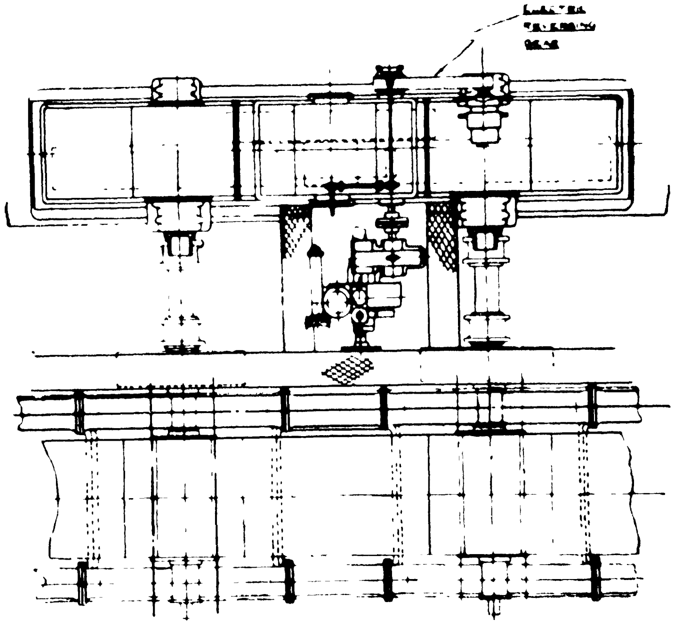


Fig. 7. Turbine and Gearing installed on two Mills of New Plant. (British patent No. 699, 432).

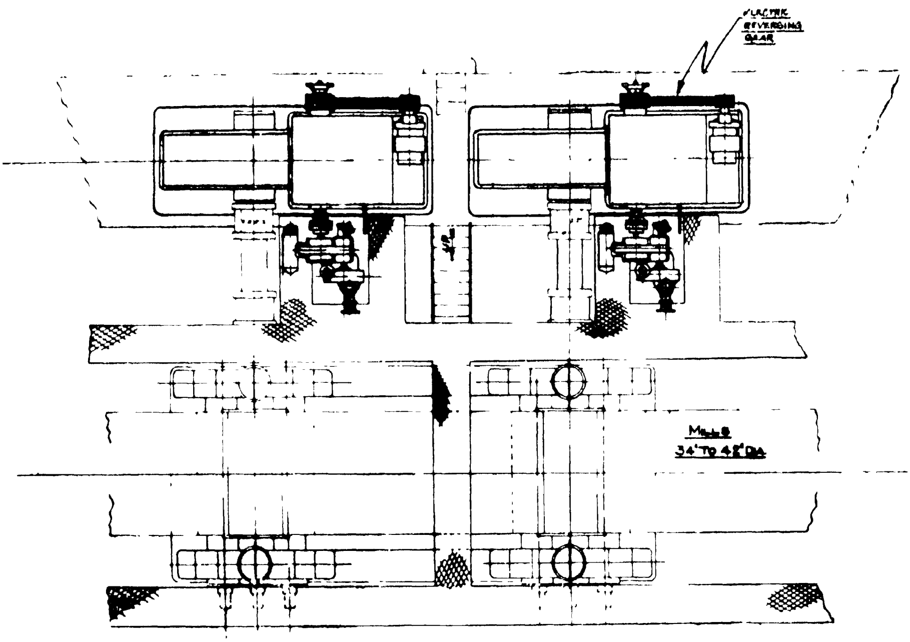


Fig. 8. Composite Turbine and Gearing driving Individual Mills.
(British Patent No. 699, 432)

The change over from the familiar slow-running steam engine to the technically different small high-speed turbine is a revolutionary development in sugar engineering. As with other similar advances, it was only to be anticipated that in the initial stages—and until sufficient operational experience had been gained—problems might arise and require to be solved. It can now be claimed, however, that the trial period is over, and that the steam turbine is fully established as an entirely convenient and economical form of prime mover for the driving of sugar cane mills, and one possessing advantages over other forms of drive. This is evidenced by the large number of plants which are now in satisfactory operation in various cane-sugar territories throughout the world, and by the confidence shown over the past few years by those purchasers of large new milling plants who have specified steam turbines as the driving units.

DISCUSSION

Mr. A. Constandse suggested that to take the cut-off figure as 0.6 for the steam engine was too late, as engines were normally designed for operating at 0.4 cut-off. He also considered that in their specifications makers should give the steam consumption for turbines at fractional loads. He enquired whether turbines were suitable for use with wet steam.

Mr. Arnold agreed that when installed steam engines may be designed to provide the power required at 0.4 cut-off. Due to later increases in crushing rate, however, the higher power demanded resulted in engines of the Corliss and drop-valve types having to be operated at much later cut-offs. He had taken 0.6 as a reasonable figure today for mill engines installed 10/20 years ago. He agreed that it was useful to know the steam consumption for fractional loads and, if makers failed initially to give these, they would normally be willing to do so on request. He replied that steam turbines would operate satisfactorily on wet steam, but superheated steam was to be preferred in order to avoid erosion wear due to moisture. Where wet steam was employed the life of the blades might be shortened.

Mr. G. P. Bhargava mentioned that with the present high Indian crushing rates, it was often necessary to operate existing mill engines at cut-offs even later than 0.7. This resulted in high steam consumption which was often the main cause of unbalanced steam conditions in a factory.

Mr. W. M. Livie commented on the large number of gear reductions necessary with turbine drive, and asked whether this introduced vibration and additional stresses in the plant.

Mr. Arnold replied that with properly designed gearing there was little vibration. He also explained that flexible couplings can be installed between the turbine and gearing and between the gearing units which would damp out any vibrations. He considered that the stresses and wear imposed on gearing by turbine drive, where the driving torque was constant, were less than what was imposed by the pulsating effect of slow-speed steam engine drive.

Mr. Wadia asked whether turbines were only suitable for individual mill drive, or whether a number of mills could be driven by one turbine.

Mr. Arnold replied that turbines could replace the steam engine in all cases, and be used for driving one or more mills. He considered, however, that for small mills—with rollers say 32″ dia. or lower—it was more economical to drive the mills in pairs, but for larger mills individual turbine drive was more flexible in operation.

Mr. Khosla enquired whether turbine drive was better than electric motor drive.

Mr. Arnold replied that from the points of view of capital cost and overall steam economy steam turbine drive was the better. When using motors the electric power had first to be generated—normally by turbo-alternators-and appreciable electric control gear had to be employed, all entailing high initial cost. It seemed preferable to connect the turbine directly to the mills.

Mr. Khosla remarked that the steam consumption would be less if the mills were driven from a powerhouse by individual motor.

Mr. Arnold replied that, although the turbo-alternator in the powerhouse might have a lower steam consumption than the smaller turbines on the mills, the overall efficiency of the electric system was nevertheless liable to be lower. Judged in lbs. of steam per B.H.P. at the mill coupling, the electric system of drive would normally have a higher steam consumption than direct steam turbine drive.

Session-Tuesday, 31st January, 9.15 A. M.

Mr. K. S. Arnold, *Chairman*

Mr. G. P. Bhargava presented the following paper.

Paper

MILL ENGINES AND POWER FOR MILLING IN INDIAN SUGAR FACTORIES

G.P. Bhargava And R.C. Sharma
National Sugar Institute Kanpur, India

On account of an increase in demand for sugar in India during the past few years there has been a general tendency in the factories to crush more with the existing equipment. Some additions are generally carried out in the boiling house, but the milling plant is taken for granted to be a flexible unit for crushing larger quantities of cane. In fact, many of the plants are working at more than 100% rated capacity. During the course of visits to factories the authors found that a general impression exists that merely by adjusting mill settings and increasing the surface speeds of mills it is possible to increase the crushing capacity. Little or no consideration appears to be given to the fact that a certain minimum power is essential for efficient milling, and that there are limitations to obtaining this power from an existing mill engine. It was, therefore, considered necessary to carry out investigations in the factories to determine the optimum crushing rates with available power. The results of the investigation are summarized in this paper.

MILL ENGINES

The modern prime-movers advocated for cane mill drive are individual steam turbines, electric motors or high-speed vertical engines, but so far almost all factories in India have slow-speed, horizontal, non-condensing, single cylinder type steam engines. These are arranged either for individual mill drive or for two or three units driven by one engine, and in some cases the whole tandem is driven by a single engine. The engines usually have cylinder diameter to stroke ratio of 1 : 2 or less, and the speeds vary from 45 r.p.m. to 110 r.p.m., the higher speeds in the case of Continental made units.

On the basis of the types of valves mill engines can be classified as :—

(i) D-Slide Valve type.
(ii) Piston Valve type.
(iii) Corliss Valve type.
(iv) Drop or Poppet Valve type.

1. The D-slide valve type is usually found on old Java plants and is arranged for individual mill drive. These are thermodynamically inefficient and unsuitable for use with superheated steam. The governing is by throttling of the steam, and reversing by Stephenson link motion.

2. The piston valve type is usually supplied by British makers. It is cheaper than the Corliss or drop valve types, and for a particular size of cylinder is rated at a higher horse power, as the cut-off is kept late. The governing is by throttling with a Pickering type governor, which often gives hunting trouble. It is easy to control with the link motion reversing gear and the time lost at mills on this account is, therefore, minimised. The valve adjustments are easy, and sturdy design and construction enables the engine to run for years without trouble. The main disadvantages of this type of engine are uneconomical steam consumption and unsuitability for super-heated steam.

3. The Corliss valve engine is found only in a few factories in India. It is costly and is fitted with rather complicated valve gear on which the wear and tear is considerable. It is economical in steam consumption as the governing

is by variation of the point of cut-off. It is, however, not suitable for a sugar mill drive where the load is very variable. On account of the complicated valve gear the engineer is often reluctant to dismantle and overhaul the engine.

4. The Drop valve or Poppet valve type of engine is usually supplied by Continental makers of sugar machinery although some British firms have also supplied this type. It is the most suitable engine for cane mill drive. It is thermodynamically efficient, and suitable for super-heated steam. The governing is by variation of the cut-off and is operated by an oil pressure governor or shaft governor, which are sensitive and provide good speed regulation. A barring engine is often provided which is an excellent arrangement for reversing or starting and saves considerable time for these operations.

The engine or engines driving the mills have a marked influence on the steam consumption of a factory. In an average plant even with the engines operating at their lowest steam consumption, appreciably more than 30% of the total steam generated at the boilers has to pass through these engines and thence into the exhaust main. An erroneous idea persists that, as all the exhaust steam is used for process work in a sugar factory, uneconomical steam power units should be installed so as to provide plenty of exhaust steam for the boiling house. This is entirely wrong. Inefficient steam-engines or pumps are not only wasteful of steam but are also wasteful of heat. To regard a mill engine merely as a reducing valve and disregard steam consumption will not only result in increased steam consumption and hence fuel consumption but will also require a larger capacity to be installed at the boilers.

POWER FOR MILLING

The power required for milling cane is dependent upon many variable factors such as fibre in cane, hydraulic loading, preparatory devices, setting of mills, speed of rollers, and number of compressions. The three factors-of mills, amount of cane crushed and the horse power required for efficient milling are closely related, but vary widely from factory to factory. Roller surface speeds so far adopted in India vary from 20 ft. per min. to 30 ft. per min. but of late speeds as high as 45 ft. per min. have been employed.

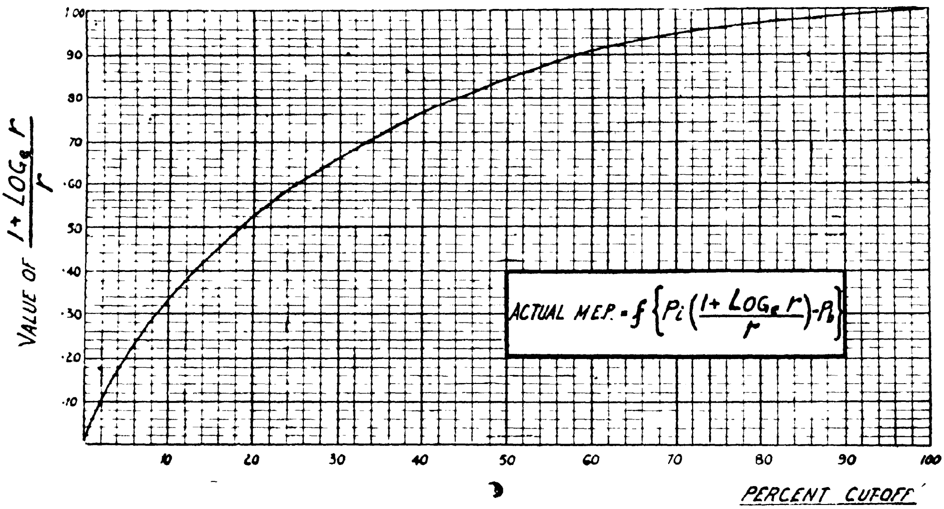
It has always been controversial as to which gives the best results for a fixed amount of cane crushed-a thin blanket at high speed, or a thick blanket at low speed. The problem is entirely different for an Indian Sugar Factory Engineer who has to crush the thickest blanket at the highest speed in order to achieve the required crushing capacity. The Engineer has often run the mill engines at speeds that would scare the makers if they could only see them.

CALCULATION OF ENGINE HORSE POWER

From the diameter of the cylinder and the stroke, the I.H.P. of an engine at a particular speed can be calculated from the mean effective pressure. The m.e.p. is given by the formula $P_m = f\left[P_a \frac{(1+\log_e r)}{r} - P_b\right]$ where P_a = admissio pressure in lbs./sq. in. abs. and P_b = Back pressure in lbs./sq. in. abs. r = rati of expansion, f = the diagram factor.

The values of $\frac{1+\log_e r}{r}$ for any cut-off can be obtained from the curv given in sheet I while the value of f for different types of engines may be take as follows :—

(i) D-slide valve engines 0.8 to 0.9
(ii) Piston valve engines 0.7 to 0.8
(iii) Piston valve with rider valve 0.75 to 0.8
(iv) Corliss Valve engines 0.85 to 0.95
(v) Drop Valve engines 0.85 to 0.9



VALUES OF $\frac{1+LOG_e r}{r}$

RESULTS OF INVESTIGATION

Figure Nos. (a) to (p) show typical indicator diagrams taken at various factories on the different types of engines described. Particulars regarding the size of engines, arrangement of drive and the powers developed are given in the corresponding sheets. The I.H.P's. of the engines have been calculated according to the above method.

It will be seen from the results tabulated in the various tables that under Indian conditions the power required for milling cane varies from 7 to 8 I.H.P. per ton fibre per hour per compression, and 16 I. H. P. per mill per ton of fibre per hour. These figures could safely be used for considerations such as (i) the rate of crushing to be maintained with the available power in mill engines (ii) additional units which could be added to be driven by the existing engines (iii) size of mill engines required for a particular plant and (iv) to assess whether the power consumed for milling is excessive due to causes such as high trash-plate setting or faulty intermeshing of gears.

CRUSHING CAPACITY OF MILLS

The power required for milling on a particular plant is evidently dependent upon its crushing capacity, but all known formulae for calculating crushing capacities give results which vary widely from actual rates attained in India. A table based on 1/10 tons per hour per sq. ft. of roller surface gave figures fairly closely representive of crushing rates 15 years ago but, with faster surface speeds and the use of feed rollers, crushing rates have been considerably increased. The following table gives the crushing rates in tons cane per day now being obtained generally on plants in India today.

Size in inches	Number of rollers				
	12	14	15	17	18
24″ x 48″	765	890	955	1080	1150
26″ x 52″	900	1050	1120	1280	1350
27″ x 54″	875	1140	1220	1380	1460
30″ x 60″	1200	1400	1500	1700	1800

FACTORY 'A'

Diagrams (a) to (d).

Type of Engines—	D-Slide Valves.
Milling Tandem—	12 Rollers 30″ x 60″.
Rate of crushing—	30,000 mds./day.
Fibre in cane—	16%.

Engine No.	1	2	3	4
Units driven	I	II	III	IV
Cylinder dia.	24″	24″	24″	24″
Stroke	42″	42″	36″	42″
Piston rod dia.	3-7/16″	3½″	3-3/8″	3½″
Tail rod dia.	3″	3″	2-7/8″	3″
Revs./min.	47	57	70	76
I. H. P.	115	96	88	126

Total I. H. P. developed = 425

I. H. P. per ton of fibre per hour per compression. = 7.24

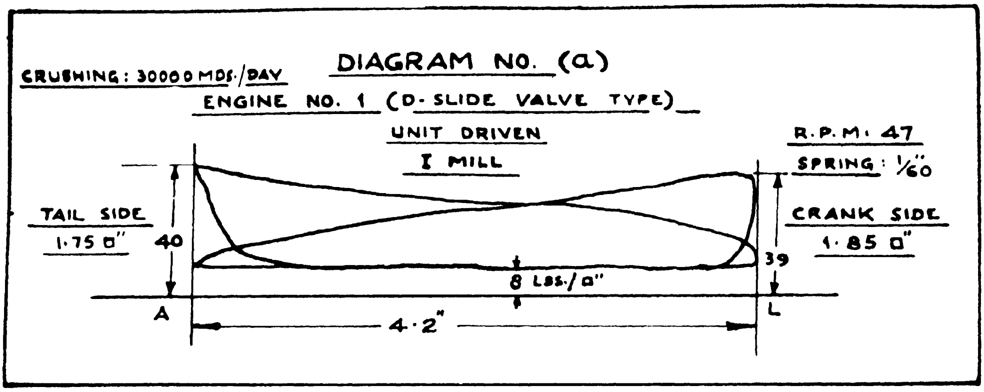


DIAGRAM NO. (a)
CRUSHING: 30000 MDS./DAY
ENGINE NO. 1 (D-SLIDE VALVE TYPE)
UNIT DRIVEN
I MILL
R.P.M. 47
SPRING: 1/60"
TAIL SIDE
1·75 □"
40
CRANK SIDE
1·85 □"
39
8 LBS./□"
A
L
4·2"

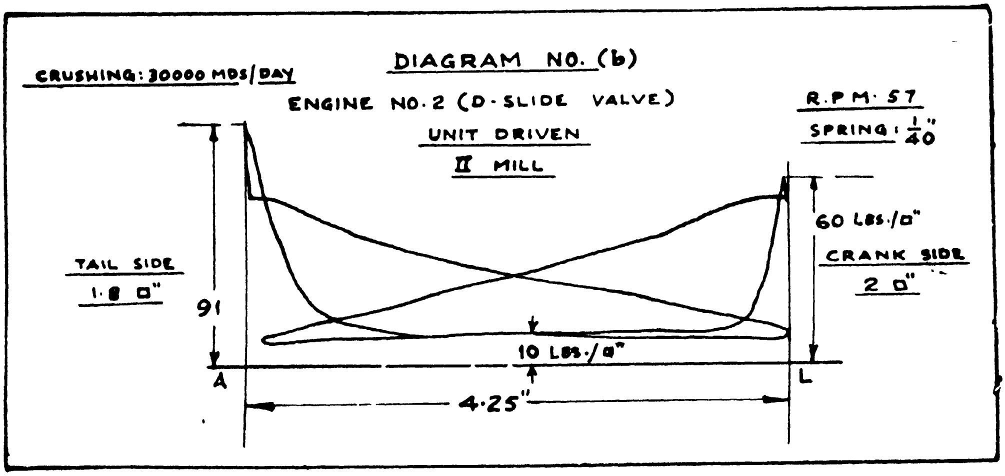


DIAGRAM NO. (b)
CRUSHING: 30000 MDS/DAY
ENGINE NO. 2 (D-SLIDE VALVE)
UNIT DRIVEN
II MILL
R.P.M. 57
SPRING: 1/40"
60 LBS./□"
CRANK SIDE
2 □"
TAIL SIDE
1·8 □"
91
10 LBS./□"
A
L
4·25"

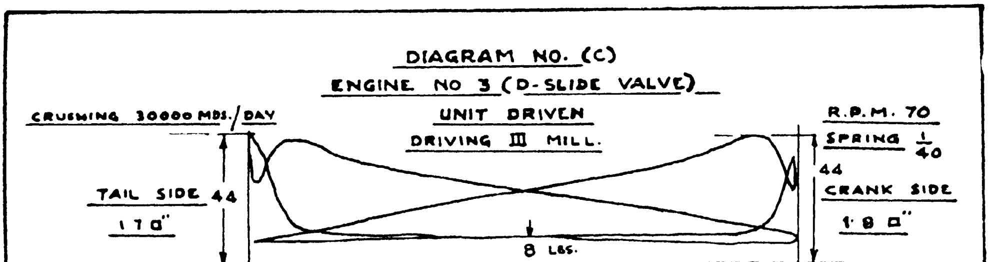


DIAGRAM NO. (C)
ENGINE NO 3 (D-SLIDE VALVE)
CRUSHING 30000 MDS./DAY
UNIT DRIVEN
DRIVING III MILL.
R.P.M. 70
SPRING 1/40
44
CRANK SIDE
1·8 □"
TAIL SIDE 44
1·7 □"
8 LBS.
A
L
4·5"

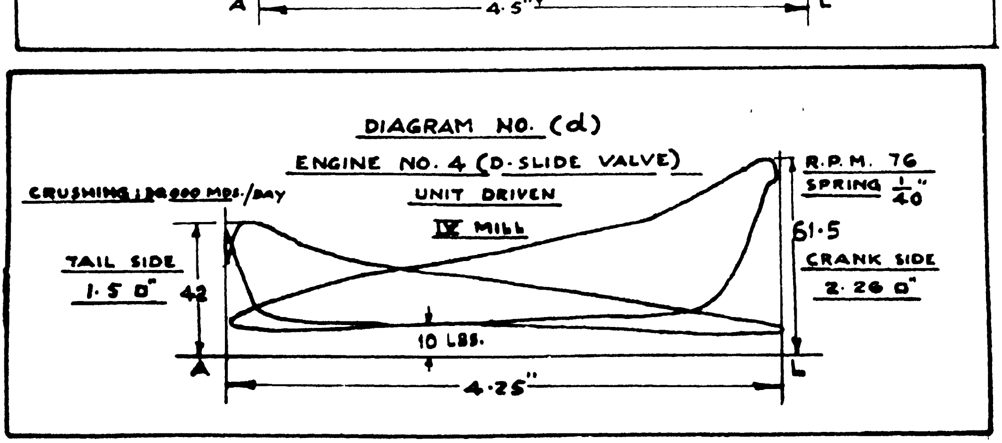


DIAGRAM NO. (d)
ENGINE NO. 4 (D-SLIDE VALVE)
CRUSHING: 30000 MDS./DAY
UNIT DRIVEN
IV MILL
R.P.M. 76
SPRING 1/40"
61·5
CRANK SIDE
2·26 □"
TAIL SIDE
1·5 □"
42
10 LBS.
A
L
4·25"

FACTORY B

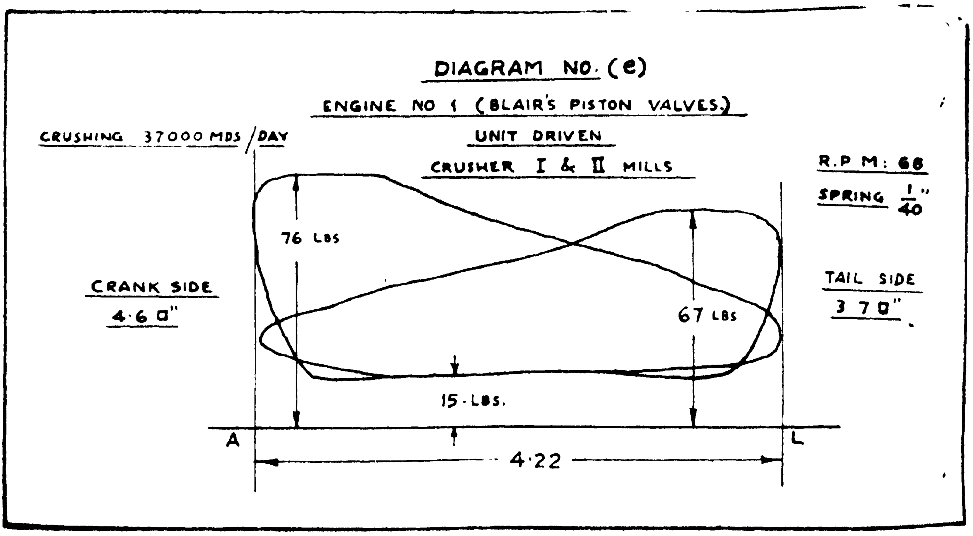
Diagrams (e) and (f)

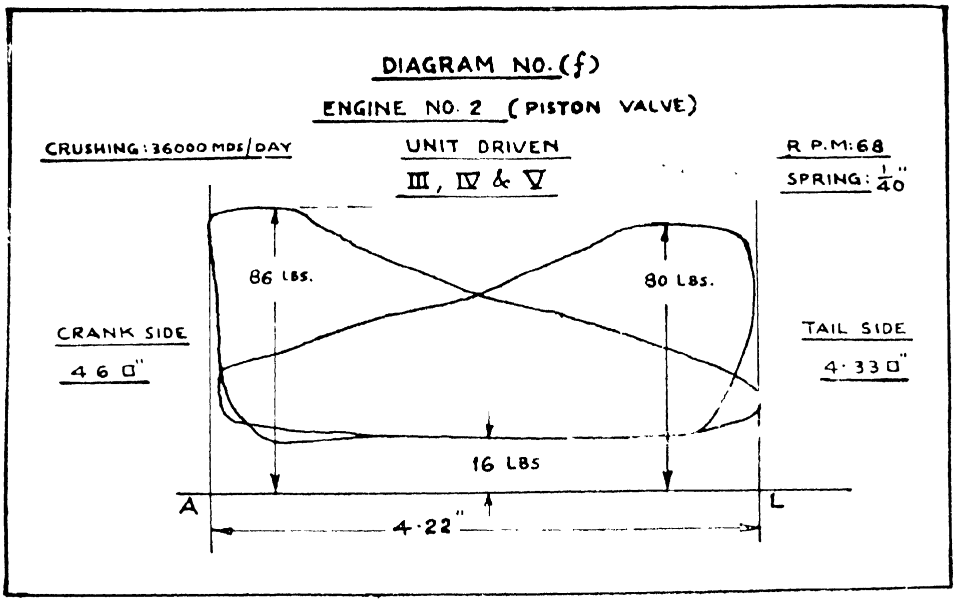
Type of Engines -	Piston Valve
Milling Tandem—	17 Rollers 30″ x 60″
Rate of Crushing -	36,000 mds./day
Fibre in cane—	15%

Engine No.	1	2
Units driven	Cr., I. II.	III, IV, V
Cylinder dia.	26″	26″
Stroke	48″	48″
Piston Rod dia.	5″	5″
Tail Rod dia.	3½″	3½″
Rev. per Min.	68	68
I. H. P.	335	360

Total I. H. P. developed = 695

I H. P. per ton of fibre per hour per compression = 7.5





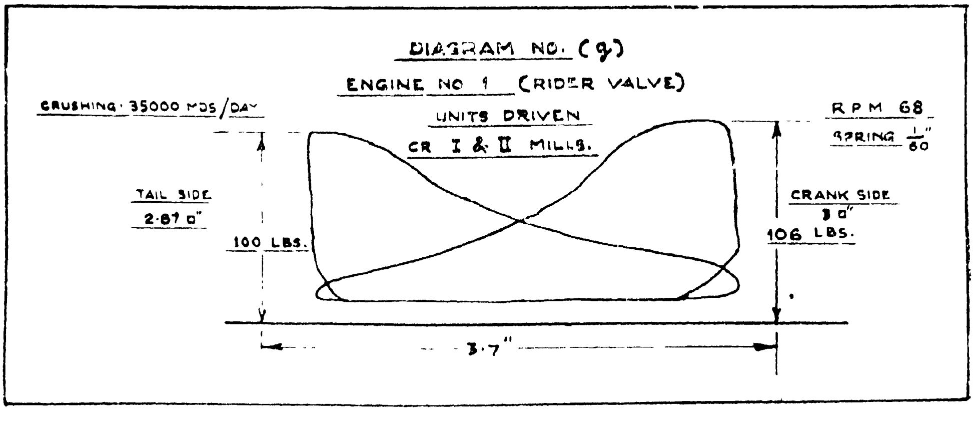
FACTORY 'C'

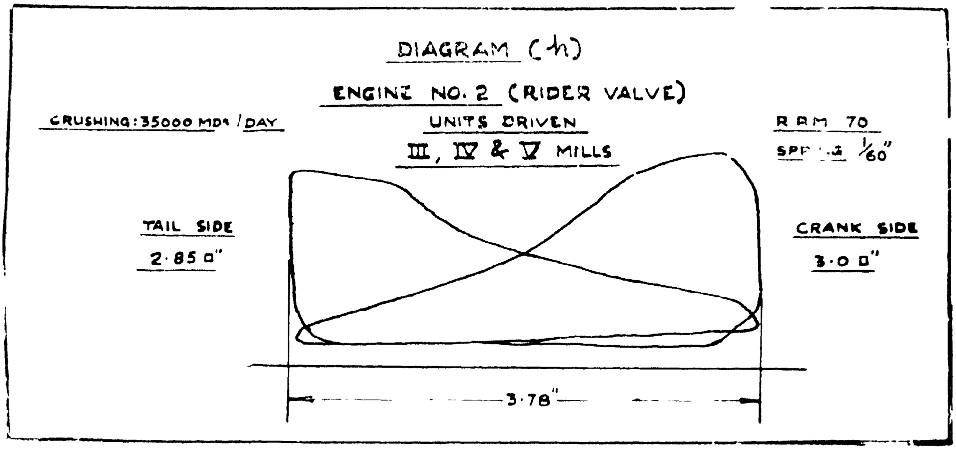
Diagrams (g) and (h)

Type of Engine—	Rider Valve
Milling Tandem—	17 Rollers 26" x 56"
Rate of crushing—	35,000 mds /day
Fibre in cane—	13.8%

Engine No.	1	2
Units driven	Cr., I., II	III, IV, V
Cylinder dia.	22"	22"
Stroke	48"	48"
Piston Rod dia.	4.125"	4.125"
Rev. per min.	68	70
I. H. P.	292	294

Total I. H. P. developed = 586
I. H. P. per ton of fibre per hr. per compression = 7.18





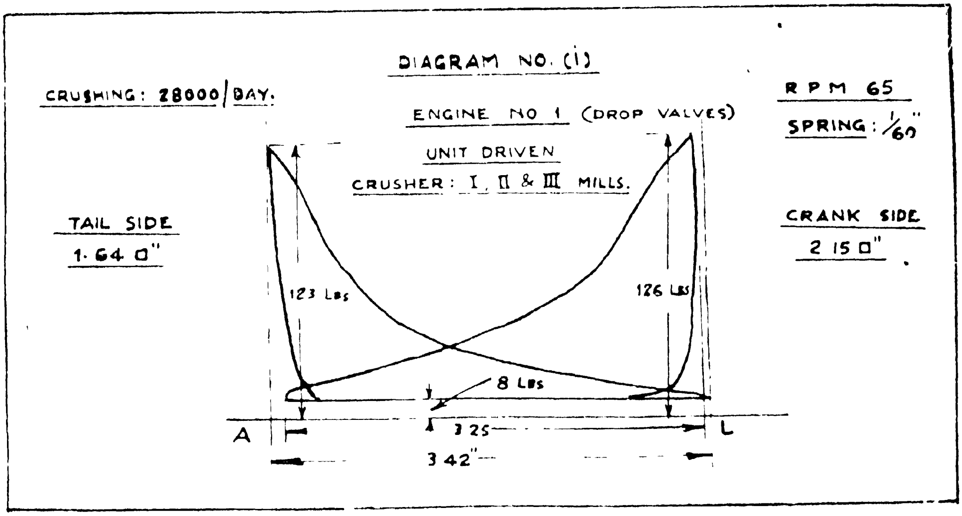
FACTORY D

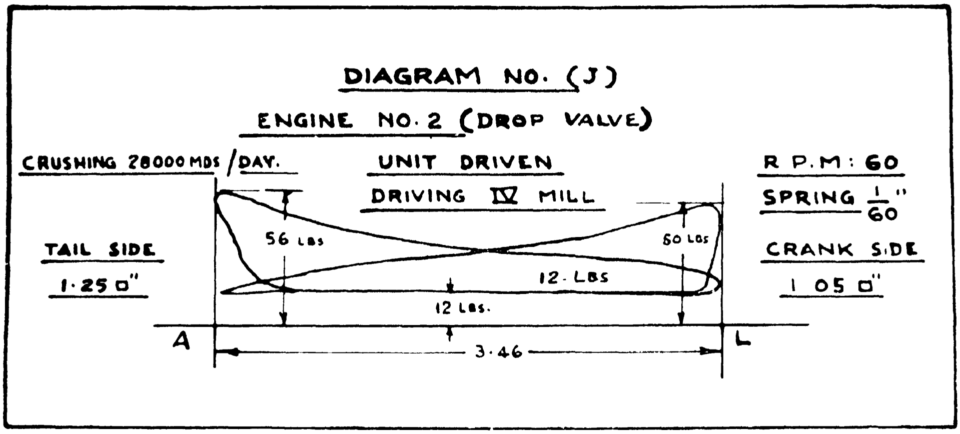
Diagrams (i) and (j)

Type of Engine—	Drop Valve
Milling Tandem—	14/30" x 60"
Rate of crushing—	28000 mds./day
Fibre in cane—	14.56 %

Engine No.	1	2
Units driven	Cr., I, II, III	IV
Cylinder dia.	31.5"	24"
Stroke	47.24"	42"
Piston Rod dia.	5.9"	3 5"
Tail Rod dia	5.9"	3.0"
Rev. per min.	65	60
I. H. P.	400	126

Total I.H.P. developed	— 526
I.H.P. per ton of fibre per hr. per compression	— 9.36





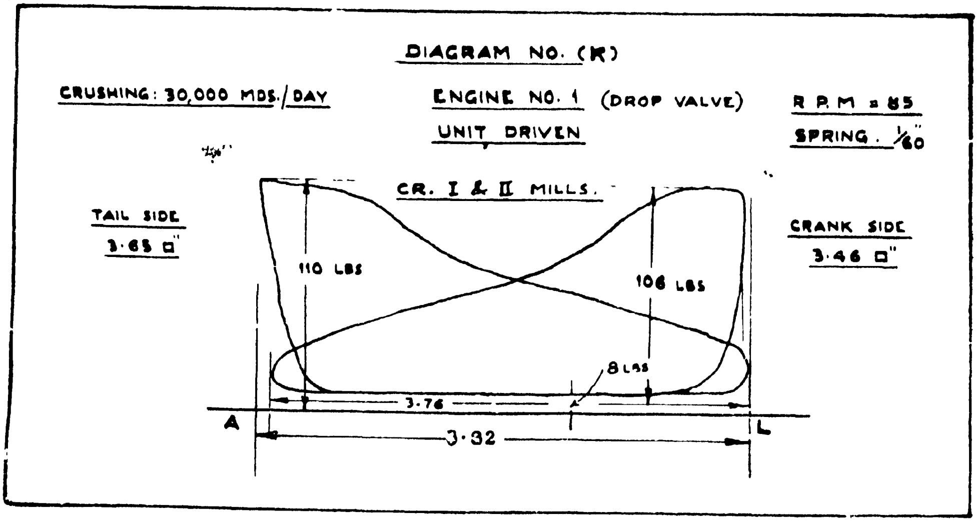
FACTORY E

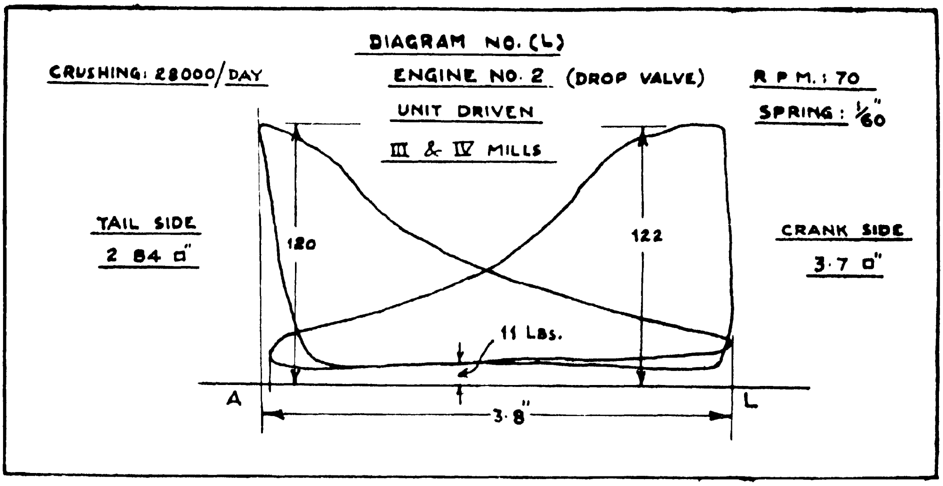
Diagrams (k) and (l)

Type of Engine— Drop Valve
Milling Tandem - 14 Rollers 30" x 54"
Rate of Crushing— 30,000 mds./day.
Fibre in cane— 15.15%

Engine No.	1	2
Units driven	Cr., I, II	III, IV
Cylinder dia	19 7"	19 7"
Stroke	35.4"	35.4"
Piston Rod dia.	3.88"	3.88"
Tail Rod dia.	3 88"	3 88"
Rev. per min.	85	70
I. H. P.	251	189

Total I.H.P. developed = 440
I.H.P. per ton of fibre per hr. per compression = 7.03





FACTORY F

Diagrams (m) and (n)

Type of Engine—	Corliss Valve
Milling Tandem	14 Rollers 30" x 60"
Rate of crushing—	27,000 mds./day
Fibre in cane—	15.5%

Engine No.	1	2
Units driven	Cr., I, II	III, IV
Cylinder dia.	23.64"	23.64"
Stroke	47.3"	47.3"
Piston Rod dia.	4.375"	4.375"
Tail Rod dia	3.937"	3.937"
Rev. per min.	65	69
I.H.P.	292	169

Total I.H.P. developed = 461

I.H.P. per ton of fibre per hr. per compression = 7.97

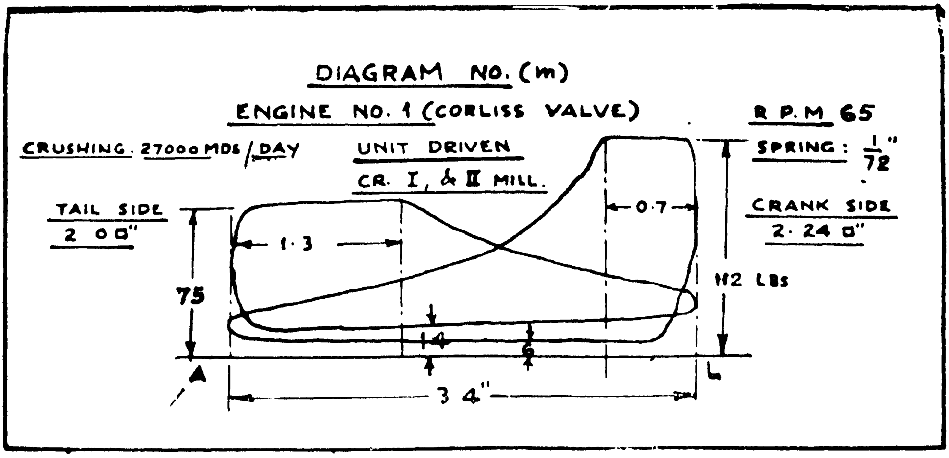


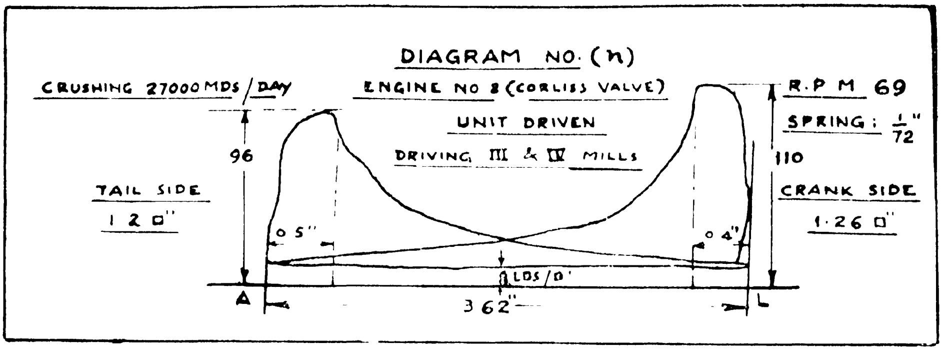
TABLE I

POWER FOR MILLING CANE

Factory No.	Size of Milling plant No. of Rolls Dia. x Length	Mill Engines :—Size, Speed Driving arrangements. 1	2	3	Rate of crushing/day Mds	Tons	I. H. P. of the Engine 1	2	3	Total	M. E. P. Lbs./sq. in. Gauge	Fibre % Cane	Mill Extraction	Imbibition % fibre	Pol % Bagasse	H. P./ton of fibre per hr. per compression
1.	12 22″ x 36″	15-7/8″ x 27½″ 88 r.p m. I & II	15-7/8″ x 27½″ 96 r p.m III & IV	—	14400	525	136	122	—	258	61.5	14.84	93.06	101.5	3.72	9.8
2.	17 26″ x 54″	26¾″ x 47¼″ 68 r.p m Cr., I & II	26¾″ x 47¼″ 80 r.p m. III, IV & V	—	24000	875	238	242	—	480	26.2	16.3	91.76	108	3.16	7.2
3.	15 24″ x 48″	24″ x 42″ 60 r p.m. I, II & III	24″ x 42″ 70 r p m. IV & V	—	24000	875	277	151	—	428	39.2	15.8	91.75	126	2.95	7.4
4.	14 30″ x 54″	19-11/16″ x 33-55/64″ 95 r.p.m. Cr., I & II	19-11/16″ x 33-55/64″ 95 r.p m. III & IV	—	32000	1170	245	257	—	502	55.3	13.9	92.01	109	3.20	8.2
5.	14 24″ x 48″	17-45/64″ x 27-35/64″. 86 r p.m. Cr., I & II	17-45/64″ x 27-35/64″ 108 r p.m. III & IV	—	22000	800	215	149	—	364	59.6	15.3	90.73	84	2.98	7.8
6.	12 28″ x 56″	24 8″ x 35 4″ 78 r p.m. I, II, III & IV	—	—	26000	950	376	—	—	376	61.0	15.6	91.13	125	2.86	7.9
7.	15 24″ x 48″	24″ x 42″ 45 r.p.m. I, & II	24″ x 42″ 50 r p.m. III, IV & V	—	20000	730	215	157	—	372	51.6	15.1	91.08	91	2.96	8.1
8.	18 24″ x 48″	24″ x 48″ 55 r.p m. I, II, III & IV	22″ x 36″ 50 r p.m. V & VI	—	20000	730	365	125	—	490	52.7	14.2	92.96	130	2.79	9.5
9.	17 28″ x 56″	16¾″ x 23-5/8″. 120 r.p m. Cr.	24-13/64″ x 35-7/16″. 75 r.p m. I & II	19-11/16″ x 47¼″ 67 r.p.m. III, IV & V	29000	1060	105	230	293	628	46.9	17.3	92.24	161	2.7	7.4

(*Continued*)

10.	15 30" x 60"	26" x 48" 60 r.p.m. I & II	32" x 60" 58 r.m.p. III, IV & V	—	48000	1750	340	556	—	896	46.5	15.7	90.25	157	3.65	7.8
11.	15 24" x 48"	28" x 48" 55 r.p.m. I, II, III & IV	—	—	24000	875	422	—	—	422	61.8	15.7	91.19	127	3.11	7.3
12.	14 24" x 48"	20" x 36" 70 r p m. Cr., I & II	20" x 36" 67 r p.m. III & IV	—	22000	810	233	115	—	349	47.4	16.0	91.04	130	3.36	7.2
13.	11 30" x 60"	30-7/16" x 48" 45 r.p.m. Cr., I, II & III	—	—	19000	700	326	—	—	326	41.0	15.2	90.65	128	4.50	8.4
14.	17 26" x 54"	26-49/64" x 47½" 75 r.p m. Cr., I & II	26-49/54" x 47½" 80 r.p.m. III, IV & V	—	30000	1100	352	377	—	729	37.0	17.9	93.15	141	2.25	7.9
15.	14 20" x 36" 3 24" x 36"	20" x 36" + 80 r p m. Cr. I & II	18" x 36" 66 r.p.m. III & IV	16" x 24" 92 r p m. V.	21000	773	185	119	67	371	38.2	17.0	92.16	118	3.20	7.4
16.	15 24" x 48"	22" x 42" 76 r p.m. Cr., I & II	20" x 36" 70 r.p.m III & IV	—	22000	810	316	77	—	493	49.75	17.5	91.98	159	3.12	8.3
17.	12 28" x 56"	24-13/16" x 35-7/16" 90 r p.m. I, II, III & IV	—	—	25000	920	512	—	—	512	68.0	16.8	91.47	161	2.88	9.8
18.	12 24" x 48"	24" x 42" 65 r p.m I, II, III & IV	—	—	17000	627	222	—	—	222	40.0	15.0	92.19	142	3.02	1.7
19.	14 24" x 48" 3 18" x 36"	20" x 36" + 77 r.p.m. Cr., I & II	20" x 36" 80 r.p.m. III & IV	19-11/16" x 31½" 60 r p m. V	26000	950	166	138	110	414	41.0	16.4	91.97	130	2.97	5.0
20.	18 24" x 48"	24-7/32" x 35-7/16" 65 r.p m. I, II, III & IV	14-11/16" x 23-5/8" 100 r.p.m. V & VI	—	27000	1000	265	95	—	360	57.5	14.4	93.83	113	3.45	5.7



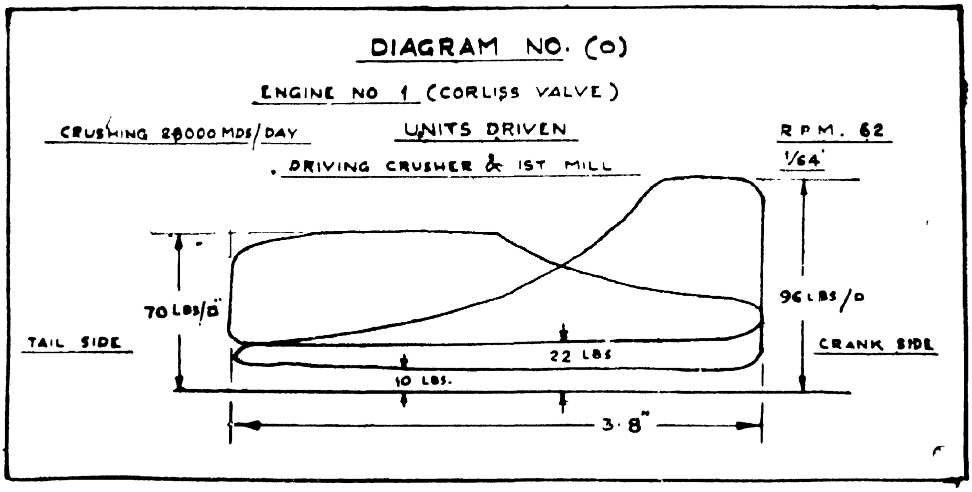
FACTORY G

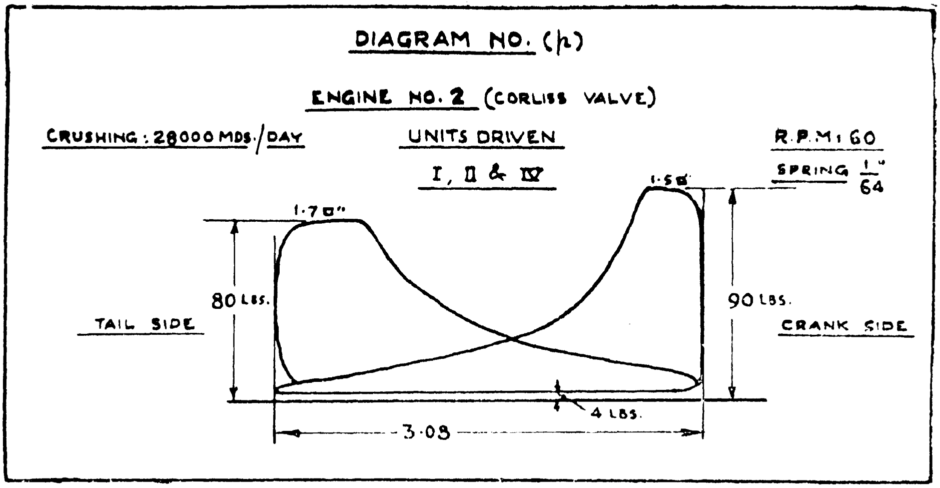
Diagrams (o) and (p)

Type of Engine	Corliss Valve
Milling Tandem	15 Rollers 26″ x 54″
Rate of Crushing	28,000 mds./day
Fibre in Cane	12.9%

Engine No.	1	2
Units driven	Cr., I	II, III, IV
Cylinder dia.	21.654″	26.016″
Stroke	39.37″	47.244″
Piston Rod dia	3.937″	4.33″
Tail Rod dia.	3.5435″	3.937″
Rev. per min.	62	60
I.H.P.	177	210

Total I.H.P. developed	387
I.H.P. per ton of fibre per hr per compression	7·03





DISCUSSION

Mr. Livie remarked that there was no reference on the use of shredders and knives in the comparisons made in this paper.

Mr. Bhargava replied that two sets of knives had been used in all the mills and no shredders had been used.

Mr. Scriven enquired about the optimum crushing rate obtained by means of modifications of gearings.

Mr. Bhargava replied that the increase in speed from 25′ per minute to 40′—45′ per minute increased the milling capacity by 25 to 30 per cent. In most cases only the first motion gears had been modified.

Mr. J.P. Mukerjee enquired whether there was any co-relation between the power required for milling and crushing rate and milling efficiency.

Mr. Bhargava stated that for new plants, the power requirement should not be less than 10 H.P. per ton fibre per hour per compression and it should preferably be 12.

Mr. Hizon stated that provision of more power in the preparatory devices improved both crushing capacity and milling efficiency. It will thus be seen that power in mill engines was not the only factor. Hydraulic load on the top roller was also an important factor.

Mr. Bhargava stated that a hydraulic load in the region of 56 tons ft. length of the roller with adequate power in mill engines and proper mill settings would result in an extraction of 95%.

The paper was summed up by the Chairman stating that it provided very useful practical data and a consistent set of figures to act as a starting point for considering power requirements in mills. He complimented the authors on the extremely useful practical data presented by them.

Mr. G. H. Jenkins then presented his paper.

Paper

A BASIS FOR ASSESSING POWER REQUIREMENTS IN CANE MILLING

G.H. JENKINS
University of Queensland, Brisbane, Australia

INTRODUCTION

In order to make any estimate of the mechanical efficiency of crushing, it is necessary to have a knowledge of the theoretical power requirements for crushing cane. In this paper an attempt is made to calculate the theoretical power requirements for a typical case in terms of normal performance figures.

Tests were made with an hydraulic press to establish the relation between pressure applied and volume of compressed bagasse. From this pressure-volume relationship the work required to compress the cane to any given degree can be calculated ; this gives a basis for estimating the power to crush a given tonnage of cane per hour in a mill under specified conditions of fibre content, degree of preparation and degree of compression.

STEPS IN THE EXTRACTION OF JUICE

The extraction of juice from cane by pressure involves three steps, each requiring the performance of mechanical work :—

(1) breaking up of the structure of the stalk to separate the cane cells from one another

(2) expressing juice from the cane cells

(3) forcing the expressed juice out through the mass of compressed fibres

These three steps to a large extent take place simultaneously. The mechanical work involved in (1) will vary greatly with the degree of preparation since, with finely prepared cane, much of this work has already been done by the cane preparation devices. This is well illustrated by the curves shown in Fig. 3, which are discussed later.

The work involved in steps (1) and (2) is readily established by laboratory tests with a hydraulic press under static or slow speed conditions, where ample time is allowed for the juice to drain away. Under these conditions the work necessary under step (3) to force the juice through the compressed mat of fibre is negligible ; but under practical milling conditions, where the cane is under pressure for a period of 3 seconds or less, the pressure drop required to force the juice through the bagasse in such a short time will involve a substantial extra load. Any estimate of power requirements at practical rates of milling will therefore involve an estimate of the work required for step (3) i.e., for maintaining the necessary rate of flow of juice through the bagasse.

REVIEW OF PUBLISHED WORK

Pressure-Volume Relationships. Tests to establish the pressure-volume relationship under static conditions were reported in 1921 (and earlier) by Deerr (2) in Hawaii and more recently by Shannon (5) in the West Indies and Atherton (1) at the University of Queensland. Shannon also describes tests at high speed to simulate mill conditions.

All these investigators report similar results, the pressure rising slowly in the early stages when the bulk of the juice is being removed and more rapidly in the later stages when only a small proportion of juice remains and the fibres are becoming closely compressed. A considerable increase in pressure is then required for a small increase in extraction of juice and a consequently small reduction in volume of the residue. Thus the graph of pressure-volume relationship consists of two portions described (according to Deerr) by the equation $PV^{2 \cdot 5} =$ constant for lower pressures and $PV^5 =$ constant for higher pressures.

Power Requirements. From the P-V relationship, Deerr calculates the work requirement per unit area as $\int dV$ between the appropriate limits for V, using the relationship $PV^5 =$ constant, as obtained by static press tests. He calculates the horse power required for a mill crushing the same weight of fibre per unit escribed area as used in the test, and at a specified rate in terms of escribed area per minute.

His numerical example gives a reasonable figure of 35 H.P. for actual crushing requirements of a three roller mill (excluding all frictional losses), for a crushing rate of 12,000 lbs. fibre per hour. Inspection shows, however, that the example postulates a bagasse containing 59 lbs. fibre per cubic foot, a figure impossible of attainment in practice, at least in a first mill. Since the figure is calculated on static P-V relationships it underestimates the power required, and it is only due to compensating errors that the example gives a reasonable figure for power requirement. It should of course be mentioned that Deerr intended this figure for comparative purposes only, and not as a firm estimate of actual power requirements. Deerr's calculation is also open to criticism as using the expression $PV^5 = K$ over a range for which it is probably inapplicable.

Using some of Deerr's figures Hugot (3) shows that the relationship, $PV^6 =$ constant, applies very closely at pressures above 760 p.s.i. (50Kg./cm.), and expresses it in the form $P = \frac{70}{(10c)^6}$ where $c = h/H$, the ratio of thickness of bagasse layer under pressure to thickness of the loose bagasse at zero pressure. By integrating P with respect to V, and expressing P in terms of the total hydraulic pressure on the top roller he derives an expression for horse power as a function of c^6. He then proceeds to derive a simple formula giving horse power as a function of hydraulic load, roller speed and other simple operating figures. These expressions however are derived from Deerr's figures for the static P-V relationship and take no account of the additional work required to maintain the flow of juice through the bagasse blanket at practical rates of milling.

Linley (4) gives some horse power figures calculated (with some assumptions) from estimated pressures between mill rollers. These show considerably higher values than those by Deerr's formula ; e.g., 127 H.P. for actual crushing compared with 73 H.P. for Deerr's conditions. Linley also stresses the importance of good drainage.

Tromp (6) considers that all the power used in milling is consumed in frictional loads. This is surely in error as it entirely neglects the work of compressing the cane and extracting the juice.

FURTHER TESTS WITH PRESS

In order to obtain further data on the P-V relationship with different degrees of preparation, and to obtain some indication of the effect of rapid application of pressure, a series of tests was carried out with the hydraulic press used by Atherton (*loc. cit.*).

The press, illustrated in Figs. 1 and 2, is designed for use with oil, to a maximum pressure of 3,000 p.s.i. and is fed from a positive displacement, cam-driven oil pump. The oil piston has a maximum diameter of 9 in. which is stepped down to 8.75 in. as shown in Fig. 2. Oil pressure is always applied below the

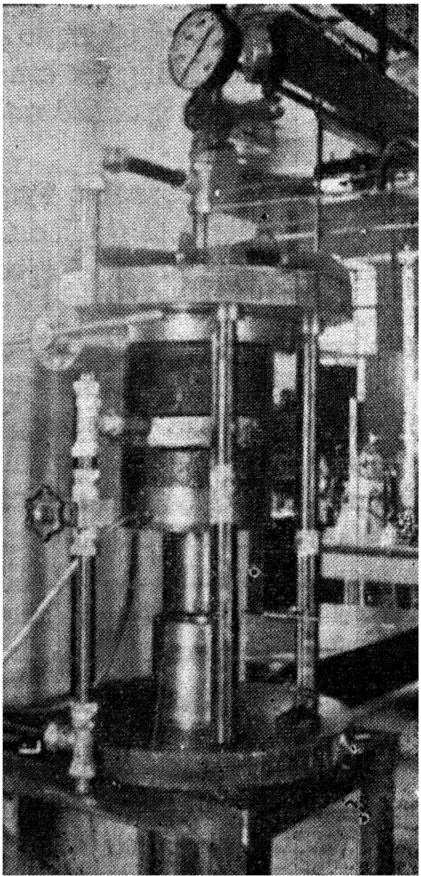


Fig. 1.

step to allow the piston to be raised by releasing the pressure above it. No leathers or other oil seals are provided between piston and cylinder as these would cause frictional resistance of unknown magnitude. The cylinder and piston are ground to close tolerance (0.0007 in. on diameter) and any leakage of oil past the piston is trapped in a drainage groove and a copper tray (not shown) attached to the bottom of the piston. The movement of the piston is controlled by means of a three-way cock on the oil line which can be seen near the top flange in Fig. 1. Several interchangeable bagasse pistons and cylinders are provided, the piston shown in the illustrations and used in most of the tests being 4 inches in diameter.

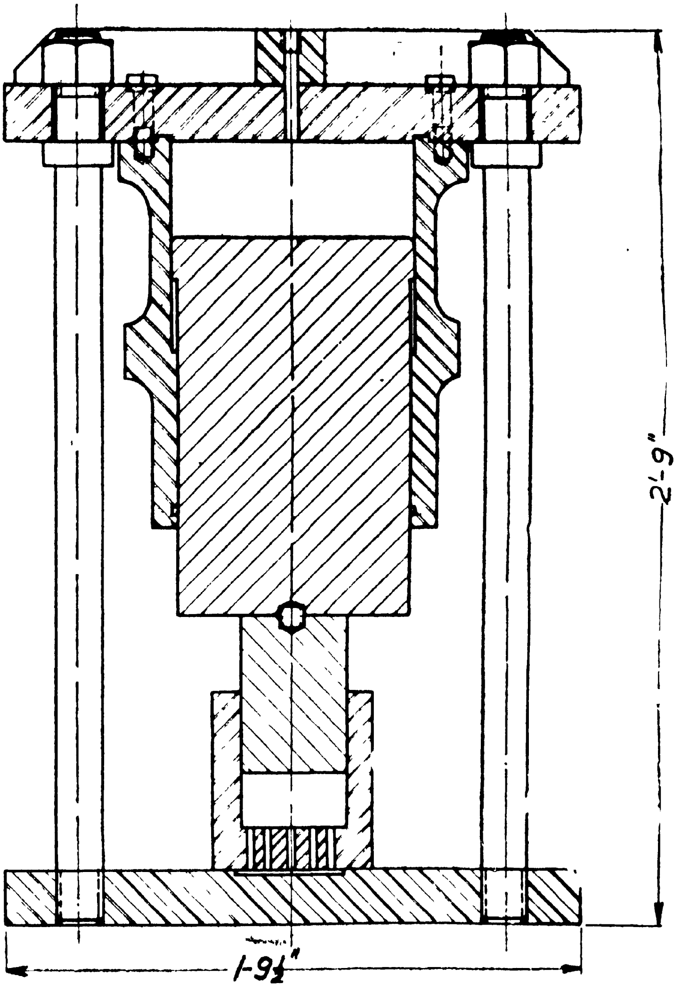


Fig. 2.

The cane was prepared by (a) a fibrator of the type used in Queensland for routine fibre determinations and (b) a small hammer mill of the type described by Waddell (7). The former gave preparation much finer than any commercial cane preparator, while the latter, using a fixed speed, a fixed weight of cane per batch and a fixed time of running, gave consistent preparation. A weight of 12 lbs. cane per batch was adopted, with a speed of 500 r.p.m. and times ranging from 15 to 60 seconds. This procedure gave a range of preparation varying from medium to extremely fine when judged on normal standards of industrial preparation.

The procedure in the static tests followed that described by Atherton. For the high speed tests, the capacity of the oil pump was insufficient for the rate of piston displacement required and a gas-oil accumulator was used. The latter consisted of a steel cylinder containing oil and nitrogen, the quantity of nitrogen being such as to fill the cylinder at 950 p.s.i. By pumping oil into the cylinder the nitrogen was compressed to 1200 p.s.i. and on opening the accumulator to the cylinder of the press, oil was admitted at a sufficient rate to move the piston through its full travel in times as short as 1½ seconds, giving a final pressure in accumulator and cylinder of approx. 1000 p.s.i. The time was regulated by setting a valve in the oil line at a predetermined opening, and the opening of the oil line to the press was effected by rapidly opening the three-way cock admitting oil to the press.

Pressure and piston travel were recorded simultaneously by means of an engine indicator coupled horizontally to the oil line just above the press and suitably connected to the bagasse plunger to register the piston travel. The time taken from opening the valve until maximum pressure was reached, was measured with a stop watch, and more accurately, with a Kelvin Hughes recorder connected to a strain gauge attached to a suitable part of the oil system.

Permissible oil pressure was limited to approximately 1000 p.s.i. by the indicator spring. By using a 4″ dia. bagasse cylinder this gave pressures up to 4840 p. s. i. on the bagasse. Cane samples of 500 g. were used in all cases. For the static tests the 4″ cylinder was used in some cases and an 8″ cylinder in others, giving bagasse pressures up to 6300 and 2560 p. s. i. respectively.

DISCUSSION OF RESULTS

The results are summarised in the graphs in Fig. 3. Considering first the static tests, the marked difference in results for different degrees of preparation is at once evident from the graphs designated A to F, where A is for fibrated cane and the others for increasingly coarse preparation ; e.g., at 2500 p.s. i. the thickness of compressed bagasse is 0.47 inch for fibrated cane and 0.84—0.9 in. for the coarsest preparation. The juice extraction at a given pressure is correspondingly lower with the coarse preparation.

The rapid pressure tests show graphs displaced well above those for the corresponding static tests, e.g., graph H for fibrated cane and M, with a preparation of 20 seconds in the hammer mill. Graph L, for a comparatively slow compression is still well above the static curve. That is, for a given pressure the bagasse volume is much greater with rapid application of pressure i.e., more juice remains in the bagasse and extraction is much inferior ; or, what is more relevant interms of mill performance, for a given bagasse volume or degree of compression, the pressure required is much higher.

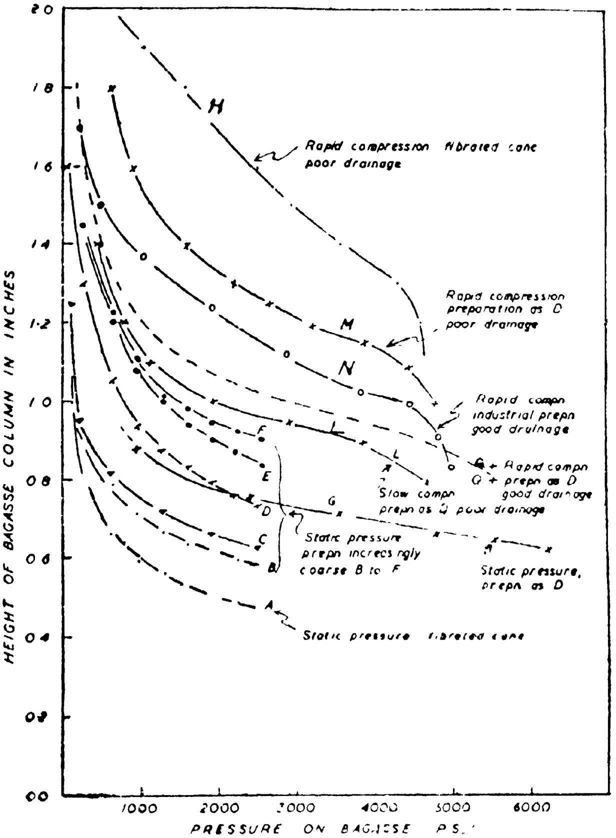


Fig. 3.

Graphs showing Pressure-volume relationships in hydraulic press tests on prepared cane.
A—slow compression, fibrated cane
B to G—slow compression, hammer mill preparation :-
B—60 seconds @ 500r.p.m.
C—30 seconds @ 500r.p.m.
E, G—22 seconds @ 500r.p.m.
D, F—15 seconds @ 500r.p.m.
H—Rapid compression, fibrated cane, time of compression 1.4 sec. M, L, Q, Q′,—Rapid compression, preparation as for D :—
M time of compression 3.2 sec.)
L ,, ,, ,, 20 sec.) poor drainage
Q ,, ,, ,, 2.2 sec.)
Q′ ,, ,, ,, 2.7 sec.) good drainage

In the rapid tests described, the drainage was definitely inferior to the above, the bottom of the bagasse cylinder being covered by a disc drilled with 21 holes of 3/32″ diameter, giving a drainage area only 1.2% of the total. In a typical Queensland mill roller with grooving of ¾″ pitch and a 3/16″ juice groove in alternate grooves, the drainage area is 12.5% of the total. " Drainage area " here refers to the area available for drainage from the bagasse blanket into the juice grooves, i.e., width of grooves per unit length of roller in this case 3/16 ÷ 3/2.

For rapid application of pressure, the volume at a given presssure will depend on the rate of compression and the efficiency of drainage. The latter in turn depends on the thickness of the bagasse layer and the area of drainage openings in the press or of juice grooves on the mill rollers. In the mill the flow of juice is partly backward (i.e., against the rotation of the roller) through the wedge shaped blanket of bagasse entering the mill, and partly downward through the bagasse blanket to the juice grooves. It is difficult to reproduce similar conditions in a press ; probably the nearest practical approximation would be a cylinder with drainage area at the bottom at least proportional to that of the juice grooves in a typical mill roller.

As a rough indication of the improvement in drainage with greater area, two tests were made using as drainage plate a disc of heavy brass gauze of 6 meshes per inch giving a drainage area of 55% of the total. In these tests final conditions only (maximum pressure, minimum volume) were measured, giving the points shown in the graph at Q-Q′, the probable position of the P-V graph for these conditions being as shown dotted. A static test with a sample from the same batch of prepared cane gave graph G. Hence for a given degree of preparation (20 seconds hammer mill treatment at 500 r.p.m.) the effect of rapid pressure with poor drainage is to displace the curve from G to M. With good drainage it is displaced from G to Q, a much smaller amount ; or the difference between good and bad drainage in the press corresponds to the distance between graphs M and Q.

A test with industrially prepared cane from a factory using two sets of knives gave graph N ; the coarse gauze drainage plate was again used in this test to give good juice drainage. Conditions for this test were not strictly comparable with the others, as the preparation was somewhat coarser than for tests G and Q, and the fibre loading slightly higher ; but it gives a useful confirmation of the graph Q.

When considering rate of compression we have to regard not only the mean rate of compression but the change of rate with time. With compression between rollers, the rate of compression decreases as the bagasse approaches the line joining the centres of the roller shafts. In the rapid press tests, the rate of compression decreases towards the end of the stroke, due to the decreasing pressure drop available between accumulator and cylinder (This is indicated by the tendency of the curves to turn downwards at higher pressures). In a 3-roller mill the pressure-volume relationship is further modified, (perhaps favourably) by the fact that the pressure is applied in two stages, and only part of the juice has to be extracted at the highest compression. These aspects have not yet been investigated.

CALCULATION OF POWER REQUIREMENT

The work required to compress a given weight of cane between any specified limits of volume is given graphically by the area under the P-V curve between those limits of volume or $\int PdV$ if the equation connecting P and V is known. It is convenient to consider unit area of cross-section of the cylinder, in which case the area under the curve represents $\int PdH$ or work per unit area or cross-section. It is obvious from the graphs that the work required for a given degree of compression would be much greater with rapid compression for a similar degree of preparation.

Any curve such as those of Fig. 3 applies only for a certain weight of cane, of a certain fibre content, per unit area, i. e., for a given weight of fibre per unit area. *Each curve in turn applies only for a given degree of preparation. In the tests represented in Fig. 3 the weight of cane was 2000 gm. (4.20 lbs.) in an 8″ dia. cylinder or 500 gm. (1.05 lbs.) in a 4″ cylinder, of cane of 11.6% fibre content, thus giving 0.0102 lbs. fibre per square inch cross sectional area (or 1.47 lbs. sq. ft.) in all cases.

The work required to compress this quantity of fibre (per unit area) from a thickness (a) to a thickness (b) is then given by the area between the graph and the H axis between the limits H = a and H = b.

The figure so derived gives a basis for calculating horse power of a mill at specified conditions, the calculation being given in the following paragraphs.

Deerr's example (2) gives a calculation for a mill handling the same weight of fibre per unit area of roller surface i. e., the same fibre loading as that treated in his experiments in the press. It is preferable that the results be applicable generally, i.e., to any fibre loading. For this some assumptions are necessary.

The work required to compress a quantity of cane under static conditions depends on (a) the degree of preparation,

(b) the quantity of fibre,

(c) the degree of compression.

The marked effect of degree of preparation is shown by the graphs in Fig. 3 and can be determined only by experiment. For a given degree of preparation it is assumed that the work required to achieve a given degree of compression is, firstly, proportional to area—to cross-sectional area for a press, or escribed area of rollers in a mill. This of course postulates uniformity of the cane layer.

Considering unit area, it is assumed that, for a given degree of compression, the work of compression is directly proportional to weight of fibre compressed. The pressure is essentially a function of the elastic properties of the fibre and the closeness to which the individual fibres are compressed : hence, at a given degree of compression, the thickness of the mat—and therefore the work of compression—will be directly proportional to the fibre loading. This assumption has been verified experimentally in two static tests, one with twice the fibre loading of the other.

For rapid compression the efficiency of drainage is also involved. This depends in part on the thickness of bagasse layer and hence the above assumption that thickness of layer is proportional to fibre loading will not apply for widely differing thicknesses. For calculation from press data to mill figures, the fibre loading should thus not differ greatly in the two cases.

The degree of compression is expressed in the graphs as thickness (H) of bagasse for *a given weight of fibre*. For general application in milling calculations

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* For convenience the term fibre loading (Hugot's 'charge-ligneux') is used to designate weight of fibre per unit area (lbs. fibre per sq. ft.)

it could be expressed as the more familiar figure of weight of fibre per unit volume of bagasse (or escribed volume) or as volume of fibre per unit volume of bagasse.

To maintain a simple relationship to the figures plotted in the graph the degree of compression is expressed as thickness of bagasse per unit fibre loading, e.g., inches per lb. fibre per sq. foot. It will be seen that this is essentially the reciprocal of weight of fibre per unit volume. For the purposes of the present discussion the figures are taken directly from the graphs and calculated to the basis of unit fibre loading.

The theoretical power requirements of a mill working under specified conditions may therefore be estimated if the P-V curve is known for the cane treated. This can best be shown by an example, the figures for which are taken from the actual records of a Queensland sugar factory.

Consider a No. 1 mill working under the following conditions :

Cane 108 long tons cane per hour
Fibre rate 13.2 tons fibre per hour
Size of rollers 38″ x 84″
Work opening (delivery) $1\frac{11}{16}$″ = 1.7″
Roller speed 24.0 f. p. m.
Cane preparation medium (high speed knives)
From these data is calculated,
Wt. of fibre per minute = 492 lbs.
Escribed area per minute = 168 sq. ft.
Hence fibre per unit escribed area (fibre loading) = 2.93 lbs. per sq. ft.

Choosing graphs G & Q as representing the corresponding degree of preparation for static and dynamic conditions respectively, it is now desired to use these to calculate the work done by the mill in the above example. The graph gives the P-V curve for 1.47 lbs. of fibre per sq. ft. of cylinder area. The mill is operating at a fibre loading of 2.93 lbs. per sq. ft. and the bagasse is compressed to a thickness H of 1.7″, the work opening at the back roller : The corresponding value of H for the fibre loading of the press (1.47 lbs./sq. ft.) will be $1.7 \times \frac{1.47}{2.93}$ or 0 85, i.e., the degree of compression in the back opening of the mill as expressed by thickness of bagasse per unit weight of fibre will be the same as that in the press at a value of H = 0.85. Hence the problem becomes one of calculating the work (per pound of fibre) to compress the cane from its loose condition to a condition where 1.47 lbs. of fibre per sq. ft. is compressed to a thickness of 0.85″.

The initial or loose condition of the cane is rather indefinite-should one take the initial volume in the cylinder as filled by hand, or the volume at a slight pressure ? A very slight pressure greatly decreases the volume, but this is not critical as the work involved in such initial compacting is negligible. For convenience a piston light (H) of 1.8″ is taken as the starting point, i.e., the small amount of work to compress the bagasse to this condition is neglected.

Calculating first for static conditions, graph G is used, and the area under the curve between the limits H=1.8 and H=0.85 is calculated. This gives the work required per square inch area to compress the cane between those values of H. The figure so obtained is 339 in. lb. per sq. in. or $\frac{339 \times 144}{12} = 4070$ ft. lb. per sq. ft. This is for 1.47 lbs. fibre per sq. ft.

The mill compresses 2.93 lbs. of fibre between those limits for every sq. ft. of escribed roller surface, hence the work done per sq. ft. escribed surface is

$$4070 \times \frac{2.93}{1.47} = 8{,}100 \text{ ft. lb.}$$

or per minute at 168. 2. sq. ft. E. S. per minute

$$8{,}100 \times 168.2 \text{ ft. lb.}$$

or power required $= \frac{8{,}100 \times 168.2}{33{,}000} = 41.3$ H. P.

This is the theoretical horse power to compress the given weight of fibre to the extent specified, and under static conditions, i.e., slow application of pressures.

Calculation of power consumption for rapid compression is similar to that for the static conditions, except that the work for the press conditions is now derived from graph Q, the area under the curve between $H = 1.8$ and $H = 0.85$ being 1184 in. lb. per sq. in. or 14,210 ft. lb. per sq. ft. i.e., 14210 ft. lb. for 1.47 lbs. of fibre.

Hence for the conditions in the mill the work per sq. ft. of escribed surface is

$$14210 \times \frac{2.93}{1.47} = 28{,}300 \text{ ft. lb.}$$

or for 168.2 sq. ft. escribed area per minute the power required,

$$= \frac{28{,}300 \times 168.2}{33{,}000} = 144 \text{ H. P.}$$

compared with 41.3 for static conditions.

The work figure could be derived in either case by integrating the equation to the appropriate graph between the limits concerned. However as the equation ($PV =$ constant) is not applicable over the full range under consideration the method of graphical integration has been preferred for the present purpose.

TOTAL HORSE POWER

The foregoing figures give the horse power for crushing only and neglect all frictional loads. These include :

Friction in the mill bearings

Friction of bagasse on the trash plate

Friction between scrapers and rollers and the work of scraping bagasse from the grooves.

The total of power for crushing and power for these purposes gives the total power input to the mill. (Where the intermediate carrier is driven from the mill, power for this drive should also be added). There are also the power losses in the engine and the intermediate gearing which must be allowed for. when estimating the I.H.P. or total power developed by the mill engine.

Hugot (*loc. cit.*) gives formulae for estimating the various losses assuming a pressure on the trash plate of 20% of the total top roller load and a friction coefficient between bagasse and steel of 0.4. For the friction between journals and bearings he assumes a coefficient of 0.03 ; with these assumptions he calculates the several power losses in terms of roller speeds and dimensions and hydraulic pressure on top roller. Hugot's coefficient of 0.03 however seems too low in comparison with figures given by other authorities, for the slow speeds, heavy pressures and imperfect lubrication of the typical mill roller. Hence a coefficient of 0.09 has been assumed in calculating for the conditions of the example. Thus the following figures are obtained :—

Friction in bearings	78 H.P.
Friction of bagasse on trash plate	39 H.P.
Friction of scrapers	10 H.P.
Intermediate carrier drive	10 H.P.
	137 H.P.

Adding the total of these to the dynamic figure of 144 H.P. derived for crushing requirements, the total power input to the mill is 281 horse power. Assuming mechanical efficiency of the engine at 85% and that of the intermediate gearing (machine cut) at 90%, the overall mechanical efficiency of the drive is 76% and the total power at the engine will be

$$\frac{281}{0.76} = 370 \text{ I. H. P.}$$

The example worked out is from operating records of mill over a period of one week, the mill engine being equipped with a revolution counter and with a recording pressure gauge registering mean effective pressure in the engine cylinder. From the records so obtained the average figure for No. 1 mill engine for the week was calculated at 320 I. H. P. The figure of 370 I. H. P. calculated above is in reasonable agreement with this ; in view of the nature of the data, closer agreement could hardly be expected, and the figures at least indicate reasonable agreement between calculated and measured power figures. The corresponding engine power calculated from the static theoretical figure of 41 H.P. is 234 I.H.P., which is far below the actual.

Mechanical efficiency of the mill. Taking the figures of 41 and 144 H.P. respectively for the static and dynamic theoretical power requirements the overall mechanical efficiency would be :—

$$\frac{41}{367} \times 100 = 11.2\%$$

or

$$\frac{144}{367} \times 100 = 39.2\%$$

depending on which figure is used as the theoretical ; it is suggested that it would be logical to use the static figure as the more fundamental basis for theoretical power requirement. In doing so the fact must be accepted that some additional power must be expended in order to work at a reasonable capacity ; but it should also be remembered that the extent of such additional power requirements is partly under the control of the engineer as dependent to a great extent on efficiency of drainage, which is controlled by thickness of blanket, efficacy of juice grooves and other factors.

CONCLUSIONS

A knowledge of the pressure volume relationship derived from a hydraulic press with static and dynamic tests provides a basis for calculation of theoretical power requirements in milling. On account of the large variations due to factors such as cane preparation and juice drainage, the present figures can be regarded as illustrative only, and not as accurate figures. However, the figures show that the power required for a given degree of compression is much greater with rapid than with slow compression, and is influenced very strongly by efficiency of juice drainage. Comparison with measured horse power figures suggests that the method is sound and with more comprehensive tests on prepared cane, or on bagasse fed to mills after the first, the method should give reliable quantitative figures.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to Messrs. J. Pidduck and K. J. Bullock of the Department of Mechanical Engineering for assistance in providing equipment and in carrying out the tests ; to Messrs. R. D. Deicke and J. D. Harland, post-graduate students in Sugar Technology, who conducted some of the static tests with the press, and to Australian Estates Ltd. for their willing co-operation in supplying relevant figures from their records of milling performance.

REFERENCES

1. Atherton, P. G. 1954. " Bagasse Compression Tests "—*Proceedings, Queensland Society of Sugar Cane Technologists, 21st Conference.*
2. Deerr, Noel. 1921. " *Cane Sugar* "—p. 187 ff.
3. Hugot, E. 1950. " La Sucreriede Cannes "—p. 108, 175 ff.
4. Linley, R. A. 1948. " Pressure Conditions in the Sugar Cane Mill "—*Proceedings, B. W. I. Sugar Technologists*, 1948, p. 34.
5. Shannon, C. R. D. 1942. " An Investigation of the Milling Process"—*Proceedings, B. W. I. Sugar Technologists*, p. 38.
6. Tromp, L. A. 1936. " Analysing the Consumption of Milling Power "—I. S. J., 38, p. 377 also " *Machinery and Equipment of the Cane Sugar Factory* " p. 194.
7. Waddell, C. W. 1943. " Effective Fibre Determination in Sugar Cane "—*Proceedings Eighth Congress I. S. S. C. T.*, p. 828.

DISCUSSION

Mr. Livie stated that cane preparation and mill extraction were very closely inter-related and the figures quoted also agreed closely. He did not agree with thin blanket and high speeds but maintained that a thick blanket and slow speed can give 97% extraction. He also stated that although conforming generally with Mr. Jenkins' figures for power requirements, he nevertheless felt that the power for crushing was on the low side and friction loss in bearings on the high side but agreed otherwise.

The Paper could be regarded as a fundamental approach to power for milling.

Dr. Doss asked whether the author had tried imbibed bagasse, i.e., bagasse and water or original cane and also the difference between time factor—2 seconds to 4 seconds. It was stated in reply that there was much less power requirement with the water addition but could give no opinion between the time factors of 2 seconds to 4 seconds as control was not fine enough.

The Chairman summing up stated that the figure of 27 H.P. per ton of fibre/hr. varies considerably from the 19 H.P. as stated in the last paper and 24 H. P. per ton of fibre/hr. specified in America for turbine drives.

Mr. Bhargava's figures averaged 10 H.P. whereas Mr. Jenkins' was of the order of 14 H.P. and that experiment and research figures seem to correlate fairly well.

The paper may be regarded as a fundamental basis for comparison of power for mills and for a proper basis of comparison B.H.P. and not I.H.P. should be taken into account.

In the absence of the author Prof. Shaw presented the following paper.

Paper

SELF FEEDING CHARACTERISTICS OF AN EXPERIMENTAL SUGAR MILL

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INTRODUCTION

The feeding of sugar cane mills has always presented a problem to the mill engineer, and in these days of high extraction efficiency and large throughput is an important factor contributing to the good performance of the milling train. Many devices have been applied for improving the feeding characteristics of sugar cane mills, among the more usual being precompressor rolls, reciprocating pushers, high feed chutes and continuous pressure feeders.

In an experimental mill it is possible to simulate the above types of feeding devices and a consideration of the characteristics of high speed-high productivity; self feeding mills with precompressor rolls suggested that these aspects might be taken as a basis for an experimental investigation into mill performance during self feeding.

The variables analysed during the series of experiments were preparation, speed, and precompression pressure. The work was primarily carried out to give confirmatory values to the coefficient of friction of cane on iron surfaces. The juice extraction was taken as supplementary to the experiments on angle of nip and the determination of the coefficient of friction.

SCOPE OF THE EXPERIMENT

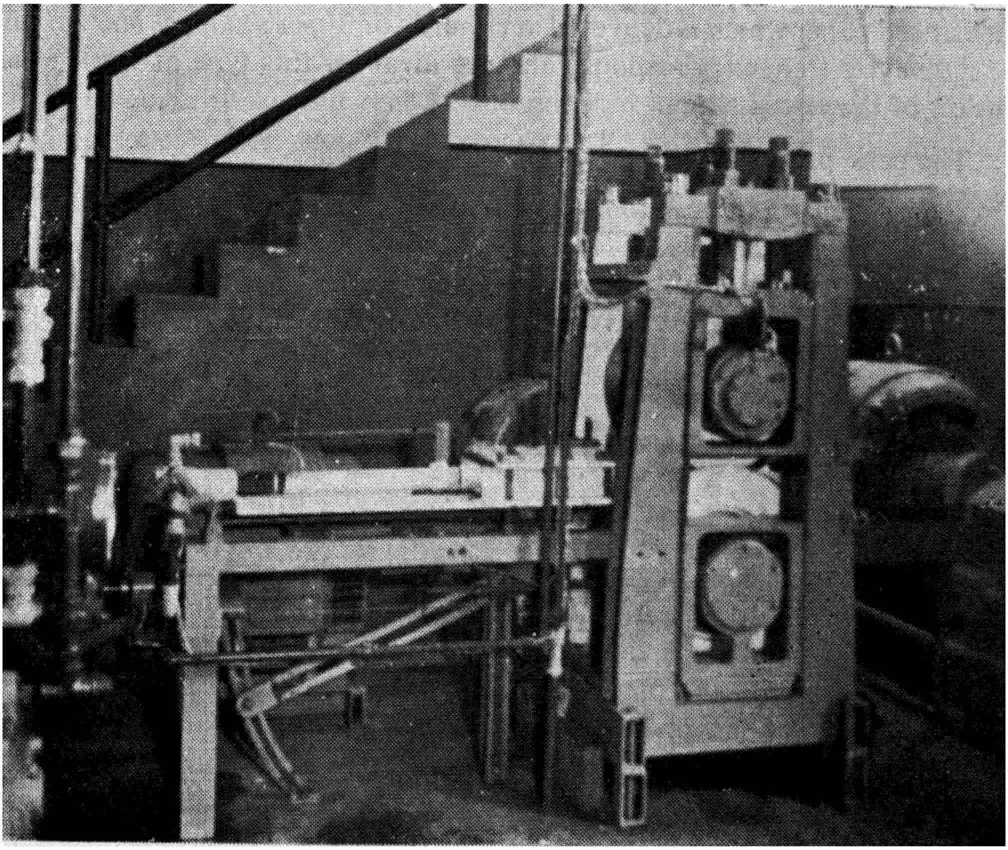
The result of the experiments give a quantitative analysis of mill feed characteristics under self-feeding conditions. The experiments included an investigation of the dynamic coefficient of friction for fibrated cane on the mill roll surface. The information on angle of nip and coefficient of friction is thought to be general. However the juice extraction information is probably limited in its practical application, because of the following differences from accepted mill practice :—

(a) 18″ diameter rolls

(b) Roll grooving of fine pitch without juice grooves.

(c) An intermittent process

Other important relationships, viz.. compression ratio, the occurrence of mill slip and the ratio of bagasse volume to escribed volume have been investigated.



APPARATUS

The experimental two roller mill is shown in Fig. 1. The rolls are 18″ dia. and 10″ wide, with grooving of 1/3″ pitch, 11/32″ deep and 34° included angle. The roll shafts are mounted in spherical roller bearings. The bearing block instrumentation enables the roll loads to be accurately determined both in magnitude and direction. The drive to the shafts is from a 50 H. P. Ward Leonard controlled motor through a worm gear unit to the lower shaft and chain drive to the upper shaft. The shafts and gearing are capable of delivering 90,000 in. lb. torque.

The rolls are fixed by the large screws seen projecting above the mill stand. The roll opening can be set at any desired value enabling accurate calculations of escribed volume to be made. The horizontal feed chute shown to the left of the mill stand was removed during this experiment. The bagasse was delivered into a copper tray which is shown at the rear of the mill. The juice drains to a stainless steel tray from which it is drawn into weighing containers.

The instruments which are not shown-normally record the two roll torques, the feed chute pressure, the horizontal and verticle components of the top roll bearing loads, and the speeds of the rolls and feed chute plunger. The instruments use electric resistance strain gauges, mounted on appropriate parts of the mill, as the measuring elements. The signal is amplified and recorded on sensitised paper which is delivered at either 1″ or 3″ per second. The instruments have a 90 cycle frequency response and are ideal for this type of work where the duration of the test is short.

The cane preparation devices are—

(a) A hammer mill to Mr. C. W. Wadell's design running at speeds of 500 or 750 r.p.m. This mill is capable of producing a wide variety of commercially prepared canes starting from whole sticks 10″ long. It is a batch process treating 6 lbs. of cane at a time.

(b) A commercial fibrator.

THE PRECOMPRESSOR

This apparatus is essentially a box with collapsible sides, a fixed bottom and a moveable top. The top is pressed down by a hydraulically operated plunger capable of compressing blocks of prepared cane 9″ wide, 18″ long in depths up to 5″. An open-ended aluminium tray, 18″ long 9″ wide, with sides 7″ high was used with the precompressor. The tray is also a suitable container for the weighing of the prepared cane samples, and facilitates the placing and removal of the prepared cane into and from the precompressor. The precompressor is filled by removing one of the ends ; the sides fold back slightly to allow easy loading and withdrawal of the material.

The precompressor is capable of exerting a pressure of 27 p.s.i. over the total plan area of the block of prepared cane.

METHOD OF TEST

The various treatments were first listed and given symbols so that a statistical approach might be made to the problem.

The code is set out in the table below—

Preparation	P_1 Fibrated	P_2 Fine Commercial		P_3 Coarse Commercial	
Precompression	f_1	f_2		f_3	
Pressure p.s.i.	2.5	5.0		7.5	
Speed f.p.m.	S_1 10	S_2 25	S_3 40	S_4 60	S_5 75

P_2 corresponds approximately to fine commercial preparation with two sets of knives and a shredder.

P_3 corresponds approximately to coarse commercial preparation with two sets of knives.

The experiment included each of the possible 45 combinations of the three variables. A typical test would be designated P_1 f_2 S_5 denoting fibrated cane, precompressed to a pressure of 5 p.s.i. and crushed at a roller speed of 75 f.p.m. The cane variety was Q. 28, and the average fibre over the period of the test was 12%.

This particular set of experiments was conducted with a fixed work opening of 0.4″, this being chosen after preliminary experiments as giving a fair extraction with maximum throughput of the mill. The cane was prepared in bulk lots of 60 lbs. approximately, which was sufficient for half a day. The height of the cane block after precompressing was naturally dependent on the weight of cane, state of preparation, and the pressure to which it was subjected. The function of the precompressor was not the expression of juice, but the formation of a block of prepared cane which by virtue of precompression possessed a tensile property. Tests showed that with fibrated canes pressure greater than 7.5 p.s.i. expressed juice in the precompressor and a pressure of 7.5 was therefore taken as the maximum. This enabled a comparison of fibrated cane to be made with commercial types of preparations. A pressure of 25 p.s.i. could,, however, be applied to cane of the coarsest preparation without any appreciable juice extraction.

After the first few tests it was possible to determine approximately how much cane the mill would self-feed with each combination of the variables. This weight of cane would then be determined from a graph of cane heights against precompression pressure, with the standard preparations as parameters.

The prepared cane was evenly packed in the aluminium tray using wooden blocks to form the ends. This tray was placed in the precompressor, and the requisite pressure applied for a standard time of 10 seconds. The pressure was then released, one end of the apparatus removed and the sides allowed to fold out for material removal. The tray and block were reweighed occasionally as a check to ensure that there had been no mass loss during this process. The average cane height was measured to 0.1″. The mill was run to speed and the tray containing the block presented to the mill opening. It was found that an inclination of 20° to the horizontal, pointing down to the lower roll, gave good results and was fixed as a standard procedure. The block of cane was then given a gentle push by hand and the criterion of the experiment, naturally enough, was " go " or " not go ". Cane heights were varied until the block would just feed with a push of approximately five pounds representing about $\frac{1}{8}$ p.s.i. on cross sectional area. This, of course, was largely required to overcome the friction of the cane on feed tray.

The bagasse and juice were then collected and weighed. In the early stages of the experiments the mill motor current and voltage only were read. However, it became evident towards the latter stages of the experiment that more mechanical records were required, and hence, both torques and the roll speed were measured.

RESULTS

Experimental data and some derived results are given in Table I.

Maximum crushing rates—

Fibrated = 11.6 tons/(hr.) (ft. width of roll) @ 75 f.p.m.
Fine Commercial = 11. 1 tons/(hr.) (ft. width of roll) @ 75 f.p.m.
Coarse Commercial = 10.3 tons/(hr.) (ft. width of roll) @ 75 f.p.m.

The maximum crushing rate at 40 f.p.m. is 8.4 tons/(hr.) (ft. width of roll) which compares favourably with some Queensland rates for pusher fed or continuous pressure fed rolls of 16.9 tons/(hr.) (ft. width of roll). Considering the 18 inches diameter rolls it is seen that these rates are good.

TABLE I

SELF FEEDING OF THE MILL

Test	Cane Height ins.	μ^1	J%J	$\alpha = \frac{0{\cdot}88J\%}{100}$	W lbs.	S f.p.m.	$\frac{WS}{1.5}\cos\theta$	$\alpha\frac{WS}{1{\cdot}5}\cos\theta$
$P_1 S_1 f_1$	4.5	0.825	79.5	0.7	14.0	10.0	72.1	50·47
$P_1 S_2 f_1$	4.2	0.785	75.5	0.664	14.0	25.0	183.3	122
$P_1 S_3 f_1$	3.6	0.695	65.7	0.578	10.5	40.0	230	133
$P_1 S_4 f_1$	3.5	0.68	59.0	0.52	9.25	60.0	305	158
$P_1 S_5 f_1$	3.3	0.65	52.6	0.463	8.75	74.2	362	168
$P_1 S_1 f_2$	4.2	0.785	77.0	0.677	14.0	10.0	73.5	49.7
$P_1 S_2 f_2$	4.0	0.755	76.0	0.669	15.0	25.0	199	133
$P_1 S_3 f_2$	3.8	0.725	68.0	0.597	13.0	40.0	281	168
$P_1 S_4 f_2$	3.3	0.65	64.0	0.563	11.0	60.0	368	207
$P_1 S_5 f_2$	3.2	0.635	52.8	0.465	8.5	75.0	358	167
$P_1 S_1 f_3$	4.2	0.785	77.0	0.677	14.0	10.0	73.7	49.8
$P_1 S_2 f_3$	3.8	0.725	77.0	0.677	14.0	25.0	189	128
$P_1 S_3 f_3$	3.7	0.715	76.0	0.669	13.5	40.0	293	196
$P_1 S_4 f_3$	3.2	0.635	62.5	0.55	10.0	60.0	338	186
$P_1 S_5 f_3$	3.2	0.635	53.6	0.471	8.5	75.0	358	169
$P_2 S_1 f_1$	4.2	0.785	69.4	0.61	10.0	10.0	52.5	32
$P_2 S_2 f_1$	3.9	0.735	60.5	0.532	9.5	25.0	127.5	68
$P_2 S_3 f_1$	3.9	0.735	58.0	0.51	10.0	40.0	215	110
$P_2 S_4 f_1$	3.5	0.68	57.5	0.506	9.5	60.0	314	159
$P_2 S_5 f_1$	3.4	0.665	45.0	0.396	7.7	75.0	320	127
$P_2 S_1 f_2$	3.8	0.725	69.6	0.612	10.5	10.0	56.7	34.7
$P_2 S_2 f_2$	3.7	0.715	63.5	0.56	9.5	25.0	129	72.5
$P_2 S_3 f_2$	3.5	0.68	56.5	0.495	9.0	40.0	198	98
$P_2 S_4 f_2$	3.0	0.605	52.0	0.457	8.0	60.0	274	125
$P_2 S_5 f_2$	2.8	0.58	45.6	0.4	7.5	75.2	324	129
$P_2 S_1 f_3$	4.0	0.755	72.0	0.633	11.5	10.0	61.2	38.8
$P_2 S_2 f_3$	3.8	0.725	67.0	0.59	11.5	25.0	155	91.5
$P_2 S_3 f_3$	3.3	0.65	63.4	0.567	9.75	40.0	218	123.5
$P_2 S_4 f_3$	2.9	0.595	55.0	0.484	8.5	60.0	291	141
$P_2 S_5 f_1$	2.7	0.56	51.4	0.452	9.0	75.0	392	177
$P_3 S_1 f_1$	4.1	0.765	65.2	0.574	10.0	10.0	53	30.4
$P_3 S_2 f_1$	3.9	0.735	59.0	0.52	8.75	25.0	117.4	61
$P_3 S_3 f_1$	3.6	0.695	52.5	0.462	8.25	40.0	180	83
$P_3 S_4 f_1$	3.0	0.605	41.5	0.365	7.0	60.0	239	87
$P_3 S_5 f_1$	2.9	0.595	42.0	0.37	7.0	74.0	296	109.5
$P_3 S_1 f_2$	3.8	0.725	64.6	0.57	10.0	10.0	54	30.8
$P_3 S_2 f_2$	3.3	0.65	57.0	0.5	9.0	25.0	126	63
$P_3 S_3 f_2$	3.2	0.635	56.0	0.492	8.5	40.0	192	94.5
$P_3 S_4 f_2$	3.1	0.620	49.0	0.43	8 0	60.0	272	117
$P_3 S_5 f_2$	2.8	0.58	42.3	0.372	7.0	77.0	311	116
$P_3 S_1 f_3$	3.8	0.725	64.2	0.565	12.0	10.0	64.7	36.6
$P_3 S_2 f_3$	3.4	0.665	60.2	0.53	10.0	25.0	139	73.5
$P_3 S_3 f_3$	3.1	0.620	57.5	0.506	9.0	40.0	203	102.5
$P_3 S_4 f_3$	2.9	0.595	51.5	0.453	9.0	60.0	309	140
$P_3 S_5 f_3$	2.7	0.56	41.6	0.366	7.0	78.6	320	117

μ^1 = apparent coefficient of friction = tan, angle of nip (θ)

J%J = juice extraction % juice 12%fib re.

W = maximum weight of cane self feed.

S = roll speed f.p.m.

θ = apparent angle of nip.

α = juice extraction % unit of cane.

The results of the analysis of variance of the figures for maximum cane heights fed to rolls is given in Table II.

TABLE II

ANALYSIS OF VARIANCE

MAXIMUM CANE HEIGHTS FOR SELF FEEDING OF EXPERIMENTAL MILL

Cause	Sum of Squares	Degrees of Freedom	Mean Square	Variance Ratio	Significance
Between Speeds	6.906	4	1.726	72.0	<0.1%
Preparation	1.244	2	0.622	25.9	<0.1%
Precompression Pressure	0.883	2	0.442	18.4	<0.1%
Interaction, Prep. x P. P.	0.125	4	0.031	1.3	—
,, Speed x P. P.	0.051	8	0.006	—	—
,, Speed x prep.	0.050	8	0.006	—	—
Residual	0.381	16	0.024	—	—
Total	9.64	44	0.218		

As there are no significant interactions the sum of squares of these components of variance can be combined with the residual to give a new estimate of error or residual.

$$\text{New residual mean square} = \frac{0.125 + 0.051 + 0.050 + 0.381}{4 + 8 + 8 + 16} = 0.0168$$

This is less than the original mean square and makes the experiment even more significant with a standard error (S. E.) of $\sqrt{0.0168} = 0.13$ inch.

Further analysis of the various variables proves—

(a) that there is a significant difference between the three preparations; P_1 is better than P_2 and P_2 is better than P_3. In other words the finer the preparation the better the feeding.

(b) that there is a significant difference between the five speeds. There is a gradual drop in feeding ability with increase of speed.

(c) that there is a significant difference between the precompression pressures f_1 and either f_2 or f_3. There is no significant difference between f_2 and f_3, although it appears that f_2 is slightly better than f_3.

There is thus statistical justification for further analysis of these results in graphical form (Fig. 2). The precompression pressures f_2 and f_3 are distinguished as individual points, but only one curve is drawn to represent both values.

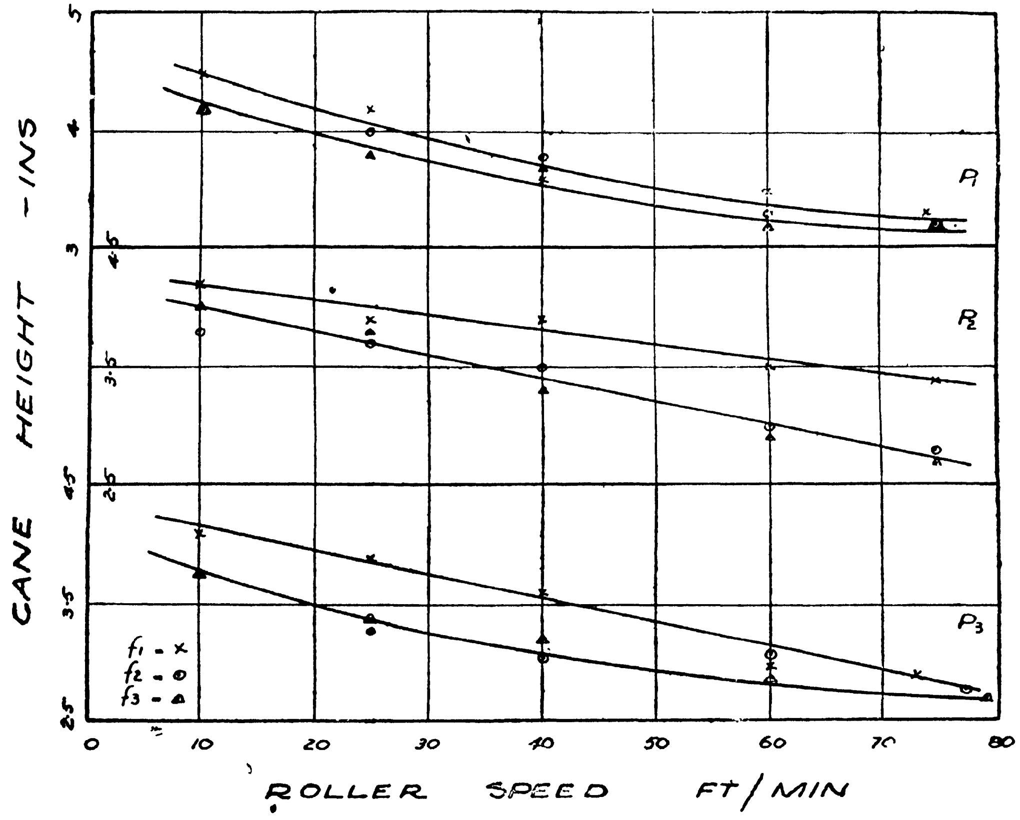


FIG 2

Values of μ^1 = tan. angle of nip are tabulated in Table I. The values range from 0.56 to 0.82, and are much higher than would be expected from other measurements of coefficient of friction. Some experiments were conducted on the self feeding of whole sticks of cane, although it was realised that this method of feeding would have little commercial value.

TESTS ON WHOLE STICKS

In these tests whole sticks of cane were cut into short lengths and the diameters of the feed end were gauged. The sticks were then graded accordingly to the diameter in steps of 0.1″.

The set opening of the mill was also changed in steps of 0.1″ to give a wider range of angle of nip with the size of cane stick available. The mill was adjusted to set openings between—0.2″ and 0.6″ and to various speeds. The method of test was to select a stick of cane with diameter which it was expected would just feed. This stick was then inclined slightly to the horizontal and the criterion again was "go" or "not go". This was duplicated immediately and the next stick taken and the process repeated until the cane size would not self feed.

A typical test result is shown in Table III below.

TABLE III

MILL SET OPENING + 0.1 ROLL SPEED 20 f.p.m.

Cane Diameter inches	Go	Go
1.2	Yes	Yes
1.3	No	No
1.4	No	No

The condensed results of this experiment are recorded in Table IV in the form of μ^1= tangent of angle of nip.

TABLE IV

ANGLE OF NIP
COEFFICIENT OF FRICTION (WHOLE STICKS)

Set Opening ins.	Speed 20 f.p.m.	Speed 40 f.p.m.	Speed 55 f.p.m.
—0.2	0.40		
—0.1	0.39		
0.0	0.38		
0.1	0.36		
0.2	0.35	0.34	0.32
0.3	0.34	0.34	0.32
0.4	0.33	0.30	0.28
0.5	0.31	0.28	
0.6	0.32	0.28	0.25

Apart from the observations of 20 f.p.m., there is insufficient data to draw conclusions. On plotting these values there appears a general tendency for the coefficient to decrease with increase of set opening, as well as decreasing with increasing speed. The value of the coefficient of friction from these experiment is 0.34—0.36 at the set opening of 0.1″. This set opening corresponds to the work opening of 0.4″, in the previous tests.

COEFFICIENT OF FRICTION FROM TORQUE MEASUREMENTS

The large discrepancy in the values of the angle of nip for the prepared canes and whole sticks, even considering the multiplication factor Cosec $\frac{\text{groove angle}}{2}$ (—3.4), necessitated the use of other techniques for verification of the coefficient of friction. One method entails the analysis of load time graphs. The only available measurements comprise some 32 determinations for the fine commercial preparation (P_2) with either 5.0 or 7.5 p.s.i. precompression pressures. The range of roll speed was 10-75 f.p.m. with a predominance of tests within the 25-40 f.p.m. range.

By measuring the time on the torque trace (See Fig. 3) from zero to full load it is possible to determine the true angle of nip. The theoretical time that the mill was under load was calculated from the length of cane fed and these lengths can be checked with the torque time trace. Fig. 4 shows the angle of nip when a cane sample of height H is presented to rolls of mean radius R and work opening h. The usual angle of nip theory states that the coefficient of friction between the cane and the roll is equal to tan θ. This is possibly true for a rigid or elastic material but cane with its large void volume is by no means rigid or elastic. In fact, if there were no void volume the height for the $P_3S_5f_1$ test would be 0.95″ instead of 2.9″. It is thus possible for the cane to be depressed by the roll surface until it reaches a point B (Fig.4) which is a distance y from the axial plane. The coefficient of friction is then sufficient for the rolls to grab the cane and pull it through the mill. This is possible since the mat possesses tensile strength after being subjected to the slight precompression pressure. By measuring the time taken for the torque to rise to full load value the distance y″ can be calculated. Thus θ^1 becomes a new estimate of the angle of nip. This does, in fact, occur and can be easily observed when crushing at 1.5 f.p.m.

Various corrections for the feed speed have to be taken into account. The actual distance for the load rise represents the distance $y\theta/(\int_0^\theta \cos\theta d\theta)$ of the 18 feed length. The feed length distance under maximum load represents (18-x) cos θ and the feed length distance for decrease of load represents $X\theta/\int_0^\theta d\theta$. The times can be calculated and checked against the actual record by drawing their positions on torque time graph as is shown in Fig. 3. The paper speed in Fig. 3 is 3″/sec. and dots on the sides are given by time markers at intervals of 1/40 second. The traces are the lower roll torque, the upper roll torque, and the roll speed. Each nip on the roll speed trace represents 3.12″ on the circumference of the roll. It is possible to calculate the roll speed with an accuracy of at least 1%. In the majority of cases the calculated times agree with the

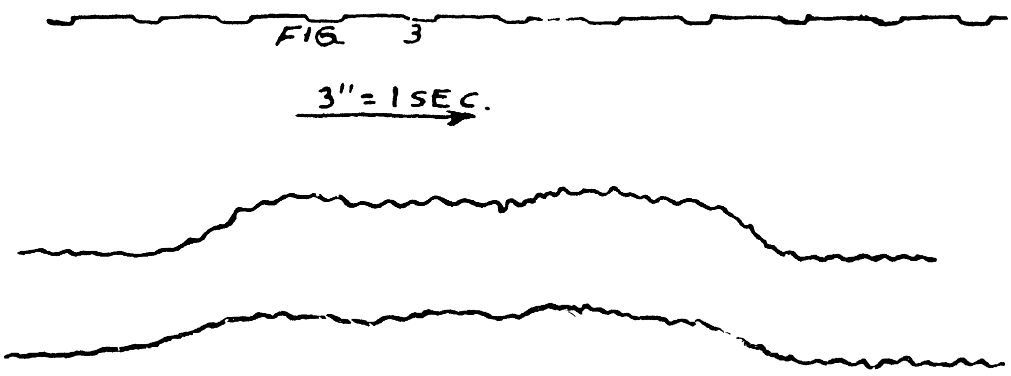


FIG 3

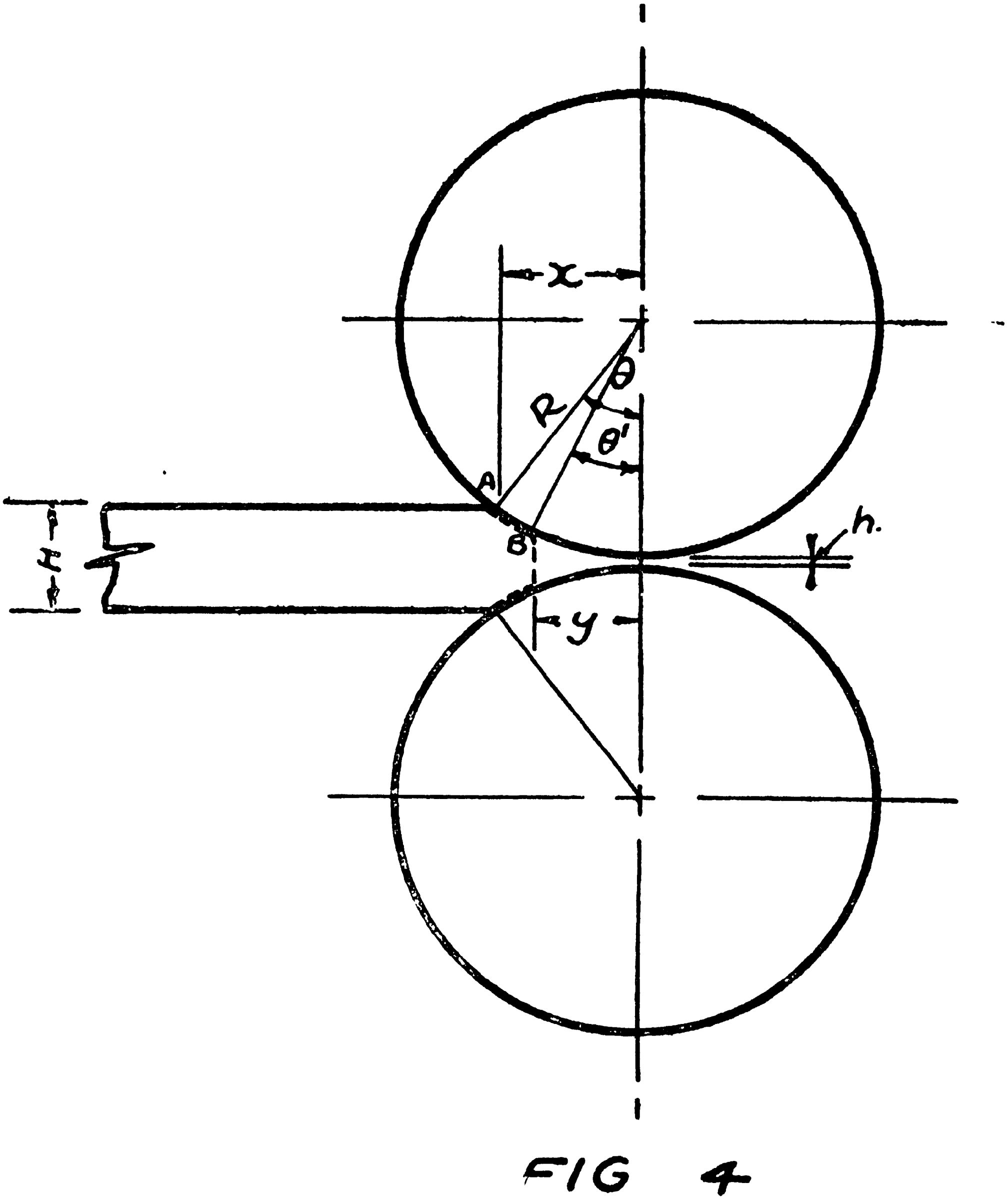


FIG 4

instrument traces as shown in Fig. 3. Occasionally the instrument traces give longer times than those calculated. This is due to roll slip at the entry. Values of the coefficient of friction are given in Table V.

TABLE V

COEFFICIENT OF FRICTION
ANALYSIS OF LOAD TIME CURVES

Speed f.p.m.	Coefficient of Friction
10	0.50
25	0.47
42	0.44
50	0.45
61	0.41
75	0.36

The values given in Table V are statistically significant at the 1% level. They lie on a smooth curve. This curve possesses the same slope as does the curve of apparent coefficient of friction.

MEASUREMENT OF THE DYNAMIC COEFFICIENT OF FRICTION

The apparatus consists of an open ended rectangular box 7″ x 5″ and 6″ long. This was bolted to the mill stand so that one end was held about 1/32″ from the upper roll surface. Two sides of this box had the same curvature as the roll periphery. Cane or bagasse was placed in the box and by means of a curved piston head—connected to the feed chute hydraulic jack—was forced against the roll surface. The mill was set in motion and the normal load and the shaft torque measured by the instruments. This equipment makes possible changes in the following variables :—rate of pressure rise, the test pressure, speed, the state of cane preparation, and—by selecting initial bagasse—the moisture content.

The only available figures for the dynamic coefficient of friction for fibrated cane at pressures from 10—90 p.s.i., are given in Table VI.

TABLE VI

DYNAMIC COEFFICIENT OF FRICTION

Speed f.p.m.	Coefficient of Friction
10	0.38
40	0.34
75	0.25

The results of the preliminary experiment given in Table VI show that a statistical design of the experiment is required to analyse the dynamic coefficient of friction as a function of the above mentioned variables. The dynamic coefficient of friction would be expected to be approximately the same as the static coefficient, possibly more reliable and probably smaller in magnitude.

MILL PERFORMANCE

(a) *Capacity*

The quantity $\frac{WS}{1.5}$ cos 0 (lb./min.) tabulated in the eighth column of Table I gives the crushing rate in lb./min. of the experimental mill. It was found that the preparation has an important influence on mill capacity. P_1 gave better performance than P_2, which in turn gave better performance than P_3. An analysis of the results would indicate that f_3 would give about 10% better capacity than f_2 or f_1. For the purpose of graphical representation the f's of each P's. test have been combined and the average has been presented in Fig. 5. The increased capacity with the very fine prepration of P_1 and P_2 is clearly seen in this graph. The curvature is important as it appears that the curves for P_1

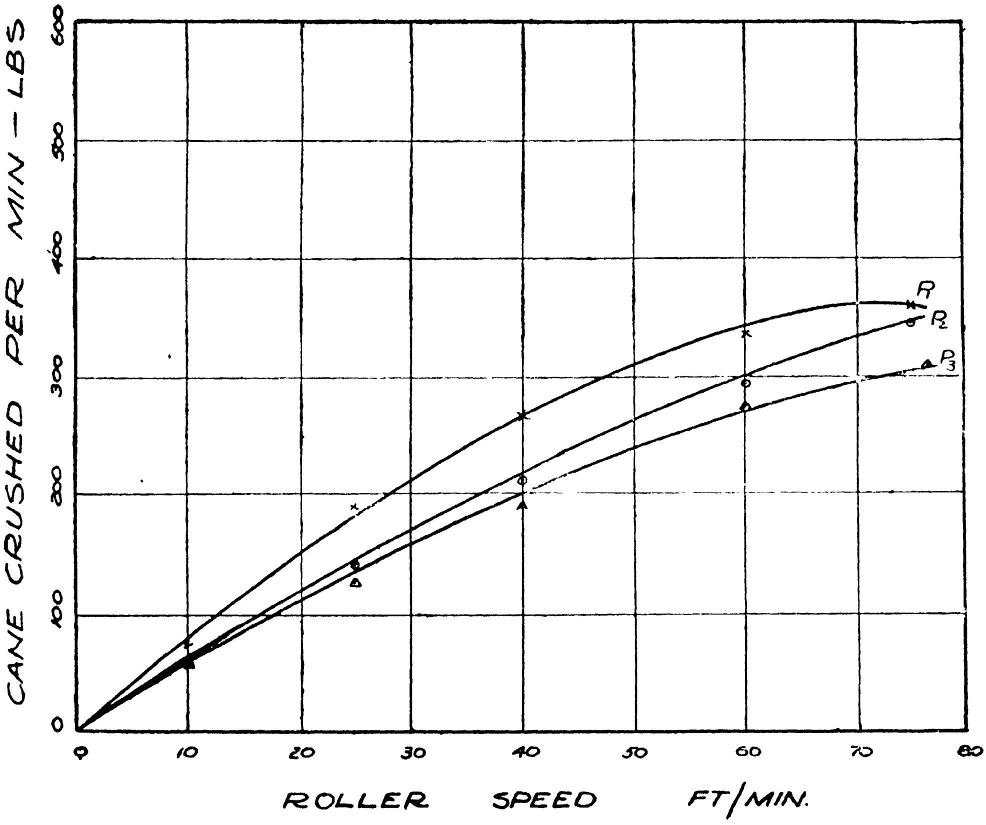


FIG 5

and P_2 are about to indicate optimum values for these preparations. The capacities in tons/(hr.) (ft. width of roll) were given previously.

(b) *Juice Productivity.*

This is a most important criterion of efficient sugar cane milling and is presented in tabular form in Table I, in the ninth column headed $\alpha \frac{WS}{1.5}\cos\theta$ (lbs./min.). As with productivity the precompression pressures have little influence when compared with preparation. Hence the averages of the three precompression pressures have been plotted in Fig. 6. Again the improved performance of the fibrated P_1 over the fine commercial P_2 over the coarse commercial P_3 is seen. The curves all reach optima which means that for each preparation when the mill is self feeding there is an optimum speed beyond which the fall in juice extraction counteracts the greater throughput of the mill.

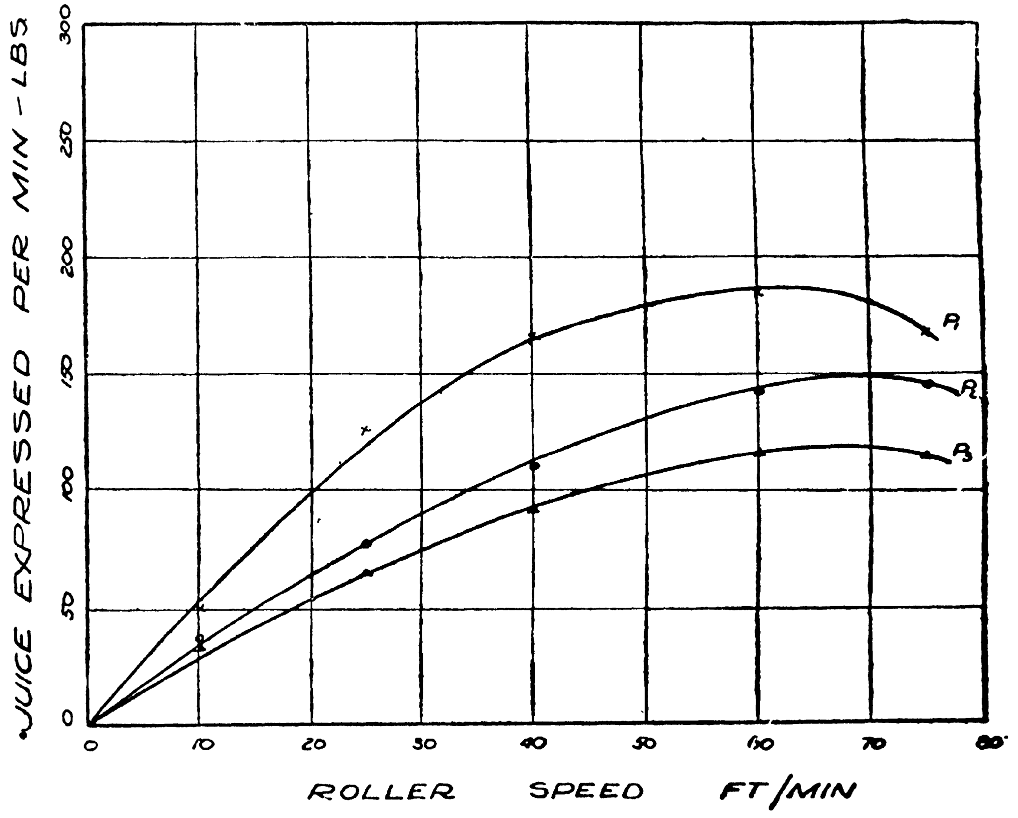


FIG. 6

(c) *Mill Efficiency*

The juice extraction % juice in the cane is tabulated in Table I, column 5, headed J%J. The analysis of variance is given in Table VII. Further analysis of the various variables proves—

(i) that there is a significant difference between the three preparations : P_1 is better than $P_2{}^2$ and P_2 is better than P_3. In other words, the finer the preparation the better the extraction. P_1 is approximately 14% better than P_2 and P_2 is 9% better than P_3 or 9 and 5 units of extraction respectively.

(ii) that there is a significant difference between the speeds. There is a gradual drop in juice extraction as speed increases.

(iii) that there is no significant difference between f_1 and f_2 but there is proof of a better extraction with f_3 than with f_1 at a significance level less than 1%.

These results can be presented in the more useful graphical interpretation shown in Fig. 7. As there is only a small significant difference between the juice extractions with the various precompression pressures the averages for the three pressures have been plotted in this figure.

TABLE VII

JUICE EXTRACTION
COMPONENTS OF VARIANCE

Cause	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Between Speeds	3119.59	4	779.89	125	<1%
„ Preparation	1524.61	2	762.31	122	<0.1%
„ Precompression Pressure	80.57	2	40.29	6.5	<0.1%
Interaction, Prep. x Precomp. Press.	15.23	4	3.81	—	—
„ Speed x Precomp. Press.	46.80	8	5.85	—	—
„ Speed x Preparation	60.05	8	7.50	1.2	—
Residual	100.08	16	6.25	—	—
Total	4946.93	44			

Residual mean square of 6.25

$$\text{S.E.} = \sqrt{6.25} = 2.5$$

New estimate of residual mean square

$$= \frac{15.23+46.8+60.05+100.08}{4+8+8+16}$$

$=6.17$

New S.E. $= \sqrt{6.17} = 2.48$

S.E. $= 2.5$

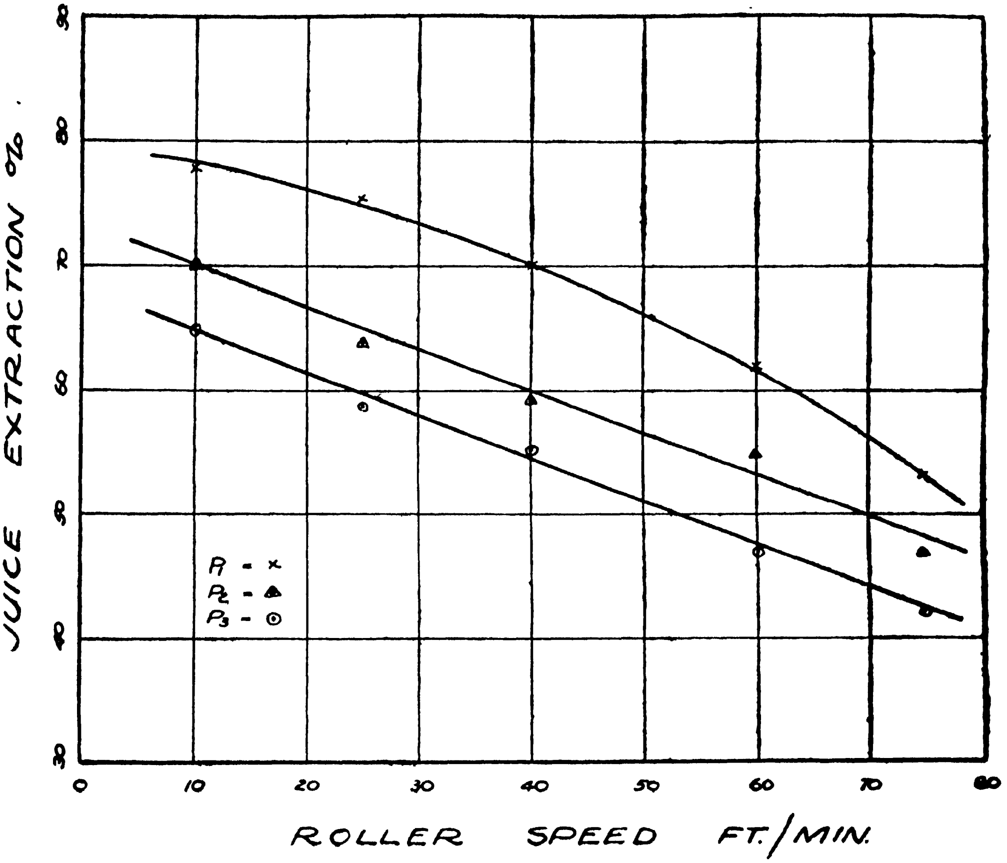


FIG 7

COMPRESSION RATIO

The compression ratio is tabulated in column 2, Table VIII. The precompression pressure again appears to have very little effect and hence an average value for compression ratio at each preparation and speed combination can be taken without causing undue error.

BAGASSE VOLUME/ESCRIBED VOLUME Vs. JUICE EXTRACTION

The ratio of bagasse volume/escribed volume is tabulated in Table VIII. There is the general tendency noted previously (2) of increasing extraction with decreasing bagasse volume/escribed volume ratios. These are hard to prepare in graphical form as the compression ratio is a parameter. In Table VIII the nominal compression ratio is seen to range from 2.1/1 to 4.6/1 and any graph juice extraction vs. bagasse volume/escribed volume would need to have a range of parameter values to show sufficient points on a parametric curve. Several values of have been checked and appear to agree well with the curves shown in (2).

TABLE VIII

Test	Compression Ratio	J%J	$\frac{\text{Bag. Vol.}}{\text{Esc. Vol.}}$
$P_1 S_1 f_1$	4.3	79.5	0.96
$P_1 S_2 f_1$	4.3	75.5	1.115
$P_1 S_3 f_1$	3.3	65.7	1.12
$P_1 S_4 f_1$	3.0	59.0	1.13
$P_1 S_5 f_1$	2.8	52.6	1.24
$P_1 S_1 f_2$	4.3	77.0	1.07
$P_1 S_2 f_2$	4.6	76.0	1.19
$P_1 S_3 f_2$	4.1	68.0	1.31
$P_1 S_4 f_2$	3.5	64.0	1.24
$P_1 S_5 f_2$	2.7	52.9	1.215
$P_1 S_1 f_3$	4.3	77.0	1.07
$P_1 S_2 f_3$	4.2	77.0	1.1
$P_1 S_3 f_3$	4.2	76.0	1.105
$P_1 S_4 f_3$	3.2	62.5	1.18
$P_1 S_5 f_3$	2.7	53.6	1.2
$P_2 S_1 f_1$	3.2	69.4	0.94
$P_2 S_2 f_1$	3.0	60.5	1.125
$P_2 S_3 f_1$	3.2	58.0	1.24
$P_2 S_4 f_1$	3.0	57.5	1.21
$P_2 S_5 f_1$	2.1	45.0	1.24
$P_2 S_1 f_2$	3.3	69.6	1.02
$P_2 S_2 f_2$	3.0	63.5	1.075
$P_2 S_3 f_2$	2.9	56.5	1.18
$P_2 S_4 f_2$	2.6	52.0	1.185
$P_2 S_5 f_2$	2.4	45.6	1.245
$P_2 S_1 f_3$	3.6	72.0	1.03
$P_2 S_2 f_3$	3.6	67.0	1.175
$P_2 S_3 f_3$	3.1	63.4	1.095
$P_2 S_4 f_3$	2.7	55.0	1.19
$P_2 S_5 f_3$	2.9	51.4	1.36
$P_3 S_1 f_1$	3.2	65.2	1.06
$P_3 S_2 f_1$	2.9	59.0	1.06
$P_3 S_3 f_1$	2.7	52.5	1.15
$P_3 S_4 f_1$	2.3	41.5	1.215
$P_3 S_5 f_1$	2.3	42.0	1.2
$P_3 S_1 f_2$	3.2	64.6	1.07
$P_3 S_2 f_2$	2.9	57.0	1.21
$P_3 S_3 f_2$	2.7	56.0	1.16
$P_3 S_4 f_2$	2.6	49.0	1.24
$P_3 S_5 f_2$	2.3	42.3	1.25
$P_3 S_1 f_3$	3.8	64.2	1.31
$P_3 S_2 f_3$	3.2	60.2	1.24
$P_3 S_3 f_3$	2.9	57.5	1.19
$P_3 S_4 f_3$	2.9	51.5	1.35
$P_3 S_5 f_3$	2.3	41.6	1.31

DISCUSSION OF RESULTS

(a) *Angle of Nip*

From the results of the experiment the angle of nip gives an apparent coefficient of friction between 0.56—0.82. This coefficient is a function of roll speed, preparation, and to a lesser extent the precompression pressure. It is only applicable to commercial practice in those cases where the mill feed is continuous, uniform and well matted (i.e., possessing a tensile strength). The feed pressures required under these conditions for good productivity are less than 0.2 p.s.i.

(b) *The Coefficient of Friction of Cane on Iron Surfaces*

If the prepared cane mat were rigid and the law $\tan\theta = \mu \operatorname{cosec}\frac{\beta}{2}$ (where β is the V groove angle and θ is the angle of nip) as proposed by Crawford (1) then the coefficient of friction would have a minimum value between 0.16 and 0.24 ($\operatorname{cosec}\frac{\beta}{2} = 3.4$).

The theory postulated by Crawford (1) when applied to the above figures gives an apparent coefficient of friction between 0.20 ± 0.04 and 0.69 ± 0.13. His quoted figures which average 0.47 fall within this range.

Whole sticks of cane are comparatively rigid and do not fill the groove at the point of entry. It would therefore be expected to give a reasonably accurate estimation of the angle of nip and hence coefficient of friction. This method gives a coefficient of friction at the set opening of 0.1 in the range 0.35 ± 0.1. The rind may have different friction properties and this has yet to be investigated.

The coefficient of friction determined from the load time curves ranges from 0.50 at 10 f.p.m. to 0.36 at 75 f.p.m. These values have a similar relationship to speed as do the apparent coefficients of friction. From other tests with different preparations it appears that preparation has little influence on the coefficient of friction. The measurement of the dynamic coefficient of friction gives values ranging from 0.38 at 10 f.p.m. to 0.25 at 75 f.p.m. This is at a considerably higher pressure (70 p.s.i.) than would be applied at the point B (Fig. 4). At this higher pressure juice is expressed and probably lubricates the rubbing surfaces. The prepared cane fills the roll grooves and if the grooving angle had any influence this coefficient would surely be much higher.

The experiment seems to indicate that the type of grooving has little effect on the feeding of sugar cane mills. The real coefficient of friction depends on speed and pressure and appears to be in the range from 0.25 to 0.50. Preparation clearly affects mill feeding but probably not the coefficient of friction. Better feeding of fibrated cane is possible, owing to its low resistance to deformation when being fed. In other words point B in Figure 4 is easily reached. The tensile properties of the more uniform fibrated cane have a better effect on feeding continuity. Increased speed definitely results in poorer feeding.

These results require verification by substitution of smooth rolls, by more elaborate tests on the dynamic coefficient of friction, by the provision of torque time graphs for other speeds and by the utilisation of the dynamic friction apparatus for the investigation of the static coefficient.

(c) *Capacity of the Mill*

It is probably not surprising that the finer the preparation the better the mill feeding. The material is more uniform and lacks the resistance to deformation which makes whole sticks of cane difficult to feed. This has been reported previously in (2). The departure from linearity of the graph of crushing rate v. speed imposes an economical upper limit on the roller speed of a self feeding mill. A self feeding mill has much to recommend it from the mechanical, economical and maintenance view points.

(d) *Juice Extraction*

The effects of preparation and speed on juice extraction are significant and clearly demonstrated in Fig. 6. Precompression pressures have little influence on the extraction, their chief function is to impart a tensile strength to the mat, and at the same time to present a uniform blanket to the mill.

As noted in Table VIII, the compression ratio decreases as the roller speed rises. This means that the slopes of the curves in Fig. 6 are steeper than would be expected for a parameter of constant compression ratios. Smaller slopes of these curves can be obtained by increasing the compression raio at the higher speeds. This is done by decreasing the work opening. Several experiments confirmed this and at least 6% increase in extraction can be obtained at $P_2S_3f_1$ by decreasing the work opening to 0.3″. However, the capacity of the mill falls off slightly.

(e) *Mill Productivity vs. Speed*

This curve in conjunction with the juice extraction curve affords a basis for an economical approach to the design of a sugar cane mill. As mentioned, these curves cannot be applied directly to commercial installations because of the small diameter and lack of juice grooves. The provision of better drainage must increase the juice extraction but the form of the curves will probably remain unaltered. The experiment when repeated with juice grooves should give an estimate of the efficacy of juice grooves.

CONCLUSION

The angle of nip for prepared canes is found to lie between 29° and 39° and depends on the state of cane preparation and roll speed. The dynamic coefficient of friction seems to lie within the range 0.25 to 0.50 depending on speed and pressure.

The use of precompression as an aid to mill feeding is confirmed and the magnitude of pressure required is immaterial in the range 2.5 to 7.5 p.s.i.

Reasonable productivity combined with good juice extraction has been obtained and may be improved by increasing the compression ratio and by the provision of juice grooves. Higher mill capacity can be obtained by the use of larger rolls.

ACKNOWLEDGEMENTS

Professor M. Shaw and Professor T. G. H. Jones for the provision of equipment and laboratory space. Mr. J. Pidduck for the provision of data on the dynamic coefficient of friction. The Sugar Research Institute of Mackay for the provision of the Research Fellowship. Fairymead Sugar Co. for the loan of Mr. J. Fleming who has assisted with the experimentation and analysis. Mulgrave Central Sugar Mill for the loan of the hammer mill used for the cane preparation.

REFERENCES

1. Crawford,W. R. 1955. " Mill Feeding—the basic factor in efficient cane milling." *Proceedings of Q. S. S. C. T., 22nd Conference,* page 167.
2. Bullock, K. J. 1955. " The Effect of Speed, Preparation etc." *Proceedings of Q. S. S. C. T., 22nd conference,* page 301.

DISCUSSION

Dr. Crawford stated that he did not agree that grooving had no influence on mill feeding and also asked whether with constant capacity, the mill settings had been adjusted to find mills feed characteristics.

The question of angle of grooves was still being investigated but that the above capacity test has yet to be tried.

In summing up, the Chairman stated that this appears to be a new field investigated in a new way and figures quoting speed of 41′ per minute and quoting coefficient 0.29 initially and later revising 0.44 showed that there were many variables which have not been fully recognised and that further research work was necessary.

RESEARCH DISCUSSIONS

At the request of several delegates a general discussion on the question of research was considered. Professor Shaw stated that he was not conversant with Indian Mill Practice and the details of equipment at the University and the tests carried out and their application to sugar mills was not really the driving factor and that research can take any form purely academic or practical and today's theory may be tomorrow's practice and he would like to know what research work is being done in this country as well as in other countries.

Actual practical results from an experimental sugar factory were mentioned by Mr. Bhargava and details provided such as the 14-roller mill, 10″ × 14″ with variable speed on crusher and mills and one set of knives driven by 5 H.P. motor and the crushing rate of 800 mds. per 24 hours.

The problems of fine and coarse grooving, speed, thinner or thicker blankets, friction in trash plate, measurement of pressure by hydraulic means and the difference between forced oil lubrication and grease lubrication have been tried.

The question of utilising aluminium in certain parts of the plant as against steel was being tried and so far on the juice side it is found that there was no deterioration in the weight of the metal.

The research on boiler furnaces had also been carried out in co-ordination with other factories.

Dr. Crawford gave an example of an experimental sugar mill with 3 rollers and sketched details of the trash plate device to measure force. Juice from front and rear rollers were collected separately.

Dr. Doss stated that the question of research should be mainly to help factories. The capacity of mills, proportional to diameter, length and number, and the question of friction required fundamental research and figures analysed statistically.

The Chairman in conclusion decided that a motion may be moved that this meeting recommends that time be allotted for a research symposium at the next Conference and this was seconded by Dr. Doss.

MANUFACTURING SECTION

MANUFACTURING SECTION

Session I—Friday, 27th January, 9-15 A. M.

DR. H. W. KERR, *Chairman*

Mr. N. C. Varma presented the following paper.

Paper

FACTORY-SCALE TRIAL OF THE SAHA- JAIN PROCESS OF CANE JUICE CLARIFICATION IN 1954-55

J. M. SAHA, N.C. VARMA AND H. C. BHATTACHARYA
National Sugar Institute Kanpur

INTRODUCTION

Saha and Jain while experimenting in the laboratory with a vegetable product for cane juice clarification were led to filter under suction, the treated raw juice of about 10 pH at a temperature of about 98°C. and obtained a very light coloured filtrate (1). The vegetable substance was subsequently not used and still a light coloured juice was obtained as a result of quick filtration of the highly alkaline juice at the above high temperature. The resulting alkaline filtrate was quickly sulphited to neutrality, again boiled and filtered and almost colourless juice was obtained. These investigators next observed that neutralisation of the alkaline filtrate with superphosphate solution led to better results in respect of colour removal and purity rise (2).

The above method of treatment of raw juice namely filtering highly alkaline juice at high temperature was put to test in a pilot plant experiment at the Ravalgaon Sugar Factory (Bombay State, India) and it was found that after a few hours' run the filtrate began to darken in colour. This indicated the need for using a quick filtering equipment such as the De Laval Separator or alternatively bringing down the temperature of the alkaline juice (3). During the trial of the same method carried out in the season 1952-53, at the Experimental Sugar Factory of the National Sugar Institute, Kanpur, India, because of similar darkening of the filtrate found at Ravalgaon, the temperature had to be brought down from about 98°C. to 65°C. The alkaline filtrate was quickly neutralised with triple superphosphate solution, boiled and refiltered. The rise in the purity of clear juice, the colour and clarity of clear juice and the quality of sugar obtained were found to be very encouraging but difficulty was experienced in the first filtration. Short duration trials with improvised equipment were subsequently tried in the same season in the Ugar, Kanhegaon and Daurala factories up to the stage of alkaline filtration only. While the alkaline filtration was found to be normal for the short duration of the trial at the first two factories named above, some difficulty was experienced with regard to filtration at the Daurala factory which was ascribed to a very low cush-cush content in the juice of this factory (4). Further trials of the new technique were carried out during the next crushing season (1953-54) at Seohara, Ugar, Plassey and Kanhegaon factories. The alkaline filtration however presented difficulties at Seohara and Ugar and at the latter factory the process was further modified, in that the neutralised juice, instead of being refiltered was subsided in the Dorr clarifier and the settlings from the Dorr consisting of precipitates obtained by neutralisation with superphosphate, were returned to the weighed raw juice which helped filtration a great deal and the process became workable. This modified technique was then tried at Plassey but as the factory had no Dorr clarifier the return of mud from settling tanks became inconvenient and there being other shortcomings in the equipment, the results obtained were not satisfactory. The modified technique was however tried at the Experimental Factory, at Kanhegaon and at Seohara again towards the close of the season 1953-54. During the working of the process at the Experimental factory it was observed that the neutralisation of the alkaline filtrate partly with a clear superphosphate solution and partly with sulphur dioxide, helped both economics and control of the final pH of clear juice (5). Subsequent laboratory investigations confirmed that while with neutralisation of the alkaline filtrate wholly with superphosphate, the drop in pH on boiling was erratic and considerable, part neutralisation with superphosphate finished by neutralisation with sulphur dioxide resulted in only a small and more or less constant drop in pH after boiling and settling (6).

The different aspects of the process as modified and developed during the various trials of the process have been studied and discussed (7).

It may be stated in this connection that Bogtstra (8) had earlier employed the same principle of alkaline filtration in his Double Sulphitation process as has been employed by Saha and Jain quite independently. No reference was available about Bogtstra's work in the Chemical Abstracts or in any of the popular journals in the English language and it was subsequently pointed out by Dr. Honig.

THE TRIALS OF THE MODIFIED PROCESS AT KANHEGAON AND AT SIDHWALIA FACTORIES

The process in its latest form was given a second series of trials at the Kanhegaon and Sidhwalia factories during the 1954-55 season. These trials were continued for 23 days at Kanhegaon and 42 days at Sidhwalia and offered for the first time the results of a new process workable under factory conditions and capable of producing carbonation quality sugar. The process again met with difficulties not experienced hitherto, nevertheless, encouraging results have been obtained. With better appreciation of the principles involved in this new process and more experience on the part of operatives, much better results should be obtained. The technical results obtained during the latest factory-scale trials of the process at Kanhegaon and Sidhwalia in the season 1954-55, have been given and discussed in this paper. The conditions under which the trials were carried out and the difficulties encountered have also been stated.

In that the process provides a new tool to the technologist to produce a carbonation quality sugar withlower initial capital cost and expectedly lower working cost than that of the carbonation process, the details furnished in this paper should prove interesting.

It may be stated here that the Government of India in the Ministry of Food and Agriculture have evinced keen interest in the development of this process in as much as it sanctioned a lump sum grant of Rs. 33,000/- for equipping the Experimental Factory of the Institute for the trial of the process in 1952-53 and sanctioned additional technical staff at the Institute for assisting the Kanhegaon and Sidhwalia factories in working the process in the season 1954-55 and for collecting the necessary technical data. The authors of this paper were closely associated with these trials.

DURATION OF THE TRIALS

(i) *At Kanhegaon* :

The first run of the new process covered the period from 25-11-54 to 30-11-54 and second run covered the period from 1-12-54 to 23-12-54. The process was stopped on 23-12-54 because the stock of superphosphate had exhausted and the factory had to crush at a higher rate than was possible with the new process in order to finish its large cane crop. Therefore from the third run onwards the usual double sulphitation process was followed by the factory.

EQUIPMENT USED FOR THE TRIALS

Sl. o.	Various Stations	Particulars of equipment used	
		At Kanhegaon	At Sidhwalia
1.	Milling Plant	One three-roller splitter crusher 660 mm. × 1270 mm. (26″ × 50″) and four mills 660 mm. × 1270 mm. (26″ × 50″) driven by a 500 B. H. P. drop valve steam engine and preceded by two sets of knives (only one set worked).	One two-roller crusher 533 mm. × 1067 mm. (21″ × 42″) and four mills 559″ mm. × 1067 mm. (22″ × 42″) driven by 230 B. H. P. horizontal steam engine.
2.	Clarification Plant	(a) Liming and sulphiting vessels-three in number, with stirrers; working capacity about 6360 litres each.	(a) Liming and sulphiting vessels four in number with circulation cones, capacity about 2955 litres each.
		(b) Alkaline juice tanks (or 2nd liming vessels)-three in number, with stirrers (34 r. p. m.) 3640 litres each, provided with lime buckets.	(b) Liming tanks-two in number with stirrers capacity about 4090 litres each.

Sl. No.	Various Stations	Particulars of equipment used	
		At Kanhegaon	At Sidhwalia
2.	Clarification Plant (*Contd.*)	(c) Presses for alkaline juice filtration-twelve in number having a total f.a. of 670 m^2, i. e., 19.7 m^2/ton/hr.	(c) Presses-nine in number with total filtering area of 535 m^2 i. e., 19.4 m^2/ton/hre.
		(d) Phosphate slurry making tank with stirrers and heating coils, working capacity 4550 litres.	(d) Phosphate slurry tank-on in number, about 2270 litres capacity fitted with stirrer and steam coil.
		(e) Phosphate Filter Press-46m^2 f. a.	(e) Settling tanks for phosphate solution-two in number of about 2730 litres.
		(f) Storage tank for phosphate solution — capacity 2960 litres.	(f) Phosphatation tanks-with stirrers, each with a capacity of about 3180 litres.
		(g) Phosphatation vessels-two in number with stirrers, working capacity 3640 litres each, provided with phosphate solution buckets.	(g) Neutralisation tanks-three in number, fitted with cone and steam coils at the top, working capacity 3180 litres.
		(h) Second sulphitation vessels-two in number with stirrers and steam coils at top, working capacity about 3640 litres.	(h) Receiving tank for neutralised juice-one in number, capacity about 3640 litres.
		(i) Neutralised juice receiving tank-with stirrer, working capacity about 3640 litres.	
3.	Evaporation Plant	A quadruple of 1300 m^2 heating surface.	A quadruple effect with tota heating surface of 991 m^2.
4.	Boilling and Curing Plant	(a) One "Fletcher" Centre Flow calandria pan 44.7 m. tons strike capacity ; three "Skoda" calandria pans each 22.4 m. tons strike capacity.	(a) Five pans ; total strike capacity 77 m. tons, one calandria pan 22.6 m. tons. Four calandria pans 13.6 m. tons each.
		(b) 18 machines of 457 mm. ×914 mm. (18″×36″) electrically driven and 3 machines of 457 mm. × 914 mm. (18″×36″) water driven i. e. in all 21 machines.	(b) 26 centrifugal machines —water driven. 3 A Fore-workers 867 mm. ×558 mm. 2 B Fore-workers (42″×22″).
		A Foreworkers-3 Machines.	6 A & B Afterworkers 457 mm. × 914 mm.
		B Foreworkers-4 Machines.	11 C Fore-workers (36″×18″)
		A & B Afterworkers-7 Machines.	4 C After-workers.
		C Foreworkers-5 Machines.	
		C Afterworkers-2 Machines.	

THE PROCESS FOLLOWED AT KANHEGAON

(a) *Clarification process* :—The mixed juice after measurement was heated to 55°-57° C. and subjected to simultaneous liming and sulphitation using 1.2-1.3% by volume, of 12-13 Be'. milk of lime. The reaction after sulphitation was kept at 7.1-7.2 pH. It was discharged into a storage tank from where it was pumped into a second set of liming tanks. A second dose of lime was added here to raise its pH to 10.5-10.6 (judged by Thymolphthalein paper) and filtered in the plate and frame presses. The free CaO content in the alkaline filtrate was maintained between 500-600 mg./litre. The press cloths from each press were washed in a washing machine with hot water on every alternate cycle. The triple superphosphate was made into a suspension with water in a tank provided with stirring arrangement and heated to boiling. This was filtered in a filter press and the clear solution of strength, varying from 8°-15° Be', was used in calculated quantities for partial neutralisation upto a pH of about 9.8. The partially neutralised filtrate was pumped to the second sulphitation vessels. The pH of the final neutralised juice was kept at 7.2-7.3. It was then heated in a juice heater to boiling temperature and sent to the Dorr clarifier for subsidation. The clear juice from the Dorr was sent to the evaporator and the muddy juice was continuously pumped by the Dorrco pumps to the raw juice received from the measuring tanks.

(b) *Boiling and Curing Scheme* :—The usual three-massecuite-system was followed. The double cured C sugar was melted and fine-screened sugar was made into magma with water and used as seed for A and B massecuites.

At Sidhwalia.

The clarification process and the boiling and curing schemes followed at Sidhwalia were substantially the same as at Kanhegaon except that the clear superphosphate solution here was obtained by settling the boiled superphosphate suspension.

RESULTS OBTAINED

The results obtained are given in the Tables I, II, III and IV (Appendices A, B, C and D).

(a) *At Kanhegaon*

From a study of Tables I and II it will be seen that—

(i) *Crushing rate* :— Against the expected crushing rate of 813 m. tons per day for which additional equipment had been put up, a crushing rate of 700 m. tons was achieved in the second run (see Table I). The maximum of 772 m. tons of crushing was done on one day. From 25-11-54 to 30-11-54, the speed of milling was only 496 m. tons per 24 hours' actual operation due to troubles at the mills. Hours lost percent season hours during the first run were recorded as 34.2 and this loss of time was entirely due to mechanical troubles. From 1-12-54 to 23-12-54, the speed of crushing improved to 700 m. tons/24 hours' actual crushing. In this period again, the figure for "hours lost percent season hours" was high, being 25.6, out of which the hours lost for process percent season hours were only 1.72. From 24-12-54 the standard sulphitation process had to be followed for want of triple superphosphate. The crushing speed increased to 859.6 m.tons, the hours lost percent season hours being reduced to 14.9 only. If the Saha-Jain process had been worked after the local conditions of the factory had settled down, it would have been possible to record an appreciably higher crushing rate.

(ii) *Manufacturing losses* :—The figures for manufacturing losses and total loss for the process were recorded as 1.61 and 2.56 percent cane respectively as compared to the corresponding figures of 1.60 and 2.28 for the double sulphitation process followed in the succeeding period. This showed that the manufacturing loss was more or less the same even though the conditions of working were very much unsettled during the period of the trial of the new process. The losses in molasses and press mud were 1.39 and 0.06 percent cane respectively which compare very favourably with the corresponding figures of 1.35 and 0.06 of the sulphitation process, although the primary juice purity was somewhat lower in the new process period than that of the subsequent usual process period being 83.5 against 84.7. The Boiling House Extraction figures for the Saha-Jain and usual process periods were 85.9 and 87.4 respectively and this difference closes up in the figures for Reduced Boiling House Extraction which were 89.3 and 89.8 respectively.

(iii) *Rise in purity and the quantity and purity of final molasses* :—The rise in purity as recorded by the factory for the Saha-Jain process was 1.63 and 1.07 for the usual process. This low rise was perhaps due to bacterial inversion as a number of analyses of check samples taken when the mixed juice was kept disinfected with bleaching powder solution gave an average purity rise of 2.7. Molasses percent cane in the new process period was 4.38 and in the usual process period 4.22 and the purities of final molasses were 33.0 and 33.3 respectively.

(iv) *Quality of sugar* :—The sugar compared in quality with the best carbonation sugar produced in the country. The colour of the new process sugar as judged visually was superior to the Indian Sugar Standard grade 29 while that of the usual process sugar was equal to ISS 29. The percentage of production of bold grain (0.83 to 1.98 mm.) was larger in the case of new process sugar than in the case of the usual process sugar. The qualities produced were according to the Indian Sugar Standards, A29, B29, C29 and D29.*

(v) *Consumption of stores* :—The consumption of stores was well within the expected limits.

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* A grain sugar passes through an opening of 2.362 mm. and retained on 1.98 mm.
B „ passes through 1.98 mm. but retained on 1.65 mm.
C „ „ „ 1.65 mm. „ 1.17 „
D „ „ „ 1.17 mm. „ 0.83 „

Nos. 29, 28 and 27 represent material standards of mill white sugars in decreasing order of whiteness.

It will thus be seen that while the manufacturing losses in the Saha-Jain process were more or less the same as in the standard sulphitation process at Kanhegaon, the quality of sugar produced by it was far superior to that of the usual sulphitation process.

(b) *At Sidhwalia*

(i) *Initial difficulties* :—The working of the first run from 16-1-55 to 25-1-55 was erratic because the operators were entirely new to the process. The return of mud from the Dorr to the raw juice receiving tank by gravity did not work satisfactorily and pumping the mud by means of Dorrco pumps had to be resorted to. There was excessive foaming in the neutralised juice due to a combination of conditions such as high free CaO content of alkaline filtrate, fall of juice in the second sulphitation tanks from a height and high content of gummy matter in the juice. On controlling the free CaO content and making the juice inlet from the bottom of the tanks this trouble disappeared. Another difficulty which came up and due to which the crushing rate had to be considerably slowed down was the stiffening of the filter-cloth. The cloth was found to have a coating which blocked the pores of the cloth and affected filtration adversely. This coating was believed to be due to unsatisfactory quality of lime and due to the increase in gummy matter caused by very serious infection of the juices by Leuconostocs. The factory had, therefore, to switch over to the usual sulphitation process.

In the meanwhile the problem of the stiffening of filter cloths had to be solved. After trying a number of ways and means of reconditioning the cloth, one of us (J.M. Saha) found that boiling the cloths in two percent commercial hydrochloric acid removed the coating, opened the pores, and brought back the cloth to its original soft condition without in anyway damaging it (9).

Arrangements were then made for the acid treatment of the stiff cloths in a wooden tank, which had an open steam connection. The process was restarted after reconditioning the stiff cloths on 12-2-55 but soon after starting the process the factory labour went on a ‘ Go-slow Strike ’. The factory staff continued with the process upto 25-2-55 when they had to stop on account of the fuel position becoming acute. The usual process was started in order to have an increased crushing rate for accumulating sufficient bagasse for future use.

The Saha-Jain process was again started on 20-3-55 and continued till 31-3-55 and further from 1-4-55 to 6-4-55. In the run from 20-3-55 to 31-3-55 juice purities were more or less of the same order as those in the immediately preceding run. The working of the new process period 20-3-55 to 31-3-55 has therefore been compared with that of the usual process period 11-3-55 to 19-3-55. The results of these two runs are given in Table IV and are discussed below :–

Table III gives the results of all those runs in which the new process was worked.

(*ii*) *Rate of crushing* :—

The rate of crushing per 24 hours working was 580.8 m. tons as against

628.2 m. tons in the previous sulphitation period, the recovery figures in these periods being 10.29 and 10.46 respectively. Although the sugar in cane during the new process period was 13.33 against 13.24 during the usual process period, the recovery figure of the Saha-Jain process period was affected by lower primary juice purity and lower mill extraction.

Manufacturing Losses :—

The total manufacturing losses were 1.79 for the Saha-Jain process and 1.64 for the usual process respectively, the difference of 0.15 being due to higher losses in press-mud to the extent of 0.05%, in molasses to the extent of 0.04% and undetermined to the extent of 0.06%. It may be pointed out that the method of computing press-mud loss at Sidhwalia was not satisfactory in view of the difficulty of taking proper samples from the big heaps of mud on the ground floor an approach to which was difficult, and that of correctly weighing the mud.

(*iv*) *Quantity and purity of Final molasses* :—

Molasses percent cane figures for the two periods were 4.53 and 4.63 and purities of final molasses were respectively 34.5 and 32.4. It is believed that with adequate capacity at the pan station and smoother working of the process the molasses loss can be reduced further.

(*v*) *Rise in purity* :—

The rise in purity from mixed juice to clear juice was recorded 1.30 as against 0.76 unit on the usual process. A much higher rise in purity is expected in this process but due either to the peculiar nature of the juice at the factory or due to abnormal infection of the juices with leuconostoc this season or due to pockets in juice lines resulting in stagnation of the juice, the expected purity rise could not be obtained.

(*vi*) *Quality of sugar* :—

The bulk production of sugar by the new process was in the grades B29 (9.83%), C29 (38.28%) and D29 (47.25%) whereas by the usual process it was in the grades D29 (90.6%) and E29 (8.09%).

(*vii*) *Consumption of stores* :—

The consumption of stores was very satisfactory, and if the quality of lime and its slaking and classification operations are improved, the lime consumption can be brought down considerably. The sulphur consumption would also be lower and possibly a too fast stiffening of filter cloth would also be avoided.

It is believed that by increasing the filter-press capacity to 23 m^2 of filtering area per ton cane ground per hour, the crushing rate can be raised up to the desired level and the working would become more smooth and easy and very much better results would be obtained.

SUMMARY

The working of the Saha-Jain process under commercial conditions in two factories has been studied. The results obtained have been given and discussed in relation to the usual process followed in the two factories in the very same season. With about 19.5 m^2/ton/hr. filtering area the process did not give the desired crushing rate and it is believed that a filtering area of 23 m^2/ton/hr. would be required. Total manufacturing losses in the two factories were respectively of the order of 1.61 and 1.79 in the new process as against 1.60 and 1.64 in the usual process. The stores consumption in the new process has also been favourable. The quality of sugar produced was far superior to that produced by the usual process fetching a higher price. The results would, therefore, appear to be encouraging. With more experience of the working of the process and better operational technique, still better results are expected.

ACKNOWLEDGEMENTS

Thanks are due to the managements and staff of the Kanhegaon and Sidhwalia factories and to the Director, National Sugar Institute, Kanpur for his kind permission to publish this paper.

REFERENCES

1. Saha, J. M., Jain, N. S., Saxena, K. S. and Nigam, G. M. *Proc. S.T.A. India*, XIX, Part II, pp. 156-173.
2. Saha, J. M. and Jain, N. S. *Proc. S.T.A. India*, XXI, Part I, pp. 3-16.
3. Gundu Rao, S. N. *et al, Proc, Deccan S.T.A.*, IX, Part I, p. 131.
4. Saha, J. M. and Jain, N. S. *Proc. S.T.A. India*, XXI, Part I, pp. 1-10.
5. Saha, J. M. and Jain, N. S. *Proc. S.T.A. India*, XXIV, Part II, pp. 168-173.
6. Saha, J. M. Bhattacharya, H. C. Nigam, G. M. and Rao, K. H. *Proc. S.T.A. India*, XIII, Part II, pp. 184-194.
7. Varma, N. C. and Bhattacharya, H. C., *Proc. S.T.A. India*, XXIII Part II, pp. 209-214.
8. Bogtstra, J. F. " Principles of Sugar Technology " by P. Honig, pp. 641-42.
9. Saha, J. M. 1955. *Indian Sugar*, March, (Annual Number), pp. 631-636.

APPENDIX A

TABLE I

STATEMENT GIVING THE RESULTS OF THE SAHA-JAIN PROCESS AT THE KANHEGAON FACTORY DURING THE SEASON 1954-55

Particulars		1st Period 25-11-54 to 30-11-54	2nd Period 1-12-5 to 23-12-54
Cane Crushed (m. tons)		1955.9	11979.3
Hours Mill worked		94.75	417.2
Crushing per 24 season hours (m. tons)		326.0	520.8
Crushing per 24 working hours (m. tons)		495.5	699.7
Recovery of Commercial sugar percent cane		8.64	10.02
Pol in cane		11.61	12.51
LOSS ACCOUNT (**percent cane**)			
Loss in bagasse		1.55	0.87
Loss in press-cake		—	0.06
Loss in molasses		—	1.37
Loss undetermined		-	0.21
Manufacturing loss		1.44	1.64
Total loss		2.99	2.51
Mill Extraction		86.7	93.0
Boiling House Extraction		85.7	85.9
Overall Extraction		74.3	79.9
ANALYSIS			
Primary juice	Brix	17.6	17.9
	Purity	81.8	83.7
Mixed Juice	Brix	16.2	16.2
	Purity	80.2	81.1
Clear Juice	Brix	15.1	14.8
	Purity	81.1	82.8
Rise in Purity (Units)		0.91	1.7
Maceration percent cane		13.3	14.4
Bagasse percent cane		35.7	25.6
Pol percent bagasse		4.34	3.41
Press cake percent cane		—	3.14
Pol percent press cake		1.93	2.05
Molasses percent cane		--	3.14
Purity of final molasses		—	32.95
STORES			
Lime percent cane		0·55	0.49
Sulphur percent cane		0.12	0.13
Triple superphosphate percent cane		0.10	0.15

Sugar Quality :—Sugars of colour better than ISS 29 and in grain sizes A—Special, A, B, and D were produced. Bulk of the production was in A, B and C grain sizes.

APPENDIX B

TABLE II

COMPARATIVE STATEMENT OF TECHNICAL RESULTS OF THE SAHA-JAIN PROCESS AND THE DOUBLE SULPHITATION PROCESS AT KANHEGAON DURING 1954-55

Sr. No.	Particulars	Saha-Jain Process 25-11-54 to 23-12-54	Usual Double Sulphitation Process 24-12-54 to 31-12-54
1.	No. of days of working	23	7
2.	Cane crushed (m. tons)	13935	5852
3.	Cane crushed per 24 working hours	661.3	859.6
4.	Sugar (m. tons)	1167.6	597.9
5.	Grades of sugar produced,	A29 Special, A29, B29, C29, and D29	
6.	Pol percent cane	12.39	13.36
7.	Recovery of sugar percent cane	9.81	11.08
8.	Molasses percent cane	4.43*	4.22
9.	Bagasse loss	0.97	0.68
10.	Press-mud loss (Pol loss percent cane)	0.06	0.06
11.	Molasses loss (-do-)	1.39	1.35
12.	Undetermined loss (-do-)	0.16	1.19
13.	Total manufacturing loss	1.61	1.60
14.	Store consumption :—		
	(a) Triple Superphosphate percent cane	0.14	0.04
	(b) Filter cloth (m^2/100 m. tons cane)	1.13***	0.19**
	(c) Lime percent cane	0.49	0.25
	(d) Sulphur percent cane	0.13	0.10

*From the beginning of the season.

**Average of entire season.

***This figure would have been lower if the process had run for a long period.

APPENDIX C

TABLE III

STATEMENT GIVING THE RESULTS OF THE SAHA-JAIN PROCESS WORKED AT SIDHWALIA DURING THE SEASON 1954-1955 FOR EACH RUN

Particulars	16-1-55 to 25-1-55 (Go-Slow Strike Period)	12-2-55 to 20-2-55	21-2-55 to 25-2-55	20-3-55 to 31-3-55	1-4-55 to 6-4-55	For the Total Period
1	2	3	4	5	6	7
Cane crushed (m. tons)	4828.8	2125.2	2563.2	612.2	2421.5	17925.8
Hours Mill worked	202-20	186-55	111-45	247-24	102-20	850-44
Crushing per 24 season hours (m. tons)	510	236	509	499	448	433
Crushing per 24 working hours (m. tons)	603	290	550	581	568	506
Sugar recovery	9.72	9.41	10.51	10.29	10.08	10.04
Pol in cane	12.63	12.81	13.28	13.33	13.27	13.07
Loss Account (**Pol loss per cent cane**)						
Loss in bagasse	1.18	1.57	1.19	1.27	1.27	1.27
Loss in press cake	0.08	0.11	0.12	0.14	0.17	0.12
Loss in molasses	1.09	1.18	1.18	1.47	1.57	1.30
Loss undetermined	0.58	0.56	0.30	0.18	0.20	0.36
Total manufacturing losses	1.75	1.85	1.60	1.79	1.94	1.78
Total loss	2.93	3.42	2.79	3.06	3.21	3.05
Mill Extraction	90.7	87.7	91.1	90.4	90.4	90.3
Boiling House Extraction	84.7	83.5	86.8	85.2	83.9	84.9
Overall Extraction	76.8	73.3	79.0	77.0	75.8	76.7
ANALYSIS						
Primary Juice Brix	-	--	- -	21.6	21.9	21.7
Purity	—	—	—	82.6	81.9	82.3
Mixed Juice Brix	15.5	15.9	16.8	16.5	17.0	16.1
Purity	83.0	80.4	82.2	80.2	79.2	81.0
Clear Juice Brix	15.0	15.5	15.8	15.3	16.3	15.6
Purity	84.0	81.6	83.1	81.5	80.4	82.1
Rise in Purity	0.9	1.2	0.9	1.3	1.1	1.1
Maceration percent cane	23.9	27.1	28.5	28.2	26.2	26.8
Bagasse percent cane	35.4	39.4	35.5	36.8	36.9	36.8
Pol percent bagasse	3.33	3.98	3.34	3.46	3.46	3.45
Press cake percent cane	3.84	4.94	4.29	4.73	5.13	4.59
Pol percent press cake	2.03	2.22	2.87	2.99	3.28	2.68
Molasses percent cane	3.49	3.80	3.74	4.53	4.82	4.09
Purity final molasses	32.2	32.3	32.6	34.5	34.5	38.2
STORES						
Lime percent cane	0.59	0.66	0.52	0.62	0.65	0.60
Sulphur percent cane	0.11	0.14	0.12	0.12	0.11	0.12
Triple superphosphate percent cane	0.19	0.18	0.15	0.12	0.13	0.15
Filter cloth, m^2/100 m.tons of cane	3.3	1.9	—	—	0.7	1.2
Hessian cloth, m^2/100 m. tons of cane	—	0.035	0.002	0.005	0.003	0.007
Hydrochloric acid (Commercial quality) kgm. per 100 m. tons of cane	—	7.90	5.47	4.98	10.33	5.10
SUGAR						
(Percent total production)						
A29	—	3.7	2.3	2.8	2.3	2.1
B29	28.5	15.1	15.3	9.8	11.8	16.3
C29	47.2	41.1	42.2	38.3	59.8	44.3
D29	24.3	40.1	40.2	47.3	26.1	36.7
Other grades	—	—	—	1.8	—	0.6

APPENDIX D

TABLE IV

STATEMENT GIVING COMPARATIVE RESULTS OF THE SAHA-JAIN PROCESS AND THE STANDARD SULPHITATION PROCESS, FOLLOWED AT SIDHWALIA DURING THE SEASON 1954-1955

		Saha-Jain Process 20-3-55 to 31-3-55	Standard Sulphitation Process 11-3-55 to 19-3-55
Cane crushed (m. tons)		5987	5366
Hours mills worked		247-24	205-02
Crushing per 24 season hours (m. tons)		499	596
Crushing per 24 working hours (m. tons)		581	628
Recovery of commercial sugar percent cane		10.29	10.46
Pol in cane		13.33	13.24
POL LOSS ACCOUNT (PERCENT CANE)			
Loss in bagasse		1.27	1.16
Loss in press cake		0.14	0.09
Loss in molasses		1.47	1.43
Loss undetermined		0.18	0.12
Total manufacturing losses		1.79	1.64
Total losses		3.06	2.80
Mill Extraction		90.4	91.2
Boilling House Extraction		83.2	86.4
Overall Extraction		77.02	78.8
ANALYSIS			
Primary Juice	Brix	21.6	21.4
	Purity	82.6	83.3
Mixed Juice	Brix	16.5	15.7
	Purity	80.2	80.7
Clear Juice	Brix	15.3	16.5
	Purity	81 5	81.4
Rise in Purity		1.3	0.76
Maceration percent cane		28.2	29.9
Bagasse percent cane		36.8	34.7
Pol percent bagasse		3.46	3.36
Press cake percent cane		4.73	2.00
Pol percent press cake		2.99	2.47
Molasses percent cane		4.53	4.63
Purity final molasses		34.5	32.4
STORES			
Lime percent cane		0.62	0.19
Sulphur percent cane		0.12	0.066
Triple Superphosphate percent cane		0.12	0.002
Filter cloth percent cane. (m²/100 m. tons of cane)		—	—
Hessian cloth percent cane (m²/100 m. tons of cane)		0.005	—
Hydrochloric acid (Commercial quality) kgm. per 100 m. tons of cane		4.98	—
SUGAR BAGS			
A29		2.84%	—
B29		9.83%	—
C29		38.28%	—
D29		47.25%	90.6%
Other grades		1.8%	9.4%

DISCUSSION

Shri N. C. Varma observed that the process was being worked on commercial scale in order to establish its economics. Stiffening of filter clothes was found to be a hinderance and though the clothes could be rendered soft by HCl treatment it was desirable to prevent the stiffening altogether.

Mr. Constandse desired to know the extent of apparent and true purity rise. Shri R. G. Pradhan desired to know if, the incrustation in evaporator tubes was normal. Shri Kothari wanted to know if the capacity of the boiling house was affected in any way after providing adequate filter press capacity. Shri S. N. Lal enquired if the crushing capacity was affected.

Dr. Douwes Dekker desired to know if the boiling house recovery, quality of sugar and the keeping quality of sugar of the new process compared favourably with the sulphitation and the defication processes. He observed that a process in which too high alkalinity had been kept was liable to yield a sugar of poor keeping quality.

Shri Gairola observed that the new process could not be cheaper than the carbonation process as the superphosphate used was a costly chemical as against $CaCo_3$ppt. which was produced quite cheaply and that sulphur consumption was about four times that in the carbonation process. Furthermore, the process involved the use of a continuous clarifier which was a costly equipment and whereas in carbonation the rise in purity was about four units, in the Saha-Jain process it was found to be about one unit only.

Shri Saha replying to the questions stated that there was both apparent and true purity rise of 1.0 to 3.5 units depending on juice quality efficiency of working ; no extension in the capacity of mill-house or boiling house was required, the boiling house recovery compared favourably with that of the sulphitation process and the quality of sugar was as good as that produced by the carbonation process and from his observations of samples kept in bottles the sugar did not appear to deteriorate any more than carbonation sugar. As regards the economics, the carbonation process involved considerable expense on transport of limestone its transhipment from broad gauge to meter gauge and on removal of press-mud which amounted to about 7.0% and which was of no use while the press-mud of the new process could be used as manure. The consumption of lime, sulphur and superphosphate was now very inornate being 0.45%, 0.075-0.09% and 0.1% respectively. The only difficulty that needed a solution was the prevention of stiffening of filter clothes for which suggestions were invited.

Dr. H. W. Kerr summing up the discussion complemented the inventors of the process on providing a process which yielded excellent quality of sugar but since the economics of the process was an important point he was glad that work was still continuing on the various aspects and hoped that the process would prove a success in due course.

Mr. S. N. Gundu Rao presented the following paper.

Paper

THE KENT UNIVERSAL pH RECORDER CONTROLLER ON CONTINUOUS SULPHITATION AT RAVALGAON

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INTRODUCTION

The success and stability of an industry depend to a great extent on quality and efficiency. On proper maintenance and control of pH during processing depends the success of white sugar manufacture. Inversion of sucrose, destruction of reducing sugars, formation of coloured decomposition products, precipitation of the colloids and of the various organic and inorganic non-sugar constituents of cane juice, the nature and size of the adsorbent precipitates produced in it and their flocculating, settling and filtering characteristics—all depend on pH. Developments in reliable methods under industrial conditions of pH measurement, indicating and recording as well as of replacement of manual control by automatic control are therefore of great consequence to the technical progress in this field.

While the colorimetric methods have useful applications in the routine manual control of pH, they cannot lend themselves to automatic control. The electrometric method on the other hand is not only more accurate, but enables automatic control.

THE SEARCH FOR A SUITABLE ELECTRODE

Researches into the practical application of pH determination have been directed to develop an electrode, which gives reliable measurements under conditions obtaining in industry. The use of the Quinhydrone Electrode (1) in conjunction with Calomel Electrode in Queensland gave only moderate success due to the inability of the Quinhydrone Electrode to give accurate value in alkaline (above 8.6) or poorly buffered solutions. Further, this electrode fails to give accurate results in solutions having other oxidising or reducing substances and Quinhydrone is unstable at higher temperatures. Promising results have been obtained in Queensland on defecation process with the Antimony Electrode which has the advantage that it is very robust and does not require the addition of any substance to the liquid under examination, the oxide film on the antimony surface being enough. The relation between pH and the E.M.F. of an Antimony Electrode is somewhat unpredictable and the antimony surface requires frequent cleaning to prevent poisoning and pH drift. Todt (2) reports satisfactory results with the Antimony Electrode at the Ist Carbonatation Station in German Beet

Sugar Factories, by keeping the electrode continuously cleaned by a rotating brush.

At Ravalgaon the Kent's Multelec pH Recorder with Antimony Calomel Electrodes, was installed for use on sulphited juice (batch process) the continuous sample for measurement being drawn from the discharge of the sulphited juice pump. The results obtained on this application were unsatisfactory, there being an indefinite difference varying from 0.2 pH to over 1.5 pH, as between the actual pH measured by a L and N Potentiometer, using the Glass Electrode and the Multelec indication. The unit was again tried during the season 1953-54 on continuous sulphitation juice, with the help of Kent's experts, when it was found that the Antimony Electrode could give reliable readings for 1½ to 2 hours only, on turbid neutral sulphitation juice, after which the readings become erratic. It is, however, still to be established, if the results can be entirely reliable and consistent even for 1½ to 2 hours with the turbid sulphitation juice. The first impression that this may be entirely due to the poisoning of the Antimony Electrode had to be altered, when it was observed that scale rapidly developed at the ground glass joint of the Calomel Electrode providing the liquid junction, thus rapidly increasing the electrical resistance at this point in the circuit. Similar experience has been reported from South Africa (private communication) with glass-electrode assemblies having a similar Calomel Electrode and liquid junction. It is, therefore, considered that the scaling at the ground glass joint is possibly one of the causes, that is making the application of the instrument to sulphitation juices difficult as apart from the influence of proteins, and reducing substances such as sulphites on the Antimony Electrode. It has been reported that the Antimony Calomel pH Recorder is the only pH instrument, which has ever given success in the Natal Sugar Industry. Though the Antimony Electrode has many drawbacks, it has been correctly observed that on account of its ruggedness and simplicity, it has been greatly helpful in the development of equipment for industrial pH measurement and control, which can be applied now to the more reliable and versatile Glass Electrode.

GLASS ELECTRODE

Industrial pH measurement took a great step forward with the introduction of the Glass Electrode, which is free from the defects of the other electrodes. The high resistance of the glass membrane necessitated the use of very thin and fragile electrodes, which were therefore unsuitable for industrial purposes. The development of Thermionic D. C. Amplifiers has, however, enabled the use of thick membranes resulting in small thick bulbs, which are quite strong. Special Glass Electrodes have been developed for the different conditions, such as high temperature and high alkalinity.

KENT'S UNIVERSAL pH RERCODER/CONTROLLER

With the adoption of continuous sulphitation process at Ravalgaon, the continuous recording of pH and if possible controlling it automatically assumed greater importance. When the Antimony Electrode failed to give satisfactory results with the sulphitation juices at Ravalgaon, it was decided to try the Glass Electrode. Kent's offered their latest Universal pH Recorder. Accordingly a Kent's Universal pH Recorder/Controller Unit was installed during the season 1954-55 on the continuous sulphitation system at Ravalgaon. The unit consists of :

1. One Universal pH Recorder/Controller fitted with Mark XX three term control mechanism with air relay and auto-manual valve, " Supply and Control " air pressure gauges, air filter etc.
2. One Electrometer Unit.
3. One flow type primary element with the appropriate Glass Electrode.

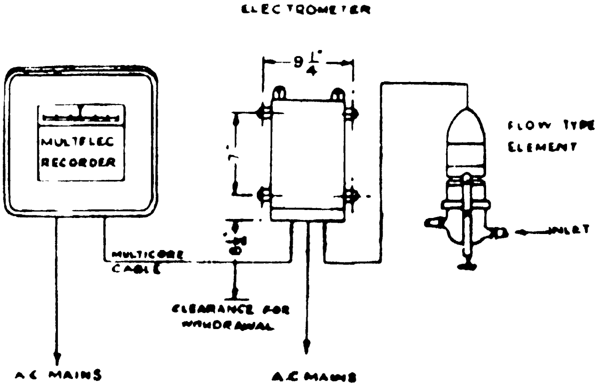
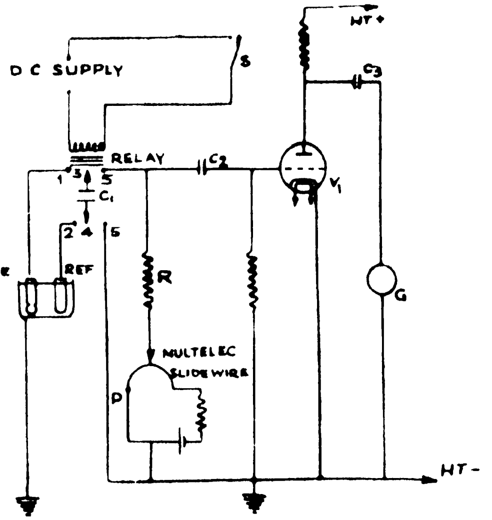


Fig No 1

From George Kent Limited



SIMPLIFIED WIRING DIAGRAM

FIG. No. 2

FROM - GEORGE KENT LIMITED

4. One 3″ bore 6″ stroke Mark IV type Power Cylinder.
5. One 3″ Butterfly Valve complete with lever for connecting to Power Cylinder, necessary connecting Cables etc.

A Schematic layout showing the arrangement of the various units is given in Fig. 1 and a simplified Wiring Diagram in Fig. 2.

TRIALS WITH THE HIGH TEMPERATURE GLASS ELECTRODE

Kent's have developed three types of Glass Electrodes to meet the different conditions obtaining in the Sugar Industry. These are (1) High temperature Glass Electrode (2) High alkalinity Glass Electrode and (3) General purpose Glass Electrode. Fig. 3 gives pH temperature limitations of the three electrodes.

pH - TEMPERATURE LIMITATIONS

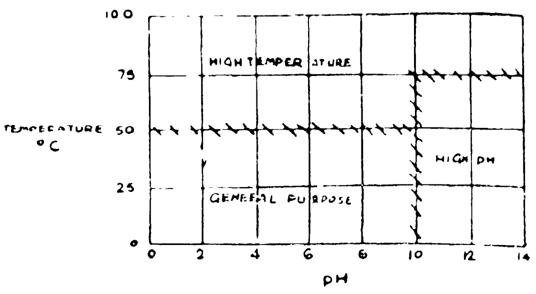
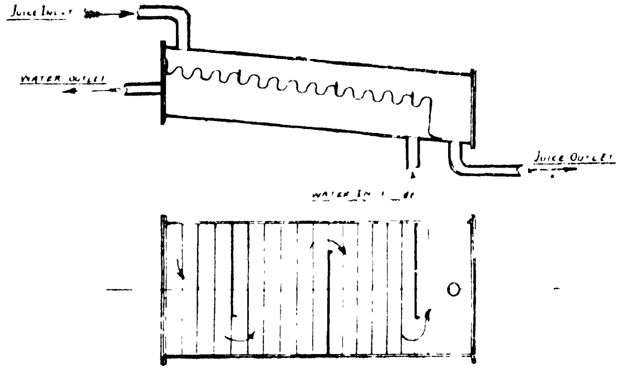


FIG N° 3

FROM GEORGE KENT LIMITED

In view of the temperatures of the juices emerging from the continuous sulphitation system varying from 55°C. to 75°C., the high temperature electrode was used in the beginning, when it was found that the sensitivity of the electrode to pH changes was affected in five hours or less due to the formation of scales on the Glass Electrode. The time for which the electrodes remained sensitive to pH changes considerably varied and depended on the scaling characteristics of the juice. To reduce the scaling tendency dilution was tried with a connection from the cold water line, but the scaling increased and the electrodes became insensitive more rapidly. Suspecting the possible scaling potential of the water, dilution with condensate water was contemplated, but before this was tried, cooling of the juice for arresting or slowing down of the progress of the pecipitation reaction and therefore of the tendency to scaling was suggested by Kent's experts, and accordingly a cooler was made and installed as shown in Fig. 4 and used. With the cooling of the juice to about 40°C. or below, the high temperature electrode was replaced by the general purpose electrode. With these changes the results became hopeful. An unexpected trouble at this stage was the entry of moisture into the leak-proof chamber housing the electrical contacts. The cause of this leakage has not been so far traced, as we had no trouble on this account subsequently.

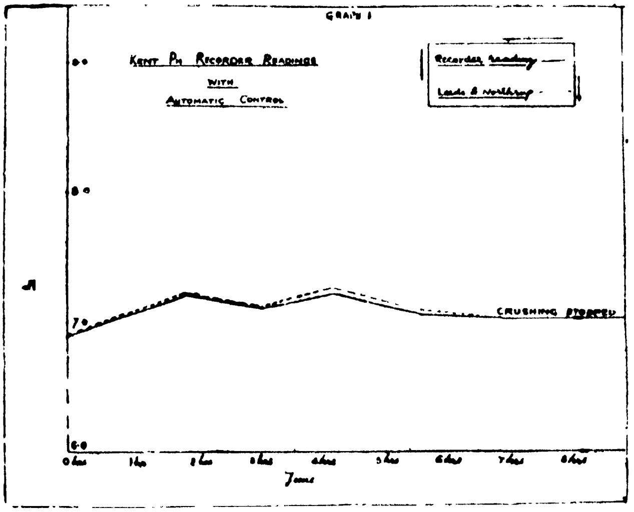


JUICE COOLER (SUGGESTION BY GEORGE KINT) SKETCH RAVALGAON

FIG. 4

DURATION OF RELIABILITY

The duration of reliability of the measurements is of very great importance for using the instrument on automatic control. The difficulties with the Antimony-Calomel and many of the Glass-Calomel assemblies have been either poisoning and fouling or scaling of the Antimony and Glass Electrodes, or scaling at the liquid junction increasing the resistance at the point. The Antimony-Calomel Electrodes could be relied upon at best for 1½ to 2 hours after which it got poisoned or the liquid junction got scaled or reducing substances interfered. With the cooling of juice and the use of the general purpose Glass Electrode, it became evident that we are having an instrument, the accuracy of which can be relied upon for much longer periods than any reported so far on dirty sulphitation juices. The cooler being not very perfect, the cooling performance varied and therefore the scaling potential. The pH Recorder was checked by taking the sample flowing out of the flow assembly and finding the pH by the laboratory Leeds and Northrup pH Meter using the Glass Electrode. Though the instrument was reliable for periods of 2 to 3 days and sometimes longer with only periodic flushing of the Glass Electrode with water, the overall experience so far has indicated that the instrument can be relied upon without touching it for about 8 hours and with flushing with water once in 8 hours for 2 to 3 days, after which washing the Glass Electrode with soap solution and keeping it in distilled water for ½ to 1 hour becomes necessary. It is desirable to have one duplicate electrode, which is washed and kept in distilled water, which can be quickly replaced, and the fouled electrode taken out for cleaning. Graph 1 shows the close correspondence between the readings of the Universal pH Recorder and the laboratory Leeds and Northrup pH instrument (Glass Electrode) during a period of 8 hours. The accuracy often continued for much longer periods, but until further work is done, it is considered safer to flush the electrode with water every 8 hours. Though the desirability of measuring the pH at the working temperature is appreciated, the difficulties encountered with dirty sulphitation juice explained before, necessitate cooling, till other methods of overcoming the trouble have been found out.



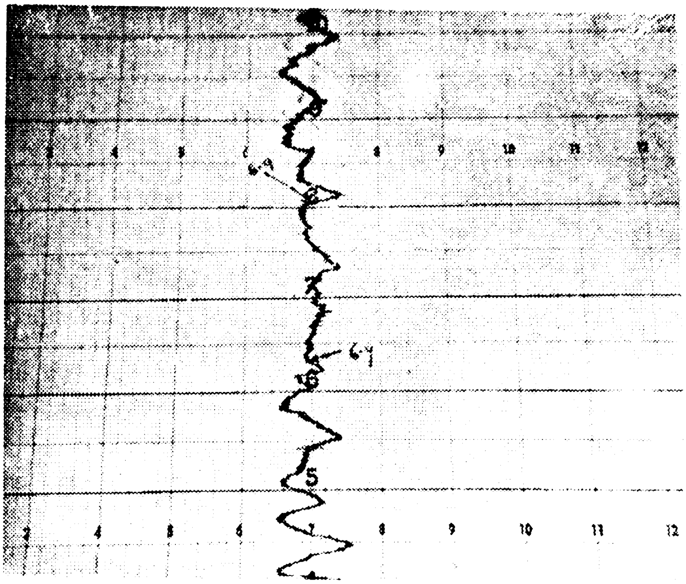
AUTOMATIC CONTROL OF pH

Having established the dependability of the Kent's General Purpose Glass Electrode for conditions obtaining in the continuous sulphitation system at Ravalgaon, for a reasonable period of 8 hours without touching and for 2 to 3 days with periodic flushing with water, the unit was linked to the automatic control system which consisted of Mark XX Control Unit connected to a power cylinder operating a butterfly valve in the SO_2 gas line. A Saunder's Valve could be used in place of the butterfly valve ; the butterfly valve, however, served the purpose admirably well.

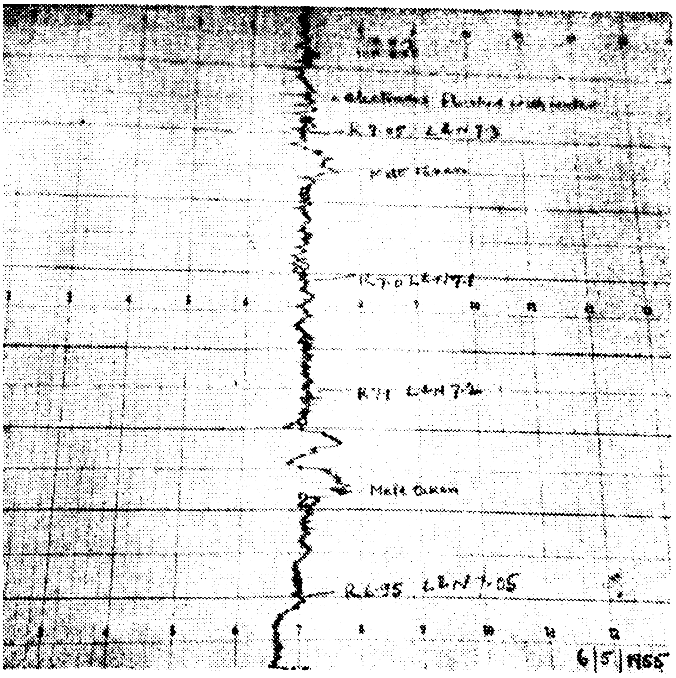
The continuous sulphitation unit consists of a tower and reaction tank. The preheated juice enters the top of the tower consisting of a series of staggered perforated plates, and falls in the form of a shower and cascade. The juice from the bottom of the tower enters the reaction tank through a preliminary vessel into which milk of lime in the set proportion is continuously discharged. The measured lime dispensing unit consists of a revolving horizontal wheel of the merry-go-round type, the speed of which can be varied through a wide range by a variable speed pulley. To the wheel are attached the required number of buckets of the required size at equal spacings. The buckets move in a circular box divided into two compartments. In the first half of the tank which discharges into the milk of lime stroage tank, milk of lime cascades along the path of the buckets. The buckets get filled and as they enter the other half of the compartment connecting to the reaction tank, they are tilted by a special stop and drag device and get emptied. By varying the size of the buckets and the R.P.M. of the wheel, any desired quantity of milk of lime can be measured out into the reaction system. As the measurement can be fairly accurately related to the crushing rate, this unit is found to be simple, positive, visible and reliable.

In the reaction tank the SO_2 is admitted through perforated coils. The reaction tank has suitable baffles to prevent short-circuiting of juice and a slow mechanical stirrer is also provided. This enables slow and efficient mixing of the reactants. The juice gets a positive stay of 8 to 10 minutes in the reaction tank. The control of the end point of the reaction is by controlling the gas inlet

Graph 2. Hand Control



Graph 3. Automatic Control



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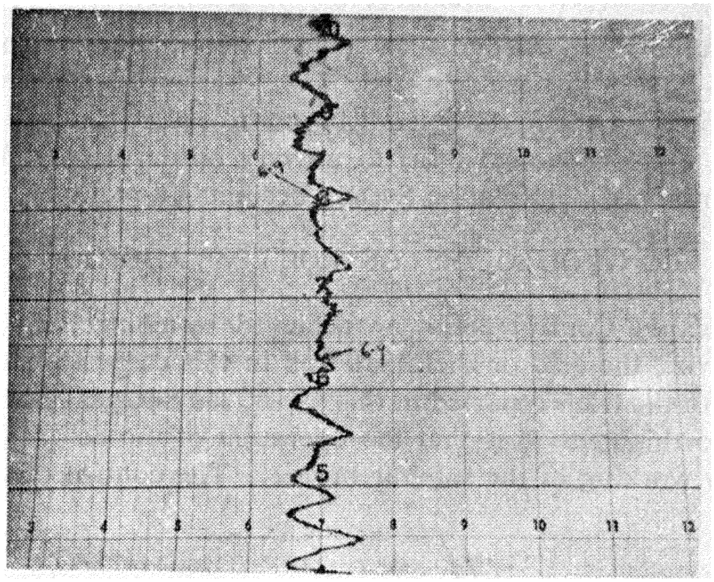
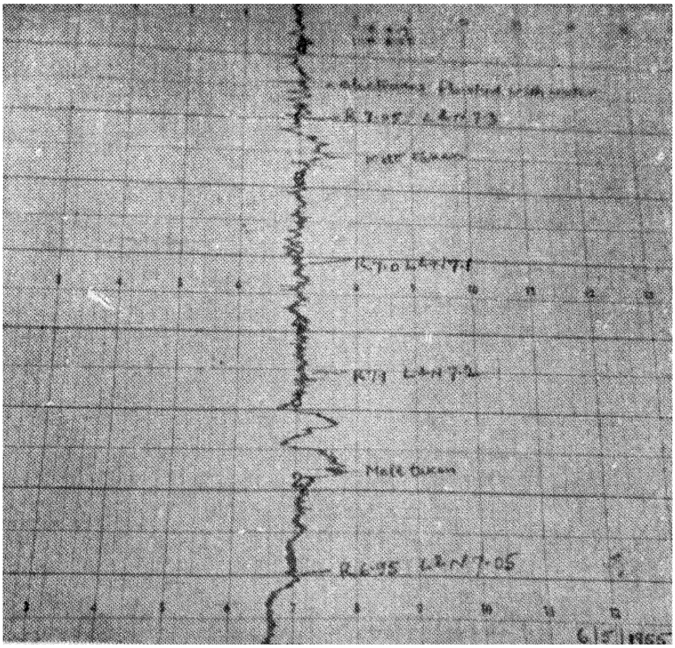


Graph 3. Automatic Control



into the reaction system. The SO_2 gas was generated in an Acme-continuous burner, but this did not work satisfactorily. With modifications that are now being made, a steady supply of SO_2 is expected.

The pH records of the juice treated in the continuous sulphitation system when (a) on hand control and (b) on automatic control are given in graphs II and III. It is seen from the graphs that automatic control has given much closer control of pH around the desired value as compared to well supervised manual control.

To the authors' knowledge such a good automatic control on sulphured mixed juice has not so far been reported. With the improvements in the reaction unit to reduce time lag and in the sulphur burner to ensure a steady and continuous supply of SO_2, there is enough basis to be very optimistic of the automatic pH Control of Continuous Sulphitation System becoming a reality.

CONTROL SO_2 OR CONTROL LIME ADDITION

Automatic pH Control could be achieved by controlling any one of the two reactants, viz., the acid or the alkali and in this case sulphur dioxide or the milk of lime. In the trials reported in this paper, the SO_2 gas has been controlled. An objection to this method is that the operation of the control valve interferes with the steady working of the sulphur burner. The control of the milk of lime on the other hand has the disadvantage that one cannot be sure of adding the required dose of milk of lime for optimum results in respect of settling, filtration

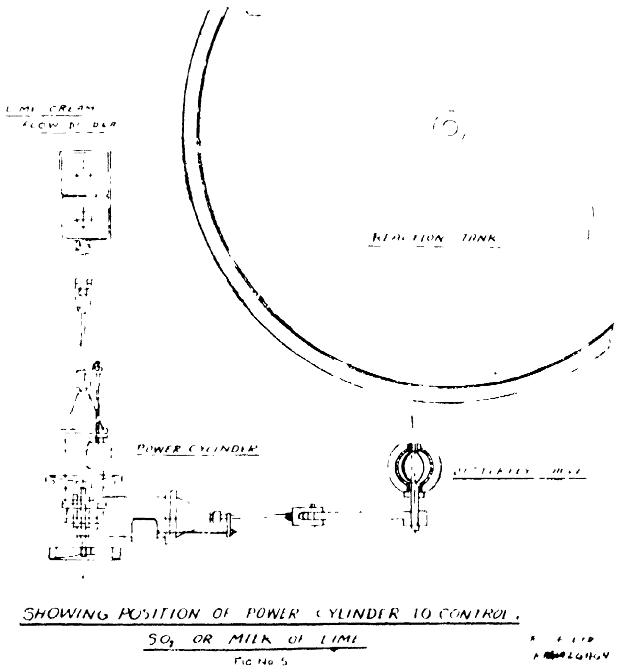


Figure No. 5.

and non-sugar elimination. So long as the fluctuations are not too wide and the gas valve operates for small corrections around an average, there should not be much interference with the sulphur burning operation. However, arrangements have now been made to make a comparative study of both the methods. By this arrangement, the power cylinder can operate (a) the butterfly valve on the gas line or (b) a flow dividing partition on the milk of lime line. The arrangement is shown in plan in Fig. 5.

ACKNOWLEDGEMENTS

The authors are thankful to Messrs. J.C. Farquhar and R.R. Orman of Messrs. George Kents Ltd., London, and to Messrs. H. G. Kulkarni, B.H. Hoshing and D.R. Wadekar, Chemists, Ravalgaon Sugar Farm Ltd., for their help and suggestions.

The authors are grateful to Seth Govindji Raoji for his help and encouragement.

REFERENCES

1. "Automatic measurement of pH" by Behne. 1934, *Proceedings, Queensland Society of Sugarcane Technologists.*
2. Honig's " Priniciples of Sugar Technology " P. 461 (Original *I.C.U.M.S.A. Proc. 16th Session* 1949).

DISCUSSION

Shri N. C. Varma desired to know if reducing the scaling potential would help in the case of Antimony Calomel Electrodes. Mr. Clayton observed that the Antimony Electrodes were working quite satisfactorily in Queensland where of course raw sugar was being made and no fouling took place up to 8-10 hours. If mechanical wipers were used the scaling difficulty would be eliminated. The use of Glass Electrode at high temperature was not found to be convenient.

Dr. Douwes Dekker wanted to know what modification had been effected in the Acme Burner. Dr. Doss observed that as the Antimony Electrode took more than 24 hours to attain constant potential he considered the Glass Electrode with the thermionic system now available better than the Antimony Electrode.

Shri S. N. Gundu Rao replied that reducing the scaling potential would not help in the case of Antimony Electrode as there was the poisoning effect also. As regards wipers he had tried them but without success. The high temperature electrode works in the temperature range of 70-80°C. whereas the general purpose electrodes worked at 35°-40°C. The Glass Electrodes now available were of robust construction and with the continuous system of sulphitation of Ravalgaon, the Glass Electrodes used by him gave very satisfactory operation.

Mr. Clayton congratulated Mr. Gundu Rao for being the pioneer in working the Glass Electrode satisfactorily in the continuous sulphitation system of sugar manufacture.

Dr. R. S. Dubey presented the following paper.

Paper

A SULPHI—CARBONATION PROCESS

R. S. Dubey and S. S. Mavi
Shri Ram Institute for Industrial Research, Delhi

INTRODUCTION

This process originated in an endeavour to cut down lime consumption in the Carbonation process. The sulphitation factories in India are eager to produce whiter sugar without resort to the use of large quantities of lime or limestone which are difficult to procure mainly due to inadequate transport facilities. Also, since good quality limestone occurs only in a few isolated places, its cost becomes too high for those of them which are located far away from the source.

Efforts had been made earlier by others for reducing lime requirement in the Carbonation process. An important advancement in this direction was the Middle Juice Carbonation process whose principles were first established and advocated by Honig (1) (p.711) in Java. This process was adopted by a large sugar factory in that country in 1938 ; but it found its fuller development in Taiwan at the hands of Chou and his associates (2) (p.711)(3). In this process it has been possible to effect a saving in lime of 19.6 to 42.5 percent (1) (p.720) under Taiwan conditions. There is a mention of the use of sulphitation in carbonation, as evolved by Teatini (4), (5), (6) (p.219), in the purification of beet juice ; but the process was considered unsound on theoretical grounds (6) (p.220). Another process which deserves mention in this context is the Double Sulphitation Process developed by Bogtstra (1) (p.641) during 1936-40. In this process the juice is limed and sulphited at 65°C. as usual and then its pH is gradually raised to 10.5. The alkaline juice is directly filtered although its requirement of filtering surface is large.

Both the Teatini and the Bogtstra processes demonstrate the great capacity of the calcium sulphite precipitate to aid filtration at high alkalinities of the juice. It may also be recalled here that a major portion of the lime used in the carbonation process mainly goes to produce a filter-aid in the form of calcium carbonate. It appeared logical therefore to subject the cane juice to liming and sulphitation before liming and first carbonation with a view to effecting a saving in lime consumption without any appreciable disadvantage in respect of juice purification and filtration. The results obtained on a laboratory scale and reported in this paper show that this expectation has been realised in a large measure.

THE PRESENT PROCESS

The present process is preferably carried out as follows :—

Mixed juice is heated to 65°-70°C. and treated with 1% by volume of 18° Be'.

milk of lime and sulphur dioxide to a final pH of about 7.0. It is cooled to 55°C. and further limed and carbonated using 2.4% milk of lime. The first carbonation juice is filtered and the filtrate goes through second carbonation, heating, filtration, and sulphitation to neutrality as in the normal carbonation process.

Alternatively, the preliminary sulphitation may be carried out at 55°C. This modification would not need a heat exchanger and would be more convenient for carrying out full scale trials in existing carbonation factories.

The present process was also studied with respect to Middle Juice treatment. For this purpose 40° Brix juice was treated by this process as well as by the usual method of middle juice carbonation, using 2.8% and 5.6% CaO on Brix, respectively. The first carbonation juices in either process proved very difficult to filter. It has not, therefore, been possible to collect any useful data in this regard.

Analysis.—Gravity purity was determined by Jackson and Gillis' Modification II of Clerget method since it was found to be more convenient among the several recommended by the S.T.A. of India (8). Undiminished sulphated ash has been reported here. Total hardness was determined by the 'Versenate' method and is reported as CaO. Reducing Sugars were determined by Eynon and Lane method.

Filtration.—500 ml. of first carbonation juice was filtered on the same Buchner funnel provided with a hot water jacket maintained at about 55°C., using Whatman Filter Paper No. 1, under a vacuum of 18 inches Hg.

RESULTS

Results given under each of the following series are the averages of a large number of experiments.

TABLE I

Series 1.

Normal carbonation was done with 10% by volume of 18° Be'. milk of lime. In sulphi-carbonation, sulphitation was done at 65°-70°C. and first carbonation at 55°C., total volume of 18° Be'. milk of lime used being 5%. Raw juice purities varied from 74.8% to 82.7% and Brixes from 17.0 to 19.0.

Kind of Juice	Gravity Purity	Purity Rise	Ash % Brix	CaO % Brix	R.S. Ratio	Filtration Time (Minutes)
Raw Juice	80.6	—	5.6	—	15.8	—
Clear Juice (Carb.)	85.0	4.4	4.9	0.14	14.9	6.5
Clear Juice (Sulphi-carb.)	84.9	4.3	5.1	0.24	15.1	2.2

Series 2.

All conditions same as in Series 1, except that preliminary sulphitation done at 55°C. Raw juice purities varied from 57.4% to 81.9% and Brixes from 10.0 to 18.0

Kind of Juice	Gravity Purity	Purity Rise	Ash % Brix	CaO % Brix	R.S. Ratio	Filtration Time (Minutes)
Raw Juice	70.9	—	7.1	—	20.0	—
C.J. (Carb.)	74.6	3.7	5.9	0.24	18.9	4.4
C.J. (Sulphi-carb.)	74.6	3.7	6.1	0.32	19.4	1.7

Series 3.

Only 4% total milk of lime used in Sulphi-carbonation, all other conditions remaining the same as in Series 2. Raw juice purities varied from 55.0% to 81.1% and Brixes from 12.0 to 17.0.

Raw Juice	63.6	—	11.3	—	31.8	—
C.J. (Carb.)	67.5	3.9	9.1	0.32	31.0	3.3
C.J. (Sulphi-carb.)	67.3	3.7	10.0	0.47	31.3	1.5

Series 4.

Only 3% total milk of lime used in Sulphi-carbonation, all other conditions being the same as in Series 2. Raw juice purities varied from 61.7% to 81.2% and Brixes from 14.0 to 17.0.

Raw Juice	70.4	—	5.7	—	21.5	—
C.J. (Carb.)	74.2	3.8	5.4	0.22	20.9	5.6
C.J. (Sulphi-carb.)	74.1	3.7	5.8	0.33	22.1	2.7

TABLE II

Gur Refining—Gur* was melted in water to give a concentrated solution of 35°-50° Brix. The solution was clarified by the double carbonation and the sulphi-carbonation processes. A few typical results are given below.

Expt. No.	Kind of Gur solution	% of 18° Be' Lime	Gravity Purity %	Purity Rise	Filtration Time (Minutes)
1.	Raw (40° Bx.)	—	75.6	—	—
	Clarified (Carb.)	20	80.0	4.4	50.0
	Clarified (Sulphi-carb.)	8	79.9	4.3	6.0
2.	Raw (45° Bx.)	—	69.0	—	—
	Clarified (Carb.)	25	74.9	5.9	45.0
	Clarified (Sulphi-carb.)	10	74.1	5.1	14.0
3.	Raw (50° Bx.)	—	68.8	—	—
	Clarified (Carb.)	30	73.5	4.7	60.0
	Clarified (Sulphi-carb.)	10	73.2	4.4	18.0

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*Solidified cane juice made and used in rural India.

DISCUSSION

From the foregoing Tables it is seen that there is no appreciable difference in the clarification efficiency whether the preliminary step of liming and sulphitation is carried out at 65°-70°C. or at 55°C. Also, with 5% by volume of 18°Be'. milk of lime (which is about 50% of the amount used in the normal carbonation process) the rise of purity is as good as in the carbonation process. Even when the quantity of lime has been reduced to as low as 3% by volume, the results are only slightly inferior. It may be remembered, however, that in actual practice increased purity rise does not necessarily give an equivalent increase in recovery due to the numerous other factors that operate in the manufacturing process. One important such factor is the pol loss in press-mud. When mud volume is very large, as in the existing carbonation process, there is also the risk of much greater pol loss in mud, a factor which might greatly offset the advantage of increased rise in purity. It is significant that compared to the normal carbonation process the clear juice obtained by the present process was invariably more brilliant, regardless of the quantity of lime used ; also, the rate of filtration was always faster. It would not be too much to expect therefore that the present process might prove technically sound and comparable with carbonation process in its results even with as low as 3 or 4 percent by volume of 18°Be'. milk of lime on juice. There seems to be no point in increasing it beyond a total of 5 volumes.

The total hardness and ash of the clear juice in the present process have been higher but at the same time the R.S. ratio is also higher. There should, therefore, be no adverse effect either on the purity or on the yield of final molasses, particularly with 5 volumes of lime.

One important feature of the process is faster filtration. Samples of mud from the present process and from the carbonation process were examined under the microscope. The crystals in the carbonation process were seen to be tiny rectangular rods whereas those in the present process were seen to consist of rods joined end to end with a little curvature in the surface at the joint. A packing of agglomerates of the type formed in the present process would naturally consist of numerous cavities which, while allowing easier passage to the liquid, would help to retain matter in suspension giving faster filtration and brighter filtrate.

The process promises to be particularly suited for gur refining. Using about one-third the quantity of lime that might have been used in the ordinary carbonation process, excellent clarification and rapid filtration were obtained even with melts as concentrated as 45° Brix. Above 45° Brix difficulty was experienced in filtration.

TENTATIVE ECONOMICS OF THE PROCESS AS COMPARED TO THE EXISTING CARBONATION PROCESS

Basis : 50% lime consumption in the present process.
1,000 tons/day crushing capacity.
110,000 tons cane crushed per season.
120 days duration of season.

Daily Expenditure :—

1. **Labour**—Many of the operations being mannual, labour requirement in Indian factories is very high. It is estimated that 33 men per shift will be required in this process compared to 48 in the normal carbonation, at the clarification stage including lime-kiln and filter-presses, under existing conditions.

Treatment of juice by liming and sulphitation has been assumed to be automatic, thus eliminating labour requirement at this station.

Therefore, daily wages (for 3 shifts) @ 3s. (=Rs. 2/-) per man per shift (allowing for weekly rest),

Carbonation — £ 24.6
Sulphi-carbonation — £ 16.9

2. **Raw Materials** :—

A. **Carbonation**—

	£
Limestone, 3.05% cane, @ £ 2.56 per ton	78.1
Coke, 0.32% cane, @ £ 4.03 per ton	12.9
Sulphur, 0.027% cane, @ £ 21.95 per ton	5.93
Filter cloth, 6.36 % cane @ £ 0.152/yd.	9.66
Total £	106.59

B. **Sulphi-Carbonation**—

Limestone (50% of above)	39.05
Coke (-do-)	6.45
Sulphur, 0.05% cane	10.98
Filter-cloth (66% of above)	6.44
Total £	62.92

3. **Steam**—Dilution of juice in the present process will be only about 50% of that in the normal carbonation process.

Therefore, cost of extra steam,

Carbonation — £ 14.64
Sulphi-carbonation — £ 7.32

4. **Depreciation**—It is expected that the overall capital investment in the present process would be less than 80% of that in the normal carbonation process. Normal carbonation involves an investment of about £ 58,500.

Therefore, depreciation and interest @ 14%, for

Carbonation — £ 68.3
Sulphi-carbonation — £ 54.6

Summary—

	Items	Carbonation £	Sulphi-carbonation £
1.	Labour	24.6	16.9
2.	Raw materials	106.59	62.92
3.	Steam	14.64	7.32
4.	Depreciation and interest	68.3	54.6
	Total	£ 214.13	£ 141.74

Therefore, daily Extra Saving in the Present Process = £ 72.39
= Rs. 986/-

ACKNOWLEDGMENTS

The authors wish to thank Dr. D. N. Daruvalla, Director, for his keen interest in this work and for his kind permission to publish the results. Thanks are also due to Mr. Harpal Singh of the Sugar Division, for his help in the collection of data.

REFERENCES

1. Honig, P. 1953. " Principles of Sugar Technology, " Elsevier Publishing Co.
2. Honig, P. 1950 *Sugar*, 45, No. 2, 39 ; [cf. 1950 C. A. 44, 4272 p.].
3. Chou, T. Y., and Chen, C. P. 1949 Ibid., 44 No. 8, 34.
4. Teatini, D.B.P. 351,160.
5. Teatini, D.U.S.P. 1,988,923.
6. McGinnis. 1951. " Beet Sugar Technology, " Reinhold Publishing Corp.
7. Dubey et al. Indian Patent, 52071.
8. " Methods of Chemical Control for Cane Sugar Factories and Gur Refineries ", published by *The Sugar Technologists' Association of India, Kanpur (India)*, 1936.

DISCUSSION

Mr. J. M. Saha expressed his doubts about the filterability of the juice by the sulphi-carbonation process. Mr. Parashar stated that it would be necessary to raise the temperature if easy filtration was desired but that could not be done at high alkalinity. Dr. Doss observed that the determination of filtration rate was difficult as reproducible results were not obtained and enquired the number of experiments carried out on the basis of which the filtration rate had been ascertained.

Mr. Gairola observed that the rate of filtration was a function of the nature of the precipitate and not its bulk. Large grain granular precipitate was more helpful than fine grain precipitate in pofuse quantity and the characteristics of the precipitate depended upon the manner in which it was formed with respect to temperature, time, ionic concentration etc. Mr. Vander Meyden enquired if the process had been tried on a large scale.

Dr. Dubey replied that the data given were based on the results of fifteen experiments. The better filterability of the juice appeared to be due to bends having been observed under the microscope in the granules of the precipitate obtained in the process which, on the formation of flocs provided porous space for the juice to pass through. The process had been tried on a large scale with improvised equipment for a short duration and the results were found to be so encouraging that arrangements were being made to try it out on large scale in the proper manner.

Session II—Friday, 27th January, 11-15 A.M.

Dr. H. W. Kerr, *Chairman*

Prof. D. N. Ghosh presented the following paper. This was discussed together with the next paper presented by Dr. Doss.

Paper

THE NEW ELECTRICAL PROCESS OF CANE JUICE CLARIFICATION AND THE MANUFACURE OF WHITE SUGAR WITHOUT THE AID OF SULPHUR

DHIRENDRA NATH GHOSH
Professor of Chemistry, Patna University, Patna

It is well known that about 90% of the Indian Sugar Factories use sulphur for the clarification of cane juice. During the second world war, when the import of this strategic raw material was stopped, Indian sugar factories had to face a crisis and the low grade sulphur from Baluchistan somehow saved the situation. With the attainment of Indian independence with partition, this bit of sulphur producing land of undivided India has also passed over to Pakistan, with the result that India is likely to face now a greater crisis, should any critical international situation arise, making nations war-minded. The members of Parliament of the Government of India, as appears from their recent deliberations over this problem (1) and its scientists are fully conscious of this fact and accordingly since the last few years constant attempts are being made to devise ways and means to minimise the consumption of sulphur in the Indian Sugar Industry.

In 1952 an attempt was made in this direction by the author, in course of which about 500 maunds of white sugar were actually produced without consuming any sulphur whatsoever, the details of which have already appeared in an article entitled "The Electrical Cane Juice Clarification Process and its maiden run at the Experimental Sugar Factory of the National Sugar Institute, Kanpur." (2). The present communication embodies, besides a fuller theoretical treatment of the Electric Process, some of the difficulties experienced during this maiden run and the manner in which these have since been overcome, making white sugar manufacture without the aid of sulphur a reality.

In the paper earlier referred, the variation of pH of the juice with different operations during clarification, has been graphically described as given in Fig. 1. From a perusal of this figure it will be clear that in this electric process, based on ionic coagulation of colloids, the juice has been clarified only between the pH range 5.4 to 7.2. with the result that during electrolysis of the acidic juice. with iron electrodes, the generated ferrous ions not only coagulate some negatively charged colloids but also form iron salts with the acid bodies present in the juice, It was observed during trial runs of this process that the first filtrate of pH = 7·2-6·9 soon developed acidity itself of pH=6.8-6.6 and the precipitation of these iron salts by the subsequent superphosphate treatment has been found to be incomplete owing to the fact that the full dose of superphosphate could not be added for their removal without rendering the finally clarified juice fairly acidic pH=6.4-6.6 which involves sugar loss by inversion during subsequent evaporation, apart from redissolving some of the precipitated ferric phosphate, causing an undesirable increase in the concentration of iron in the finally clarified juice. The cause of this internal development of acidity was soon traced to the incomplete hydrolysis of the pectic bodies present in raw juice during its electrolytic clarification at or below the maximum alkalinity corresponding to pH = 7.2, as against a much higher pH used in the orthodox processes of juice clarification. Accordingly it was thought desirable to add one more operation to the Electric process and the electrically treated juice which developed acidity of pH=6.8-6.6 was treated with lime to a pH of 8.4, as graphically shown in Fig. 2, when not only the unhydrolysed pectic bodies got completely hydrolysed but also the dissolved iron salts were simultaneously more or less completely precipitated as Fe $(OH)_2$ as shown by Pickering (3), rendering a greenish and alkaline clear first filtrate. After a short time interval this was neutralised with superphosphate to a pH=6.8, as usual, heated to boiling and filtered, when a more sparkling clarified juice than before was obtained, which was directly sent to evaporators.

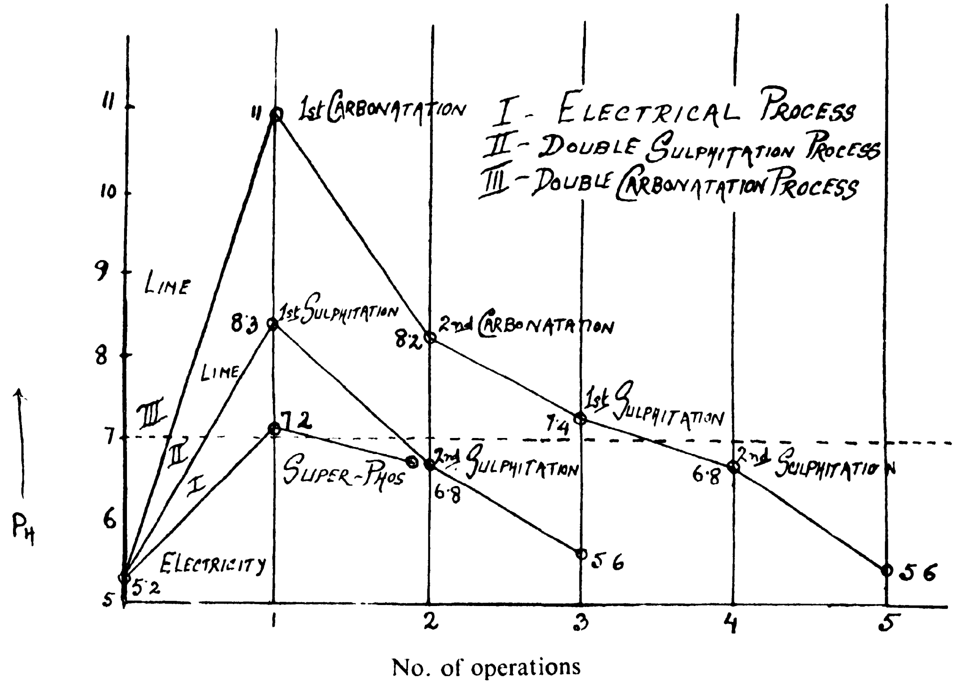

FIGURE 1.

In the maiden run of the Electric Process at the Experimental Sugar Factory, Kanpur, the Electro-clarifying batteries were provided with rectangular iron after some time, considerable difficulty was experienced in cleaning them and accordingly these rectangular plates have now been substituted by semi-circular

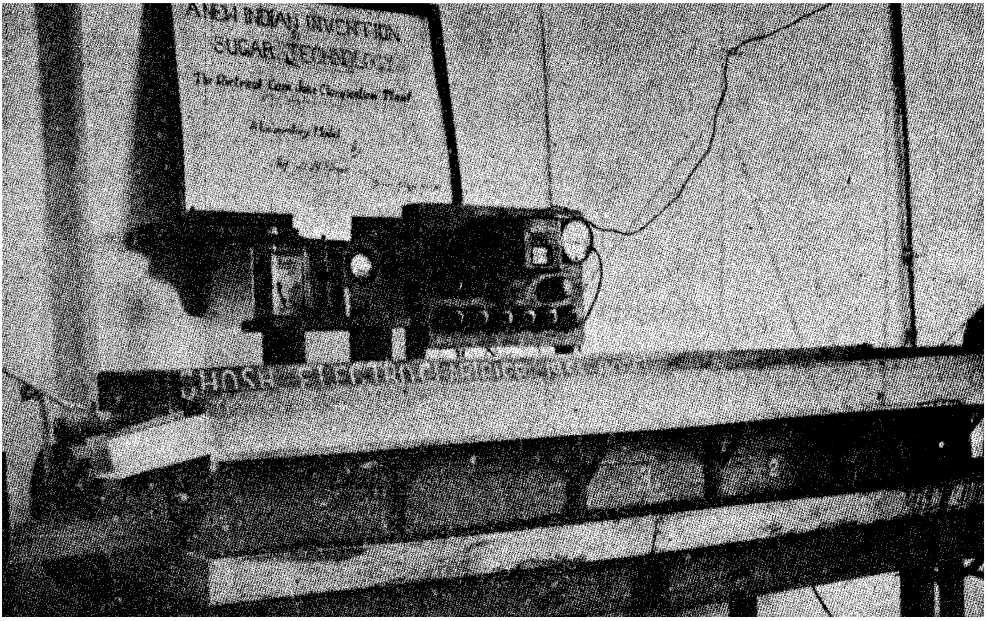

FIGURE 2. A laboratory model of Ghosh Electro-Clarifier (1955) with the original apparatus (1940) in the background.

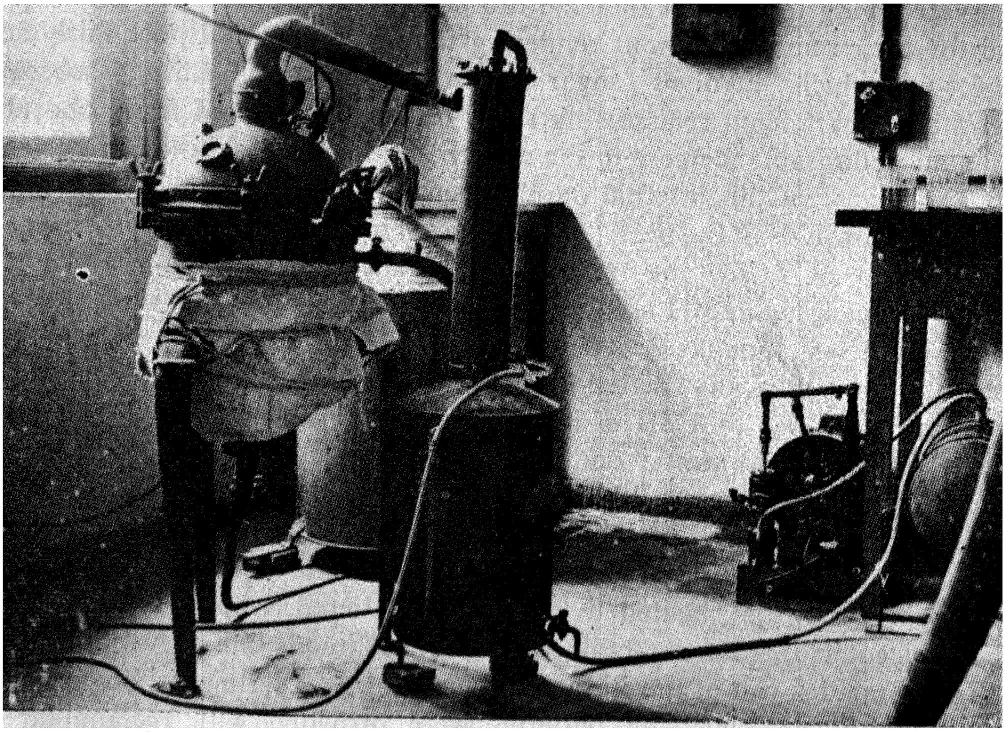

FIGURE 3. A laboratory unit of vacuum pump, boiler, Vacuum pan and condenser.

ones with a small similar opening at their centres, through which centre line a long and round shaped wooden shaft, fitting in this opening, passes horizontally and concentrically. The two ends of this shaft are fitted with metallic collars which are loosely fitted inside two suitably grooved metallic holders, grouted on the two end walls of the battery. A large number of stout brushes, one for each of the gaps between two adjacent plates, and made of hard bristles or nylon fibres are rigidly fixed at right angles throughout the length of this wooden shaft. With one end of a lever fixed at the protruding end of this shaft and the other end connected to a suitable mechanical arrangement, this shaft is given a to and fro motion, when the brushes move similarly, each cleaning thereby its enclosing plate surfaces aided by a spray of water. A photograph of such an Electro-clarifier as set up in the Chemistry Department of the Patna University is given in Fig. 3. During the cane season 1953-54, using the above Electro-clarifier and following the three operational procedures as per Fig. 2, fairly large quantities of juice were clarified and the sugar recovered therefrom with a laboratory model vacuum pan a photograph of which is also given in Fig. 4. This sugar was whiter, had better keeping qualities and was found to contain much less iron than that recovered from the earlier two stage processed clear juice, although the gradual darkening of the first molasses continued to take place in common with that observed in the orthodox processes.

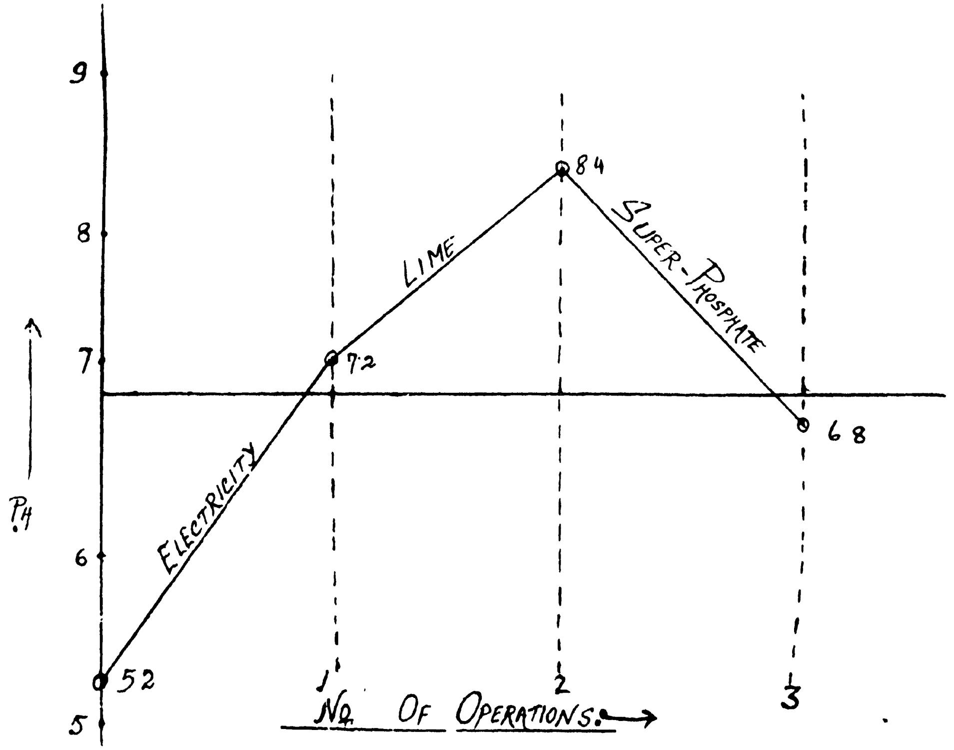

FIGURE 4.

From some recent studies on the behaviour of cane juice colloids in an electrical field, the details of which are being published separately, it has been concluded that the cane juice colloids behave like colloidal electrolytes and possibly possess a *structure similar to that of a molecular compound formed from the pectinic acids and the basic Anthocyanins.* In an electrical field this molecular complex dissociates *into the brownish pectinic acid anions and the greenish anthocyanidine cations* and move in opposite directions forming a boundary layer of their separation, from the rate of movement of which, the mobility of the Anthocyanidine cations can be calculated. During electrophoresis with cane juice at 30°C. this motion was observed to be about half inch in 15 minutes with a 10 volt per inch field intensity. The Cataphoretic velocity of colloidal particles in an electrical field is governed by the equation,

$$U = \frac{EHD}{4\pi n}$$

Where U = Velocity of the particle.
E = Double layer potential of the particle.
H = Field intensity.
D = Di-electric constant of the medium.
and n = Viscosity of the medium.

and it will be clear from the above that the viscosity of the juice is an important factor controlling the movement of the juice colloids undergoing electro-phoresis and that it varies inversely with the particle velocity. *As the heat coagulable albuminous proteins occurring naturally in raw juice are partially responsible for its high viscosity*, this is accordingly much lowered with their removal by heating the juice prior to electro-phoresis to a temperature of 70°-80°C. The speed of the moving boundary layer was thus observed to increase by about 50%. When a more or less complete deposition, is ensured in about 10 mts.. of the anthocyanidine cations on the negatively charged surfaces of the bipolar iron plate electrodes in the Electro-clarifier, where these are usually kept $\frac{1}{2}''$ apart and at a potential difference of 4 volts between any two adjacent plates. With continuous working of the Electro-clarifier this time period of 10 minutes is likely to be increased by a few minutes consequent on the widening with time of the $\frac{1}{2}''$ gap by anodic corrosion and the deposition of thin films of colloids on the plate surfaces, both the factors causing thereby a fall in the field intensity. This also explains the great necessity of prevention of plate fouling by alternately changing the battery polarity with a commutator placed in the circuit and an efficient mechanical arrangement for the brushing of these plates combined with spray washing, the wash liquor being mixed with the froth liquor and retreated in a secondary battery as usual (2).

As the development of the dark colour in the first molasses occured, inspite of working with this improved Electro-clarifier fitted with mechanically driven brushes for avoiding plate fouling and following the three operational procedure as per Fig. 2 it was believed that this might be due to the action of lime on some of the pectinic acid-anthocyanidine molecular complex, which have been earlier incompletely removed by electro-deposition and have thus leaked into the first filtrate. It was accordingly thought desirable to avoid the addition of lime altogether in the alkaline range of the juice clarification process. It is well known that coagulation of colloids can be brought about not only by oppositely charged ions but also by oppositely charged colloids and as in an alkaline medium colloidal Fe $(OH)_2$ is negatively charged, it was expected that if juice electrolysis is carried on in the Electro-clarifier only within the alkaline range, the resulting negatively charged Fe $(OH)_2$ sol will more effectively remove, the anthocyanidine cations, than their removal by cathodic deposition alone. In the absence of ferrous ions as during the electrolysis of an alkaline juice with iron electrodes, the possibility of iron salt formation with the acid bodies in the juice also becomes remote unlike its formation during the original acidic juice electrolytic process and this alkaline juice electrolytic process also gives the additional advantage of lowering the consumption of iron by anodic corrosion, which is less as compared to its dissolution during an acidic juice electrolytic process.

According to the new electrical process of cane juice clarification, the raw juice of pH=5.2 after measurement is heated quickly to about 70°C. to coagulate its albuminous bodies and thereafter the juice is quickly almost neutralised to pH=6.8 by regulated addition of milk of lime preferably of 5°-10° Be'. with constant stirring to avoid as far as possible any local alkalinity. This juice, now partially thinned due to the removal of heat coagulable protein bodies and the free juice acids as calcium salts, is next reheated to about 95°C. to further lower its viscosity and sent to the primary electro-clarifying battery where it is kept exposed for 10-15 minutes. Here it gets clarified as the residual juice colloids are removed partly by adsorption at the gas-juice interface of the uprising froth, partly by direct contact with the Electrode plates and mainly by surface adsorption with the nascent colloidal Fe $(OH)_2$ which is simultaneously generated within the bulk of the juice. The alkali metal salts of Na and K, present in the juice also undergo electrolysis simultaneously, when the pH of the juice rises in about 10 mts. from 6.8 to 8.4, which alkalinity brings about a more or less *complete hydrolysis of the neutral pectic bodies as well*, rendering them electrolytically dissociable. After removal of the top froth layer the juice is discharged into a tank where if necessary, it is reheated to about 80°C., mixed with the phosphatic mud obtained from the second stage filtration and filtered. The first filtrate of pH=8.3 which is transparent and yellowish in colour, is next treated with superphosphate liquor till its pH is lowered to about 6.8, when it is heated to boiling and filtered again, the operations being graphically described in Fig 5.

This second filtrate of pH=6.8 is colourless, sparkling and almost free from colloids and gave a rise in the purity coefficient of about 4-5 units, and it is sent directly to the evaporators. The quality of sugar recovered from this clear juice is found to be better than that obtained by the previous process and no more gradual darkening of the first molasses was observed as before, which now continued to preserve a reddish brown tinge. As a matter of fact the colloids removal by this new process appears to be so perfect that a sample of syrup of 70°Bx. obtained from open boiling of a sample of the clear juice in an iron vessel was observed to remain yellowish for a long time, when kept exposed to air in a cotton plugged sample bottle, with no evidence of any development of brown colour was from the top as previously observed with other syrups, similarly made and preserved from clear juices with imperfect colloid removal.

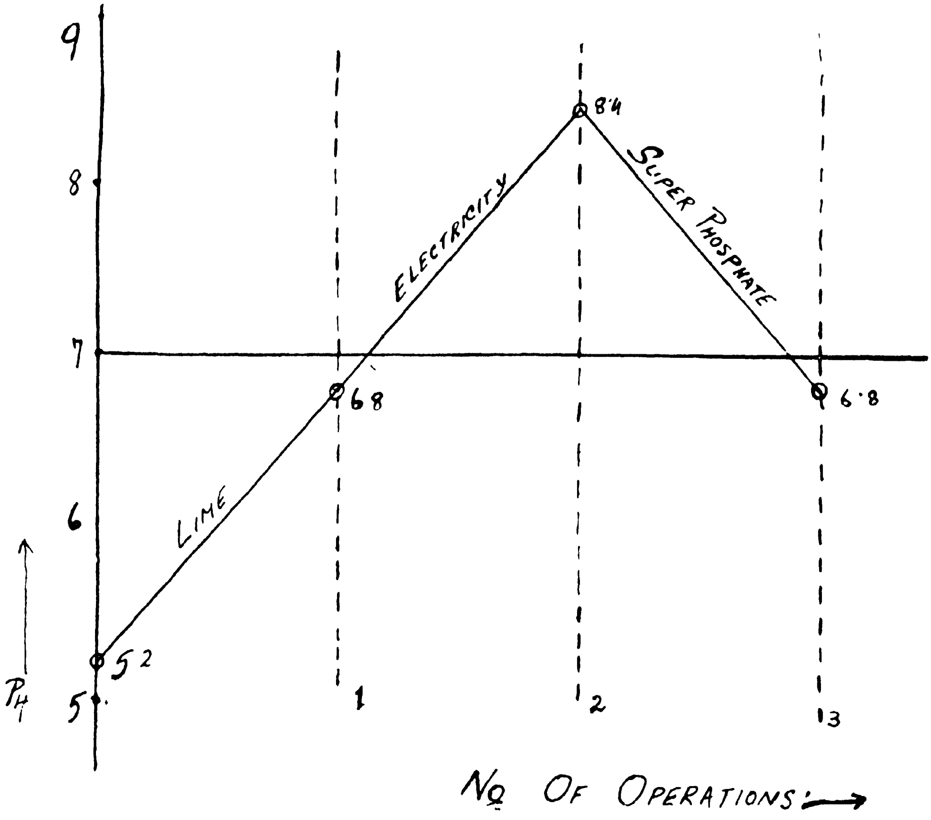

FIGURE 5.

During the cane season 1954-55 successful demonstration of this new process was given for two months in the Chemistry Department of the Patna University. The Secretary, Indian Sugar Mills Association was also duly informed about this new process who in turn issued a circular to all its members to come to Patna and witness the demonstration. In response to this circular many sugar technologists from different parts of India had come to Patna to witness this demonstration, which was in the nature of a revelation to them, as cane juice clarification without the aid of sulphur was till then unknown to them. The new process soon attracted the attention of the Government of India and the Deputy Director (Sugar), Ministry of Food and Agriculture, New Delhi and the Director, National Sugar Institute Kanpur, had also come to Patna to witness this demonstration, which they highly appreciated. The Director, National Sugar Institute Kanpur, was also presented by the author with a portable laboratory model of the Electro-clarifier for further experiments at Kanpur, and he has since reported about its satisfactory working and has also confirmed the average 3 to 4 units rise in clear juice purity as earlier recorded at Patna. The following extracts from his official report on this new process, submitted to the Government of India, are also quoted in this connection :

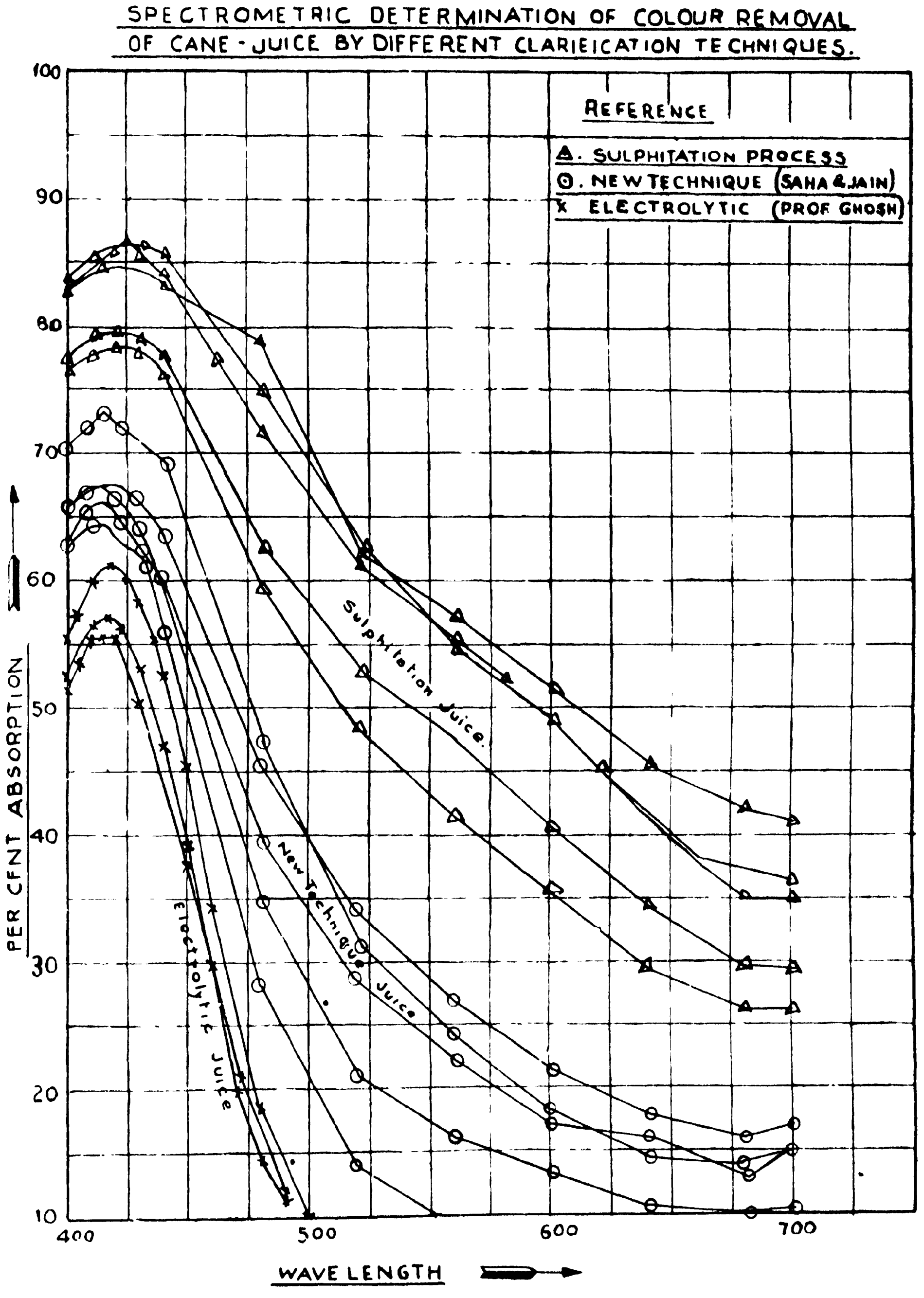
SPECTROMETRIC DETERMINATION OF COLOUR REMOVAL OF CANE-JUICE BY DIFFERENT CLARIFICATION TECHNIQUES.

FIG VI

"Colour removal :—Even the visual observation shows that the juice obtained by the electrolytic clarification is definitely better than the juices obtained by sulphitation, carbonation or the Saha-Jain technique. Spectro-photometric examination confirms the above observations. In Fig. 6 are given (a) five curves for sulphitation juices (b) five curves for the Saha-Jain technique juice and (c) three curves for the electrolytically clarified juice. The three sets of curves form separate bands by themselves and their is no overlapping showing thereby that the electrolytic process is far superior to the other methods of clarification and perhaps second only to the ion-exchage process.

Purity rise :—An examination of the data shows that the pol-purity rise as well as sucrose purity rise is higher by about two units in the electrolytic process as compared with the sulphitation process. This would mean that the recovery would be increased by about 0.15% on cane.

Consumption of iron :—It is to be noted that the consumption of iron in the modified process is nearly half of what was obtained in the pilot plant trial using Ghosh's first procedure.

For a 1000 ton factory, electricity consumption is approximately 7000 units per day, and the iron consumption including 25% scrap will be 1.1 tons per day.

Extra Expenditure per day :— ...

(1) Electicity—8000 units (assuming 12½% loss in conversion etc.) at (½ anna per unit)	Rs. 250/-.
(2) Iron consumed 1.1 tons including 25% scrap ...	Rs. 500/-.
(3) Superphosphate 1 ton	Rs. 600/-.
(4) Filter cloth 50 sq. yds.	Rs. 150/-.
(5) Labour 24, at Rs. 2/- per day	Rs. 48/-.
(6) Interest and depreciation per day assuming 100 days season	Rs. 468/-.
Total	Rs. 2066/-.

Savings :—

(1) Lime 10.2 tons	Rs. 144/-.
(2) Sulphur 0.4 tons	Rs. 120/-.
Total	Rs. 264/-.
Net Extra Expenditure per day ...	Rs. 1802/-.

Extra Income per day :—

(1) Extra sugar bagged 1.5 tons	Rs. 1200/-.
(2) Extra price due to better quality at Rs. 15/- per ton ...	Rs. 1500/-.
Total	Rs. 2700/-.
Overall net income per day	Rs. 898/-.

CONCLUSION

From the above study it appears that the Ghosh process of Electrolytic clarification deserves a pilot plant trial.

ACKNOWLEDGMENTS

The author takes this opportunity to thank the Indian Sugar Mills Association for inviting its members to Patna and the management of the various sugar factories, which had deputed their technologists to Patna for witnessing the demonstration of this new electrical process of cane juice clarification. He is also grateful to the Deputy Director (Sugar), Ministry of Food and Agriculture, Government of India, and the Director, National Sugar Institute Kanpur, for their kind interest in witnessing a demonstration of this process at Patna. Lastly he expresses his indebtedness to the Government of India, which has since accepted the recommendations of the Director, N.S.I., Kanpur, and is soon arranging to have a full scale trial of this new process at its Experimental Sugar Factory at Kanpur under the author's direction, the publication of the details of which forms the subject matter of a future communication.

REFERENCES

1 Proceedings of the Rajya Sabha. The Hindustan Times, 27-4-1955, page 9.
2. Ghosh, D. N. 1953. *Indian Sugar. Annual Number, February*, pages 453-461.
3. Pickering. "Comprehensive Treatise on Inorganic and Theoretical Chemistry" by Mellor, Vol. 13 Part 2, page 718.

Dr. K. S. G. Doss presented the following paper.

Paper

LABORATORY EXPERIMENTS ON ELECTROLYTIC METHOD OF CANE JUICE CLARIFICATION

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National Sugar Institute, Kanpur

INTRODUCTION

Attempts have been made for making use of electricity for clarifying cane juice for a long time past although unsuccessfully. This can be seen from the following statement of Geerligs (1) " Better assistance may be expected from the electric current although the results of manifold experiments in treating juices with electric currents of various degrees of intensity, using all kinds of electrodes combined or not with dialysis, have not been able to solve the problem". According to a patent taken in U.S.A., the juice is electrolysed by using aluminium electrodes (2). This patent, however, has not been exploited commercially. The high cost of aluminium is presumably one of the factors which has come in the way of adoption of the process on a large scale.

GHOSH'S FIRST PROCEDURE

The use of iron electrodes has been worked out in the laboratory for the first time by D. N. Ghosh (3). The process as claimed by Ghosh consists of exposing the raw juice heated to 80°C. to the action of direct current in a battery fitted with iron electrodes, when the stabilising lyophilic colloids which are negatively charged bodies are almost completely removed, partly by direct contact with anode plates, partly by charge neutralization with the positively charged ions generated by the current and partly by adsorption at the surface of the electrolytic gas bubbles. The removal of the lyophilic colloids results in automatic coagulation of hydrophilic particles and the pH of the juice rises from 5.2 or 5.4 to 7.2. The juice is then filtered. This faintly alkaline filtered juice is rendered faintly acidic (pH 6.8) with superphosphate and heated to boiling. This on filtration gives the clarified juice which is sent to the evaporators. The juice obtained by this process is clear and of a pale colour.

After his laboratory experiments and a few incomplete trials on a large scale, the electrical process of Ghosh was given a regular trial in the Experimental Sugar Factory, Kanpur in 1951-52. The results are given in Table I. Due to high consumption of electricity and iron, the process proved to be uneconomical for its being applied to sugar industry. The high iron content of clear juice affected the colour of sugar adversely and no appreciable improvement could be affected by sulphiting the syrup although Ghosh's process aims at white sugar without the use of sulphur. In spite of the very clear juice and syrup obtained by this process, the colour of the sugars obtained was disappointing. The iron in sugar would form a complex with tannin when added to tea and would produce dark colour in tea.

TABLE I

FACTORY TRIAL OF THE ELECTRICAL PROCESS OF CANE-JUICE CLARIFICATION 1951-52

GHOSH'S FIRST PROCEDURE

No.	Description of the analysis	Result
1.	Pol-purity rise	0.3
2.	Sucrose-purity rise	0.8
3.	% Reducing matter destruction	29.6
4.	Electricity consumption	58.1 units/ 100 Mds. of cane.
5.	Iron consumption	0.19% on cane.
6.	Iron content of final juice	10.2mg./100 gm. juice.
7.	Iron content of first filtrate	12.0 mg./100 gm. juice.
8.	Superphosphate consumption	0.03% on cane.
9.	CaO content of final juice	91 mg./litre

GHOSH'S SECOND PROCEDURE

With a view to overcome these difficulties Ghosh has modified his process which consists in heating the raw juice (4.5 litres to 5 litres) quickly to (70° to 80°C.) and immediately neutralising with milk of lime (5° Be.) to 6.8 pH. The juice is then sent to the electro-clarifier, and the current is switched on and it is seen that the electrolysis is going on in every chamber (froth coming out). After 10 to 12 minutes, 10 ml. of juice are taken out from the battery by a pipette, heated to 80°C. and filtered. The pH of the filtrate should be about 8.3. The froth is scraped off from the clarifier and the electrolysed juice is dropped from the bottom. This is heated to 80°C. and filtered. To the filtrate, superphosphate extract (about 50 ml. for 4.5 litre) is added until the pH is 6.9. This is heated to boiling and filtered to get the final juice.

It was proposed first to collect some data on laboratory scale with a view to examine the desirability of trying the process on a pilot plant scale. A number of laboratory experiments have, therefore, been tried on Ghosh's second procedure for cane juice clarification and the results are discussed in this paper.

EXPERIMENTAL

Electrolytic Cell :—The electrolytic cell used in the present work was kindly made available from the Chief Chemist, Industries Department Bihar, by the good offices of Prof. Ghosh. It consists of wooden box (15.5″ x 8.5″ x 5.5″) and 25 iron plates forming 24 chambers. Iron plates are situated at a distance of ½″ and may be cast iron or mild steel. They are of ⅛″ thickness. The cell holds about 4.5 to 5 litres of juice. End plates are connected to positive and negative terminals of 100 volts D.C. supply so that potential difference between any two plates of one chamber is about 4 volts. Intermediate plates serve as bi-polar electrodes.

In order to minimise the quantity of juice used for processing, a small electro-clarifier about half the capacity of the above was made at the Institute. It consists of 12 iron plates forming eleven chambers.

As the time required for electrolysis according to Ghosh's second procedure was varying too much, it was proposed to slightly modify the technique. The modifications introduced are as follows :—

(1) Heat the raw juice quickly to 55 to 65°C.
(2) Electrolyse for 10 minutes only.
(3) Raise the pH of the electrolysed juice to 9.5 by adding milk of lime.

After raising the pH of the electrolysed juice to 9.5 and heating to about 65°C. the same technique as in Ghosh's second procedure was followed.

In order to compare the clear juices obtained by Ghosh's process as well as modified process with that of clear juice from standard sulphitation technique, a few experiments were also tried to get clear juice by standard sulphitation process.

The cane was crushed by a power crusher and the juice was diluted to 15° to 16° Brix. This diluted juice was analysed for pol-purity, sucrose-purity, reducing matter, and conductance per unit Brix and was clarified by —

(1) Standard sulphitation process.
(2) Ghosh's second procedure using big and small clarifier, and
(3) Modified process.

The clarified juice was analysed for pol-purity, sucrose-purity, reducing matter, iron, conductance per unit Brix and CaO. Spectrophotometric determination of colour at different wave lengths was carried out using clear juices obtained by different techniques. The results are given in Fig. 1. The quantity of iron dissolved during electrolysis in Ghosh's process as well as modified process was examined. The time of filtration of the juice in different processes under controlled conditions in a Buchner funnel at a constant vacuum has been recorded so as to get some idea about the filtrability of the juice by different techniques.

The iron content of the first filtered juice by Ghosh's process and modified process has been noted in some cases.

The other controlling factors viz.,

(1) pH of raw juice,
(2) Temperature of raw juice after heating,
(3) pH after liming,
(4) Time for electrolysis,
(5) pH after electrolysis,
(6) Average voltage used,
(7) Average current used,
(8) pH of the first filtrate,
(9) pH after addition of superphosphate and,
(10) pH of final juice,

were recorded. Some of the important average figures based on the above data are given in Table II.

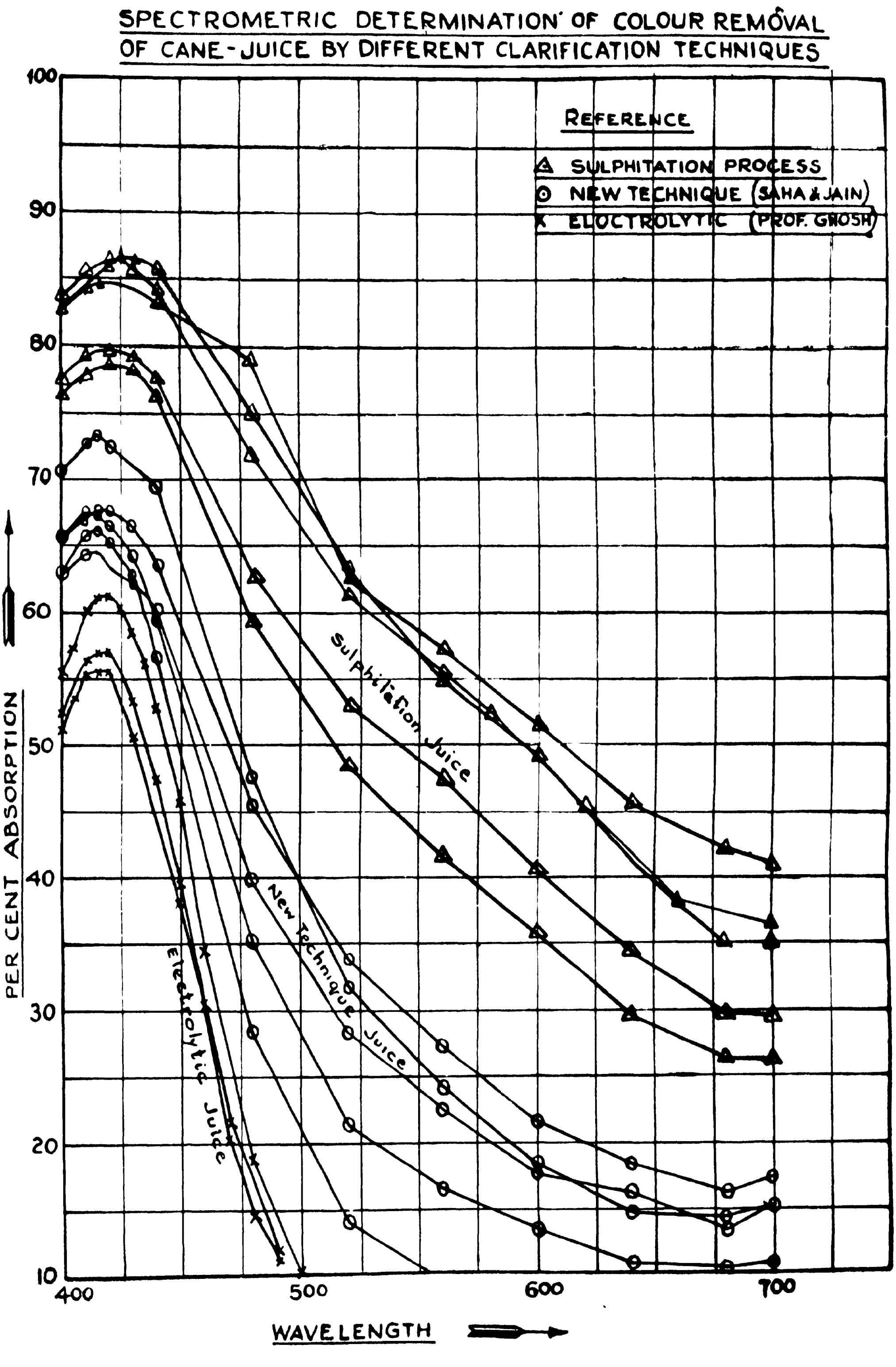
SPECTROMETRIC DETERMINATION OF COLOUR REMOVAL OF CANE-JUICE BY DIFFERENT CLARIFICATION TECHNIQUES
REFERENCE
△ SULPHITATION PROCESS
⊙ NEW TECHNIQUE (SAHA & JAIN)
× ELOCTROLYTIC (PROF. GHOSH)
Sulphitation Juice
New Technique Juice
Electrolytic Juice
PER CENT ABSORPTION
WAVELENGTH
100
90
80
70
60
50
40
30
20
10
400
500
600
700

Fig. 1.

TABLE II

QUANTITY OF RAW JUICE—4.5 LITRES

Sl. No.	Description of analysis	Ghosh process	Modified process	Standard Sulphitation process
1.	Pol-purity rise	3.2	3.1	0.99
2.	Sucrose-purity rise	3.8	3.0	—
3.	%Reducing matter destruction	12.1	2.2	—
4.	Electricity consumption	0.06 units	0.03 units	—
5.	Iron consumption during electrolysis	129 mg./100 gm. of juice	101 mg./100 gm. of juice	—
6.	Iron content of final juice	3.5 mg./ litre	2.2 mg./ litre	—
7.	Iron content of first filtrate	201 mg./ litre	9.9 mg./ litre	—
8.	Time of filtration for 500 c.c. juice	2'35"	2'42"	2'50"
9.	Increase of conductance per unit brix, percent of initial value	10.5%	8%	7.5% extra over electrolytic juices
10.	Quantity of lime used	0.07 to 0.08%	0.07% to 0.08%	—
11.	Quantity of superphosphate used	0.09% on cane	0.1% on cane	—

DISCUSSION

Colour removal :—Even the visual observation shows that the juice obtained by electrolytic clarification is definitely better than the juices obtained by sulphitation, carbonation or the Saha-Jain technique. Spectrophotometric examination confirms the above observation. In Fig. 1 are given (a) five curves for sulphitation juice (b) five curves for the Saha-Jain technique juice and (c) three curves for the electrolytically clarified juice. The three sets of curves form separate bands by themselves and there is no overlapping showing thereby that the electrolytic process is far superior to the other methods of clarification and perhaps second only to the ion-exchange process. It is to be noted however that the Ghosh process juice is likely to have a slightly deeper colour when the juice is got by a full scale factory process.

Purity-rise :—An examination of Table II shows that the pol-purity rise as well as sucrose-purity rise is higher by about two units in the electrolytic process as compared with the sulphitation process. This indicates that the recovery would be increased by about 0.15 percent on cane.

Reducing matter destruction and ash content :—In the electrolytic process as per specification given by Ghosh, the destruction of reducing matters comes to about 12% on the reducing matters present. With the modifications introduced in the present work there appears to be no destruction ; the inversion appears to take place and the reducing matters increase on the average to the extent of 2.7 percent on the reducing matters already present. This is negligible. The change in the soluble ash content of the juice can be gauged by the change in the conductivity. The percentage increase in conductance referred to unit brix comes out to be nearly the same in Ghosh and modified processes i.e., 10.5 and 8.0% respectively, whereas the ash of sulphitation process juice is about 7.5% higher than that of the electrolytic process. It is, therefore, very probable that the exhaustibility of molasses will prove to be at least as good as in sulphitation process. It is likely however, that while the process is tried on the pilot plant scale the heating of the alkaline juice may have to be avoided, as such a juice remaining for a long time at high temperature may mean considerable destruction of reducing matters as well as development of coloured products.

Iron content :—It is found that a good portion of the iron dissolved is removed during the alkaline filtration. The iron content is further diminished by treatment with superphosphate and filtering. The final iron content is about the same in the Ghosh and the modified processes being about 3.4 and 2.2 mg. per litre respectively. This is much lower than what was reported in the pilot plant trial of Ghosh's earlier specifications, vide Table I. It is, however, to be noted that the iron content of the sulphitation juice is far lower. It is a matter for further examination whether this iron would produce a yellow tinge in sugar. If this happens it may be necessary to adopt partial sulphitation as ultimately adopted by Saha and Jain (4). Iron content can also be brought down by increasing the addition of lime to get a pH of 10.5.

Consumption of iron :—It is found that the Ghosh process consumes 0.13% iron on juice whereas the modified process consumes 0.1%. The difference is entirely due to the fact that the control of the period of electrolysis is difficult in the Ghosh's process whereas it is very easy in the modified process. It is to be noted that the consumption of iron in the modified process is nearly half of what was obtained in the pilot plant trial using Ghosh's first procedure.

Consumption of electricity :—It is found that the modified process takes up only half the amount of electricity consumed by the Ghosh process. This is mainly due to the fact that electrolysis in the Ghosh process is done with comparatively high pH juices wherein the current efficiency for iron dissolution is low. This has been established by us by further experiments. In the modified process, however, the juice is always on the acid side of the neutral point and hence the current efficiency is high. Dissolution of iron appears to be a very important factor in clarification. This is why the cutting down of the time of electrolysis to five minutes in two experiments gave clarified juice which showed low colour removal and low purity-rise and was also very hazy. The electricity consumption is approximately 7000 units (kilowatt-hours) per day for a 1000 ton factory.

Filtrability :—The results indicate that the filtering quality of the electrolysed juice is nearly the same as that of the sulphitation juice. This would mean that the filtering area required would be the same as that for whole juice filtration in the sulphitation process. This means that the filter-press capacity should be very large indeed. This observation is, however, at variance with the pilot plant trial of Ghosh's process according to his first specification, for in the pilot-plant trial it was noticed that the filtration of the alkaline juice offered no difficulty. This question can only be decided by the pilot plant trial.

Lime and superphosphate requirements :— Whereas an accurate record of the quantities used of these two materials was not kept by oversight, it is estimated that the lime requirement would be about 0.07 to 0.08% and the superphosphate about 0.09 to 0.1% on cane.

CONCLUSION

From the above study it appears that the Ghosh process of electrolytic clarification deserves a pilot plant trial. The cleaning of the electrodes presents an engineering problem. A suitably designed mechanical brushing system will have to be introduced. The press cloth used for filtering the alkaline juice may require special treatment for reconditioning after a few filtration. It is to be noticed that the modifications introduced in the Institute has meant a considerable saving in electricity and iron. It is, however, to be emphasised that any new idea discovered in the laboratory normally undergoes profound modifications by the time it is finally adopted on the large scale. We consider that the modifications by the Institute is only a first step in this type of evolution. It is also possible that further experiments may reveal possibility of adding iron directly in the form of either its salts or in the form of colloidal hydroxide or use of similar material such as sodium aluminate. The success of this would depend upon the relative importance of the introduction of iron and the bubbling of the electrolytic gas in the electrical clarification process.

ACKNOWLEDGEMENT

The authors wish to thank Shri N. C. Jain and Shri J. K. P. Agarwal for their active cooperation in determination of iron content. Our thanks are also due to the Chief Chemist, Industries Department, Bihar for having spared one of the electrolysers used in the present work.

REFERENCES

1. Geerligs. "Cane sugar and its manufacture", p.146.
2. U.S.P., 653. April 3, 1953.
3. Ghosh, D.N. 1946 : *J. Indian Chem. Soc. Ind. & News Ed., Vol. IX,* Nos. 3 and 4.
4. Saha J.M. and Jain, N.S. 1954. *Proc. Sugar Tech. Assoc. of India,* 23, p. 168-173.

DISCUSSION

Mr. J.M. Saha wanted to have details of the size of plant necessary to operate this process. He asked if the authors could tell the electrode plate area required per ton of cane per hour, and also what filter area was used per ton of cane per hour in the first and second filtrations. He further asked how was the scum from the cells treated so as to prevent loss of sugar.

He added that from observations at the Experimental Factory at Kanpur it seemed that the grain size of the sugar was much smaller than that obtained by the sulphitation process.

Finally, he asked, if the authors could provide any information on molasses exhaustion when that process was used, as compared with that obtained with conventional clarification procedures.

Mr. S .N. Gundu Rao remarked that in the second process described by Dr. Doss lime was added after electrolysis to give a pH of 8.5-9.5, but it might be better to lime further to about pH 10.5 to obtain better elimination of the sesquioxides.

He also mentioned that in the neutralization of alkaline juices with superphosphate it was very difficult to obtain the desired pH end-point. The process resembled simple defecation in that the only chemicals used were lime and phosphate. In order to determine the value of the electrolytic part of the process it would be worthwhile to make a control experiment without the use of the electrolytic cell. The grain size of the sugar produced by this process at Kanpur seemed rather small and the colour was probably between 27 and 28.

Mr. Villano remarked that it had been found that the extent of pH rise above 6.8 during electrolysis was probably a function of the cleanliness of the plates, for if the plates were dirty the pH did not rise. It might even be worth commencing the electrolysis on juice limed to a pH higher than 6.5.

Mr C. Davis enquired what was the voltage and amperage used on the plates and how far were they apart. He further asked if these were critical factors. Mr. J.M. Saha stated that it was desirable that the first filtration should be carried out at pH 10.5 instead of 8.5 to remove objectionable impurities. Although the process used no sulphur dioxide the quantity of superphosphate required would be 1½-2 tons per 1000 tons of cane and this would be very expensive. In order to accurately assess the value of this process it was essential that we had complete data on the cost of the cell house operation.

Dr. K.S.G. Doss stated that we must consider the useful comments which had been made in relation to the pilot plant operation at Kanpur as the process was by no means in its final stage.

In the absence of the authors the following two papers were presented by Dr. J. L. Clayton. These were discussed together.

Paper

RECENT DEVELOPMENTS IN THE CHEMICAL CLEANING OF EVAPORATORS

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INTRODUCTION

The chief constituents of evaporator scale have been listed as the phosphates and sulphates of calcium, magnesium, iron and aluminium, together with silica and the salts of certain organic acids (12). It has been shown that in the evaporation of a given mixed juice the composition of the scale varies with the concentration of the liquor from which it is deposited. Recent analyses of scale samples from each vessel of evaporators in a number of factories throughout the world (6), (8), (14) have shown that while the proportion of phosphate always decreases and of sulphate always increases from first to last vessel, the corresponding change in the proportion of silica varies from factory to factory. These marked variations in scale composition would appear to preclude the successful universal use of a single chemical cleaning agent.

The use of alkali and acid in evaporator cleaning has been discussed by Honig (12) who has pointed out that the chief effect of these agents is that of softening the scale in preparation for mechanical removal. Libkind (13) has reported the successful use in the U.S.S.R. of 2—10% hydrochloric acid containing a corrosion inhibitor, while Cangelosi (5) has reported the complete removal of scale by first boiling with acid, and then spraying with 58% caustic soda.

In some factories it has been found that evaporator scale may be removed by a mixture of chemicals. Briklya and Obushinski (4) report the successful use of a mixture of sodium carbonate and sodium phosphate, while Floro (10) has found that no mechanical cleaning is necessary after the evaporators have been sprayed and boiled with a mixture of caustic soda and sodium carbonate, followed by 1% hydrochloric acid.

Scale softening prior to removal by brushing has been obtained with "Sumaloid" (1) and with a mixture of aluminium and ferric sulphates, followed by 2% caustic soda (9).

It is quite clear that the success of each of these methods must be limited to a small range of scale types. The chemical principles involved make it extremely unlikely that any one method could be used successfully throughout the world, and although the use of exceptionally strong acids and alkalies would probably be effective against any scale type, the highly corrosive properties of these agents must preclude their use in some factories.

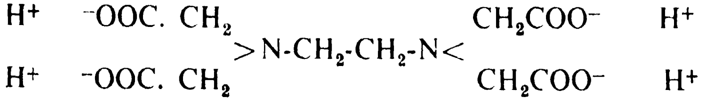
In recent years, however, there has come into prominence a group of organic substances which have a remarkable ability to form highly soluble complexes with metallic ions. These substances are known as chelating agents, and by far the most outstanding member of the group is ethylene-diamine-tetra-acetic acid (EDTA). This substance, which is manufactured on quite a large scale in several countries, forms very strong chelates with nearly all metallic ions, and hence readily dissolves insoluble metal salts. With particular reference to the constituents of evaporator scale, calcium and magnesium phosphates, silicates and sulphates are all extremely soluble in EDTA solution, while iron and aluminium form even stronger chelates. It was in 1953 that Wiggins and Schmidt (15) showed that a 5% solution of EDTA completely removed every trace of scale from a length of badly scaled evaporator tube.

EDTA is sold commercially under several trade names. The work described here has been carried out with a product called " Versene ",.which is the tetrasodium salt of EDTA. During the course of our laboratory investigations on the cleaning action of EDTA, two trials have been carried out using Versene in the cleaning of the evaporators in a commercial sugar factory. A third trial is planned for 1956.

THE USE OF VERSENE IN EVAPORATOR CLEANING

Theoretical Considerations

EDTA contains four ionizable hydrogen ions



$$\begin{array}{lll} H^+ \;\; {}^-OOC.\,CH_2 & & CH_2COO^- \;\; H^+ \\ & >N\text{-}CH_2\text{-}CH_2\text{-}N< & \\ H^+ \;\; {}^-OOC.\,CH_2 & & CH_2COO^- \;\; H^+ \end{array}$$

and therefore in solution we have the equilibria

$$\begin{array}{lcl} H_4Y & \rightleftharpoons & H^+ + H_3Y^- \\ H_3Y^- & \rightleftharpoons & H^+ + H_2Y^{2-} \\ H_2Y^2 & \rightleftharpoons & H^+ + HY^{3-} \\ HY^{3-} & \rightleftharpoons & H^+ + Y^{4-} \end{array}$$

where Y^{4-} is the quadrivalent EDTA anion.

In acid solution H_4Y is the main species present, and as the pH is increased by the addition of alkali, hydrogen ions are removed successively until above pH 11 the main species present is the Y^{4-} ion.

Metallic ions may be chelated by any of the species H_3Y^-, H_2Y^{2-}, HY^{3-} and Y^{4-} with the liberation of hydrogen ions in every case save that of Y^{4-}. For example, the calcium chelate CaY^{2-} may be formed.

$$\begin{array}{lcl} Ca^{2+} + HY^{3-} & \rightleftharpoons & CaY^{2-} + H^+ \\ Ca^{2+} + H_2Y^2 & \rightleftharpoons & CaY^{2-} + 2H^+ \end{array}$$

Similarly, the magnesium, iron and aluminium chelates may be represented by MgY^{2-} FeY^- and AlY^- EDTA cannot form chelates with metals, as such, but can only complex the metallic ion.

A consideration of the stability constants of these chelates and of the solubilities of the scale-forming salts shows that the chelates are not stable at all pH values. For example, calcium sulphate precipitates out from the EDTA-scale solution below pH 3 while ferric hydroxide precipitates above pH 7. Undissociated EDTA (H_4Y) is not particularly soluble in water and itself precipitates when the pH of the EDTA solution falls below 2. Thus it may be seen that calcium ions may be dissolved from an insoluble scale by EDTA above pH 3, magnesium ions above pH 2 and iron between pH 2 and 7.

Although calcium and other silicates are readily soluble in alkaline EDTA, silica (SiO_2) is not soluble. Any silica present in scale must come away from the tube surface as the matrix of sulphates and phosphates is removed, the silica forming an insoluble sludge. If, however, silica is present as a homogeneous layer nothing save very strong caustic soda can remove it chemically.

The Process

Evaporator scale may be removed by circulating EDTA solution through the tubes. the calcium, magnesium, iron. aluminium and other metallic constituents going into solution as chelates while any silica present or formed by precipitation from silicate ions at pH values below 10 remains as an insoluble sludge which may be removed by settling or by passing through a vibrating screen.

The price of EDTA (Versene) is so high (U.S.$0.60 per lb.) that it is uneconomical to use it once and then discard the exhausted solution. However. the variation of chelate stability with pH may be utilised to regenerate the spent solution, for if the solution is made acid to pH 3, calcium sulphate precipitates and may be removed. The supernatant solution may be readjusted to a higher pH value with caustic soda and this solution reused for dissolving scale, the cost of the Versene being replaced by the cost of the chemicals (acid and alkali) used in the regeneration process. Magnesium is not removed in this manner but since calcium sulphate is soluble in a solution of the magnesium chelate (2) (calcium may displace magnesium from its chelate), accumulation of magnesium is not particularly serious. When the amount of magnesium in solution becomes great, EDTA may be precipitated free from the soluble magnesium and other accumulated salts by acidifying the solution to pH 1·5, this procedure being used to recover the EDTA at the end of crop.

Factory Trial, 1954 *crop*

A full scale trial of Versene was carried out throughout the whole of the 1954 crop at the Reform Factory of Ste. Madeleine Sugar Company. The results of this trial have been reported in detail elsewhere (11) but the important features of the trial are as follows :—

(a) Reform Factory grinds about 5,000 tons of cane per week. The average pol % cane was 12.8 for the crop, the corresponding Brixes of the mixed juice and syrup being 14.6 and 64.1 respectively. The evaporator was a triple effect, with heating surfaces 3,200, 2,400 and 2,400 sq. ft. for the first, second and third bodies respectively. For this evaporator, 1,200 lbs. of Versene was present during cleaning, the solution being 5% in concentration, at pH 11.

(b) Versene solution circulation was effected by spraying at the rate of 60 gallons per minute in each vessel for about 3 hours. The tubes in the first and second vessels were always cleaned completely free of scale but, on the other hand, the third vessel was never sufficiently clean for it to be used without having a rotary cutting tool passed through the tubes.

(c) Regeneration of the spent Versene solution was carried out in a tank coated with an acid-resisting plastic paint. On the average 450 lbs. of sulphuric acid were used to lower the pH from 11 to 3, calcium sulphate precipitation being accelerated by heating to 50°C. The precipitate was allowed to settle and the supernatant liquid withdrawn to a storage tank where the pH was increased to 11 by the addition of an average of 360 lbs. caustic soda. The solution was then ready for the next week-end cleaning.

During the whole trial, estimations of the total Versene content of the solution showed that overall losses amounted to 8% per week, a seriously high figure representing 100 lbs. of Versene each week.

Further Developments and Factory Trial, 1955 *Crop*

Laboratory experiments (2), (7), subsequent to the first factory trial showed that the efficiency of the cleaning action of EDTA could be substantially increased by using solutions at pH 6 instead of pH 11. It was found that the rate of scale removal was approximately doubled, and that the magnesium chelate dissolved calcium sulphate almost as readily as EDTA itself. Using a solution at pH 6, the pH must fall as scale is dissolved, and it was found that the exhausted 5% solution had a pH value of 4. Quite obviously, the amounts of sulphuric acid and sodium hydroxide required for the regeneration process were substantially reduced.

Making use of the results of this investigation, cleaning experiments with Versene were again carried out at Reform Factory during the last four weeks of the 1955 crop. A full account of this trial will be published elsewhere (3). These experiments were restricted to the third vessel of the evaporator and the important features of the trial were as follows :—

(a) The Versene solution was 5% in concentration and adjusted to pH 6—6.5. Circulation was effected by boiling, the vessel being filled to the top of the tube plate. After three hours' boiling, the solution was always found to be completely exhausted, this never being achieved in the 1954 trial when the solution was sprayed at pH 11.

It appeared that the Versene was being exhausted mainly in dissolving the great amount of scale which had accumulated in the body of the vessel during the previous weeks of crop before the trial commenced. When this scale had been removed and the Versene solution had only to dissolve the scale accumulated in the body and tubes after one week of evaporator use, the tubes were cleaned satisfactorily for subsequent use, no brushing being necessary. It must be pointed out that during the 1954 trial, although the tubes of the third vessel were not adequately cleaned, there was no accumulation whatever of scale in any of the vessel bodies.

(b) The amounts of sulphuric acid and caustic soda (per lb. Versene present) used in the regeneration were less than half of those required during the 1954 trial.

(c) By using Versene at pH 6, the iron constituents of scale were dissolved whereas at pH 11 the iron remained suspended as colloidal ferric hydroxide.

It was noted however that the exhausted solution (at pH 4) was capable of dissolving iron rust from the storage tank during the week, and hence the tank should have been protected with a coating of plastic paint.

(d) An important observation was that the Versene losses were reduced to less than 2% per week.

CONCLUSION

The use of a chelating agent for the removal of scale deposits in evaporator tubes constitutes the introduction of a new chemical principle to the sugar industry, and although it is apparent that the two trials so far carried out can only be considered to be of a preliminary experimental nature, in 1956 a full trial will be made at another factory elsewhere in the West Indies.

Nevertheless, it has been demonstrated that EDTA is capable of removing all traces of scale from evaporator tubes and that the factory trials have, in fact, borne out the results of laboratory experiments and theoretical considerations. It should be pointed out that EDTA is by no means the only chelating agent known, although laboratory experiments with other substances, for instance, gluconic acid and arabonic acid, have proved unpromising.

The cleaning operation using chelating agents is simple, the necessary equipment being a storage tank, a regeneration tank and a suitable pump. In contrast to the alkali-acid scale softening process only one bulk solution is handed. and in the case of EDTA regeneration of the spent solution may be carried out conveniently during the week.

Thè long term effects of the use of chelating agents must be mentioned briefly. These substances can produce no pitting of the tube surface such as might be obtained using a strong acid, and there can be little doubt that the preservation of the smooth surface of a new tube must both impede scale nucleation and accumulation and assist the cleaning agent. The wear and distortion produced by mechanical cleaning methods must both be obviated.

The advantages of an efficient and safe method of cleaning sugar factory evaporators with chemicals over mechanical cleaning methods might perhaps be elaborated.

In many countries it is the time required to complete the evaporator cleaning that enforces a week-end shutdown of the plant and indeed makes the full 36-hour break necessary. In the British West Indies some factories use only mechanical cleaning, others use only chemical cleaning with either hydrochloric acid and caustic soda or both, whilst some use mechanical and chemical cleaning. All need the whole time to get through the work. Some times the scale is so intractable that the evaporators have to go into service imperfectly cleaned which, of course, soon leads to inefficient operation. When mechanical or a combination of chemical and mechanical procedures are used it is impossible to wait for the evaporators to cool down thoroughly before sending men inside them to operate the mechanical cleaning devices and it is becoming increasingly difficult to get labour to turn out to do this work. The procedure described in this paper offers the distinct advantage that as soon as it is decided to clean the evaporators they can be emptied of syrup, washed out, and Versene solution pumped in. In our experience, four hours at the most is all that is needed to remove all the scale from the tubes and body of the vessels. If a light scale obtains, an hour's boiling is all that is necessary. The regeneration of the Versene can of course be carried out at leisure during the period between the cleanings. This method therefore provides the possibility of greatly diminishing the time necessary to get the evaporators cleaned and hence, if other factors permit, of decreasing the time of the week-end shutdown. Another advantage lies in the fact that Versene really does clean the evaporator tubes and even removes the oxide film on the metal, and perhaps for this reason alone ensures that less scale builds up subsequently and therefore the evaporator station operates more smoothly.

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REFERENCES

1. Armstrong, L. N. 1948. *Int. Sug. J.*, 50,7.
2. Bennett, M. C. and Wise, W.S. 1955. Unpublished data.
3. Bennett, M. C., Connolley, F. H., Schmidt, N. O., Wiggins, L. F. and Wise, W. S. 1955. *Proc. B.W.I. Sugar Tech. Conf.*, Paper 3/55.
4. Briklya, M.F. and Obushinski, I.E. 1952. *Sakhar. Prom.*, 8. 34.
5. Cangelosi, R. A. 1952. Man. XXVI *Conf. Ann. A*ssoc. *Tech. Azuc. Cuba*, 211.
6. Chen, W. and Tsai, M.T. 1953. *Rep. Taiwan Sug. Exp. Station*, No. 10, 135.
7. Connolley, F.H. 1955. *A.I.C.T.A. Thesis, Trinidad.*
8. Douwes-Dekker, K. 1953. *S.A. Sug. Tech. Assoc.*, 27, 63.
9. Drinnen, L.D. 1954. *Proc. Queensland Soc. Sug. Tech. Assoc. Conf.*, 21, 85.
10. Floro, M.B. 1954. Private communication.
11. Holland, I.D., Massiah, B.V., Mayers, J.C., Schmidt, N.O., Wiggins, L.F. and Wise, W.S. 1954. *Proc. B.W.I. Sugar Tech. Conf., Paper* 7/54.
12. Honig, P. 1950. *Proc. Int. Soc. Sug. Tech.* 7th Congress, 529.
13. Libkind, L.I. 1951. *Sakhar. Prom.*, 11, 21.
14. Schmidt, N.O. 1954. *Proc. B.W.I. Sugar. Tech. Conf., Paper* 4/54.
15. Schmidt, N.O. and Wiggins, L.F. 1954. *Ind. Eng. Chem.* 46, 867.

Paper

EVAPORATOR CLEANING AND CORROSION IN LOUISIANA SUGAR FACTORIES

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INTRODUCTION

Corrosion of evaporators and vacuum pans has become a matter of considerable interest in the Louisiana sugar industry during the past decade as more and more factories are installing equipment made of mild steel to replace cast iron units which have become inadequate or worn out through long service. Until about 1935 practically all evaporators and vacuum pans used in this industry were made of cast iron. At that time because of the increasing cost of cast iron equipment, the generally distressed condition of the industry and the rapid developments which had occurred in arc welding techniques, factories began to purchase evaporators made of mild steel rather than cast iron because of its lower initial cost. Many local shops were able to build such equipment. Cast iron equipment, of the size required in most sugar factories, was beyond the capabilities of the average small foundry and only a relatively few large foundries in the country were able to build such vessels.

Cast iron in massive form such as is found in the bottoms, vapour sections and domes of evaporators and vacuum pans is fairly resistant to corrosion. Such equipment has had exceptionally long life under operating conditions which prevailed in the Louisiana sugar industry. Since factories in this area normally operate not over twelve weeks per year, it must be realized that a year of life in our industry is only one fourth that of an area such as Hawaii, or Peru where factories operate on a year-around basis.

A survey of twenty-six of the fifty-two operating factories in Louisiana recently indicated that in seven of the factories cast iron evaporators are in service which were purchased fifty-five years ago or longer. The oldest reported evaporator is sixty years of age.

The same survey revealed that quite a number of evaporator units are in service which are built of mild steel or low alloy steel. A typical analysis of the various alloys which are mentioned by their trade names will be found in the Appendix. The oldest reported steel evaporator unit was installed seventeen years ago. In this unit, the bottoms, calandria, vapour section, domes, vapour lines and tube sheets were all made of mild steel. Generally, most factories purchase evaporators constructed of mild steel but insist that the tube sheets and tubes be of copper.

About ten years ago. quite a number of evaporators and vacuum pans were constructed of wrought iron. This material was used because of its reported high corrosion resistance plus its availability. Other mild steel alloys which had proven satisfactory were not available at the time. Because of the generally satisfactory record of mild steel as a construction material for evaporators, little attention was given to the wastage suffered by evaporators of wrought iron construction until two factories experienced collapse of the bottoms of vacuum pans, and a third discovered to its dismay that the sheets of the vapour section of an evaporator had wasted from 5/8″ original thickness to 1/16″ thickness during the course of seven grinding seasons, or approximately twenty-one months of operation. It was these failures which resulted in the present investigation being undertaken.

All factories in Louisiana clean evaporator and vacuum pan heating surfaces periodically with a combination of caustic soda boiling followed by boiling with dilute hydrochloric acid. Control of the concentrations of the cleaning materials has received relatively little attention from factory personnel. The practice has been followed of increasing concentration, particularly of acid solution, if heating surfaces were not thoroughly clean at the end of the operation. Since most factories are operating their equipment at considerably above their originally designed capacity, scaling of heating surfaces has become a limiting factor in further capacity increases. The ever present freeze hazard, high labour costs, and the need to grind as large a volume of cane as possible during the short season, severely limits the time which factories feel that they can dedicate to the cleaning operation. In part, at least, factories have attempted to overcome this handicap by using more drastic cleaning methods. All factories involved in the tests which are reporterd later in this paper employed a simple lime clarification system, and were engaged in the production of raw sugar and final molasses.

EXPERIMENTAL APPROACH

Workers in the field have generally agreed that the most satisfactory way of determining corrosion resistance of materials is actual exposure of specimens under conditions which will be met in the field. Techniques have been developed for creating or simulating such conditions in the laboratory but generally are not considered as satisfactory as actual field exposure tests. For this reason, the co-operation of nine Louisiana factories was solicited and arrangements made to place test spools containing a selected group of metals and alloys in the evaporators of these mills. Spool type specimen holders were made up substantially in accord with A.S.T.M. Recommended Practice for Conducting Plant Corrosion Tests, A-224-46(1). Pyrex glass tubing was used for separating specimens from one another and from the brass rod on which they were carried.

Such spools were mounted in each evaporator body in three locations. One spool was mounted in the section below the bottom tube sheet, another was fixed to the wall of the vapour section at a point approximately 6″ above the upper tube sheet where the specimens would be in contact with the boiling liquid. The third specimen was affixed to the dome of the vessel where it would normally be in contact with the vapours of the boiling liquids and occasional droplets of entrained material.

Each co-operating plant reported the amount of evaporation between boilings and for the period during which the specimens were exposed. In addition, plants were requested to sample and analyse solutions of caustic soda and hydrochloric acid used for cleaning, both, before, and after the cleaning operation. At the end of the grinding season all specimens were removed from the equipment, cleaned and reweighed to determine weight loss due to corrosion. The intervals between cleanings, the method of cleaning, and other procedures followed were dictated by the conditions existing at each plant and were not under our control.

Most of the factories purchase caustic soda in liquid form and obtain their hydrochloric acid in bulk shipments. The general practice is to reuse caustic soda solutions throughout an entire grinding season. The strength of such solutions is adjusted after each cleaning to maintain a normality which that particular factory considers most desirable for its need.

Acid used for cleaning is introduced into each evaporator body. Prior to introduction of acid, the body has been filled with water to some predetermined point and mixing of acid and water is accomplished with a steam jet. These agitators, called "silent heaters" in the local industry are arranged so as to produce considerable agitation without the excessive hammering which would be produced by injecting live steam directly into a cold acid solution. This type of mixing is not the most satisfactory but nevertheless is that practiced by the industry. Samples of caustic and of acid were withdrawn from each evaporator body as soon after their introduction and mixing as possible. Samples were also withdrawn of the spent cleaning materials at the conclusion of their respective boiling periods. In the case of the acid samples, it is recognized that the strength reported will not necessarily be the actual strength of acid solution introduced since reaction between the acid and the scale in bodies begins immediately. Unfortunately, it was not possible to have the factories mix their acid outside of the body and sample it there. Neither was it possible to calculate the acid strength from the amount of water and acid used since in general the amounts of water employed were not accurately measured.

The concentration of acid and soda solutions was determined by titration against standard alkali or acid using phenolphthalein as an indicator. These determinations were made by the individual factory laboratories except in those cases where the amount of iron present was excessive to the point that it interfered with the titration. In these cases, the acid samples were collected and analyzed at the University laboratories.

DISCUSSION OF DATA

The individual factories reported the amount of time used for boiling their equipment at each cleaning period. The total number of cleanings to which the evaporators were subjected was also reported for the 1954 crop when the studies were made. Since the number of cleanings, the time required for each cleaning, and the concentration of reagents used varied widely from one mill to the other, a comparison of results between factories was not possible except by reducing the data to some suitable basis. The basis selected was purely arbitrary but does facilitate rough comparison of results from one plant to another. The amount of cleaning which would be done by boiling an evaporator for one hour with acid of one percent concentration by weight was designated as a unit amount of cleaning. The concentration of acid employed in this discussion was that reported by the factories as the concentration at the beginning of the cleaning period. This varied from one body to another in the evaporator and from one cleaning to another. The average of all reported values for a given body of a specific factory is termed the average acid concentration for that case. The number of units of cleaning done by any given factory would be the product then of the total number of hours during which the evaporators were boiled with hydrochloric acid times the concentration of acid employed expressed as weight percent. For example, if factory A had five one hour acid boilings with a concentration initially of 1% HCl by weight in the cleaning solution, then we can say that this factory had five units of cleaning done. This unit does not take into consideration the temperature at which the material was boiled nor the nature of the acid employed.

Any term used to report corrosion rates should include units of weight, time and area or depth of penetration per unit of time. The conventional method for expressing corrosion rates in the United States is "Inches Penetration per Year", abbreviated ipy. This term represents the depth to which uniform corrosion would penetrate if the specimens were exposed to corrosion, on one side only, twenty-four hours per day for 365 days. In the metric system, corrosion rates are expressed as "Milligrams per Square Decimeter per Day", abbreviated mdd. Weight loss units can be converted into penetration units by using the equation :

$\frac{\text{mdd.} \times (0{\cdot}001437)\text{—ipy}}{\text{d}}$, where *d* is the density of the metal in grams per cubic centimeter. The dimensions of all test specimens and the exposed areas were determined prior to the beginning of the corrosion tests. The weight loss suffered by the specimens was calculated into "Inches Penetration per Year" using the known surface area of the original specimen. the loss in weight, the actual time the specimen was exposed to the cleaning operation and calculating the corrosion per unit area per hour. This was subsequently multiplied by a suitable factor to determine the total penetration which would have occurred had the specimen been exposed for twenty-four hours per day for 365 days.

For comparative purposes, we were concerned more with the intensity of corrosive conditions rather than the total amount of corrosive penetration. For purposes of comparison, the penetration rate in ipy was divided by the amount of cleaning as defined previously. The quotient from this operation yielded what we termed the corrosive penetration per unit amount of cleaning for the particular cleaning agent employed. In the tables where average corrosive penetration in inches per year of exposure is reported, it is a figure obtained as a result of this last operation. This technique permitted us to make comparison between one factory and another and one vessel and another in the same set of evaporators. Since acid strengths used by the various factories and by the same factory in the various vessels vary within fairly wide limits, comparison would not be possible except on some basis such as this. The data presented are intended to be indicative of what it is to be expected rather than to be absolute measures of corrosion rates.

By placing samples in each vessel of a multi-effect evaporator, it should be possible to determine the relative intensity of scaling conditions, cleaning requirements and the resulting corrosion variations from one body to another in the train. Location of test specimens in the bottom, surface of the boiling liquid, and in the dome of each body of the set of evaporators makes possible a comparison of corrosive conditions to be found at each of these points in the various vessels.

Finally, to determine, if possible, the rate of corrosion of the acid and soda cleaning solutions on clean metal specimens, arrangements were made at one factory to have the spools inserted in each vessel during the weekly cleaning period. The evaporator bodies were opened, the test specimens were mounted about 6″ above the upper tube sheet, and the cleaning conducted in the usual manner. At the completion of the cleaning operation, the specimens were removed to the laboratory and preserved in an atmosphere of dry air until the next cleaning period.

Some of the factories co-operating in this study used sulfamic acid, others used inhibited hydrochloric acid while still others used hydrochloric acid without an inhibitor. One factory used uninhibited acid for a part of the grinding season and an inhibited material for the balance of the season. The inhibitors will be referred to by their trade names but a discussion of each type of inhibitor employed will be found in the Appendix.

DISCUSSION OF RESULTS

A. *Range of Corrosion Exhibited by Metals*

Table I shows the resultant average corrosive penetration, for all bodies and factories as suffered by test samples located above the upper tube sheet level and the life expectancy in years of effect operation a 1″ plate of these metals would have before corroding completely.

TABLE I

AVERAGE LIFE, IN YEARS, FOR ONE INCH PLATE AND AVERAGE CORROSIVE PENETRATION, IN INCHES PER YEAR OF EXPOSURE, FOR METAL SAMPLES LOCATED ABOVE THE UPPER TUBE SHEET LEVEL IN MULTIPLE EFFECT EVAPORATORS

Representative Metal Type Exposed		Penetration ipy	mdd	Years of life
1/8″	Electrolytic Copper	0.0043	26.70	284
1/4″	Deoxidized Copper	0.00553	34.35	181
1/8″	304 Stainless St.	0.00085	4.696	1177
3/16″	A Nickel	0.00221	13.64	451
1/4″	Bayers Wrought Iron	0.12503	683.2	7.89
3/16″	ASTM-A7 Mild Steel	0.13814	754.9	7.24
3/16″	ASTM-A7 Copper Bearing steel	0.09584	523.7	10.43
3/16″	Jalten 2	0.22330	1220.0	4.475
1/4″	Corten	0.27831	1521.0	3.535
1/4″	Triten	0.23966	1309.6	4.175
3/16″	Toncan	0.05150	281.4	19.95
11″	Ga. Pure Iron	0.08185	447.3	12.22
1/4″	Cast Iron	0.21226	1061.3	4.71
Ferrous Alloy Average		0.14467	785.0	6.26
Non Ferrous Alloy Average		0.00315	24.90	318

B. *Effect of Cleaning Agents Versus Overall Effect*

Table II shows the average corrosive penetration exhibited in the case of metals located about the upper tube sheet level, but only during the cleaning period. A comparison of Table I and II reveals how much greater are the corrosive conditions once the protective scale is dissolved from the metal surfaces. Since cleaning time is only a fraction of operating time, one can see from the above comparison how much damage can be done to the bodies by a short time of acid boiling beyond that necessary to remove the scale. This emphasizes the need for very close control of acid concentration so that virtually all of the acid present will have been used up during the scale removal operation and there will be very little free acid left to attack the clean metal surface.

TABLE II

COMPARATIVE OVERALL AND FERROUS ALLOY CORROSIVE PENETRATION BETWEEN THE SEVERAL BODIES, FOR METAL SAMPLES EXPOSED ONLY DURING THE CLEANING PERIOD, IN MULTIPLE EFFECT EVAPORATORS AT TWO FACTORIES (FIGURES IN MILLIGRAMS PER SQ. DM. PER DAY)

Factory			Body					
			1	2	3	4	5	Average
E.	Ferrous	mdd	184,500	289,300	210,000	200,800	107,500	213,900
		ipy	34.0	53.3	38.7	37.0	19.8	39.4
	Overall	mdd	173,300	272,800	196,700	188,200	92,600	185,100
		ipy	30.9	48.63	35.06	33.55	16.51	33.0
F.	Ferrous	mdd	202,400	173,300	210,900			196,700
		ipy	37.29	31.93	38.85			36.23
	Overall	mdd	174,500	149,400	181,900			186,400
		ipy	31.11	26.64	32.43			30.06
Average	Ferrous	mdd	193,400	231,300	208,000	200,800	107,500	205,300
		ipy	35.64	42.61	38.32	37.0	19.8	37.83
	Over all	mdd	173,900	211,100	189,300	188,200	92,600	185,750
		ipy	31.0	37.63	33.74	33.55	16.51	31.53

C. *Effect of Temperature*

Some factories in the group operated their evaporators under vacuum during the cleaning period. Others boiled their vessels at atmospheric pressure. Generally, it is recognized that removal of encrusting materials will proceed at a higher rate under the latter conditions than would be the case with vacuum boiling. The data obtained in this study was not conclusive as to the effect of temperature on corrosion rates for reasons which will be discussed below.

Table III shows a summary of data on the corrosive intensity of different cleaning practices. This data cannot be taken as conclusive. Inhibitor exerted such influence as to be an important variable which eliminated the possibility of securing enough similar tests where type of acid and open or vacuum boiling coincided to make comparisons feasible. The case of Factory F is discussed with reference to a special experiment conducted there.

TABLE III

COMPARATIVE CORROSIVE PENETRATION AMONG SUGAR HOUSE EVAPORATORS FOR DIFFERENT METHODS AND INTENSITIES OF CLEANING

Factory	Amount of Cleaning		Other Chemicals	Corrosive Penetration per unit amount of cleaning Or Corrosive Intensity × 100
	Soda	Acid		
A. HCl Open	21.6	13.7	Bartlett Inhibitor	11.0
C. Sulfamic Vacuum	111	15.6		9.3
E. HCl	420	56	Bartlett Inhibitor	1.49
F. HCl Vacuum	93	10.2	Used Inh. Part of Time	31
H. Sulfamic Open	115	14.3	Gulf. Engr. Wetting Agent (Petrowet)	18.9
I. HCl Open	81	5.6		21.7

In general, it can be stated that open boiling is about twice as harmful in the case of sulfamic acid as is vacuum boiling. A study of the figures in Table III will show that Factory C had a corrosive intensity of about 9.3 versus 18.9 for Factory H. Factory C boiled under vacuum while Factory H boiled at atmospheric pressure. For the case of muriatic acid, we have for Factory A a corrosive intensity of 11 against one of 1.49 for Factory E which cleans under vacuum. This latter factory was employing a special electrostatic treatment of their cane juice to prevent deposition of scale in the evaporator. This might have affected the results of our tests.

Table IV has been prepared to show the percentages of all tests in each body for which that body occupied a definite place in order of magnitude of corrosive conditions with respect to the other bodies in that particular multiple effect installation. There appears little doubt that the first bodies in a multiple effect installation operate under more severe corrosive conditions. This may be due to temperature but observation seems to indicate that it is the lesser scaling which occurs in these bodies combined with over treatment with acids which is responsible for the results reported.

TABLE IV

PERCENTAGE OF TESTS IN WHICH A GIVEN BODY OCCUPIED THE SAME RELATIVE PLACE OF ORDER IN MAGNITUDE OF CORROSION WITH RESPECT TO THE OTHER BODIES IN THE SAME MULTIPLE EFFECT EVAPORATOR

Place Occupied	Body				
	1	2	3	4	5
First Place	41.1%	41.2%	16.7%	0.0%	0.0%
Second Place	42.8%	52.3%	0.0%	0.0%	4.9%
Third Place	20.0%	16.6%	53.4%	10.0%	0.0%
Fourth Place	14.3%	0.0%	14.3%	71.4%	0.0%
Fifth Place	0.0%	16.6%	0.0%	0 0%	83.4%

Note : The abrupt changes noticed in the general trend are due to the fact that only three factories had Fourth bodies and a single one a Fifth body ; so that there were not enough cases considered in the last two bodies to verify clearly the law of probability when using it to illustrate general trends.

It was noted upon inspection of some of the steel evaporators used in this study that corrosion was most severe in the section of the vapour belt which was in more or less continuous contact with the boiling liquid. At the junction of the steel vapour belt with the copper tube sheet, there was evidence of corrosion due to galvanic action. Three to six inches above this line, however, corrosion was severe and was characterized by pitting. It was not possible to determine on the basis of the evidence available to us whether this pitting was the result of a combined corrosion erosion action on poor quality steel or whether some other causative phenomenon was reponsible.

D. Comparative Corrosive Power of Acids

Assuming equal influence of inhibitors, Table III shows that sulfamic acid at open boiling is more harmful than muriatic, when comparing factories H and A. Inhibited sulfamic acid at open boiling is less corrosive than uninhibited muriatic acid if one compares factories H and I. Where the results obtained from factories E and F averaged and compared with those of Factory C. it would appear that sulfamic acid when under vacuum boiling does half the harm as muriatic. This averaging of results must be accepted with reserve, since, as noted above, Factory E employed an anti-scaling treatment and Factory F showed exceptionally high corrosive conditions. This factory used an inhibitor during only a part of the crop.

The major American producer of sulfamic acid has released information concerning the corrosive action on typical metals of both inhibited and uninhibited sulfamic and muriatic acids at two different temperatures. A comparison of their data with ours shows that our findings agree reasonably well with theirs in that sulfamic acid using the inhibitor recommended by the manufacturer appears to be slightly more corrosive than inhibited muriatic acid.

Under vacuum boiling the last body operates at a temperature of around 135°F. The laboratory tests of this manufacturer conducted at 140°F. showed that inhibited sulfamic acid seems to be 30%, 50%, 60%, and 66% as corrosive as inhibited muriatic when attacking respectively cast iron, mild steel, wrought iron, and copper, or agreeing roughly with our results in that sulfamic acid under vacuum boiling is half as corrosive as muriatic acid under vacuum boiling when both acids are inhibited.

Rabald (2) reports that in the case of copper, if the hydrochloric acid is aerated, "the corrosion rate increased 200 times" over unaerated acid, and in general, aeration increases the action of hydrochloric acid on any metal. The same author also reports a penetration of about 0.002" per year of exposure for copper when immersed in sugar cane juices. This is about the same order of magnitude as our findings in Table I.

E. *Effect of Inhibitors*

Table V summarizes the results of special tests conducted at Factory F to determine the effect of using inhibited versus uninhibited muriatic acid. The inhibited acid was used during the last 58.3% of the grinding (and cleaning) time for that season, with the result that only 36.3% of the total corrosive penetration occurred during that portion of the season in which it was elected to use inhibited acid. That the cleaning itself was responsible for these results and not the variations in cane juice composition is evident from the fact that tests were run with the samples introduced inside the bodies only during the cleaning periods.

TABLE V

PERCENTAGE OF THE TOTAL CORROSIVE PENETRATION FOR THE PERIOD (58.3% OF THE TOTAL CROP TIME) DURING WHICH INHIBITED ACID WAS USED FOR CLEANING THE EVAPORATOR BODIES AT FACTORY F

Representative Metal	Type Exposed	Percentage of Total Corrosive Penetration
1/8"	Electrolytic Copper	41.6
3/16"	ASTM-A7 Mild Steel	33.5
1/4"	ASTM-A7 Copper Bearing Steel	43.1
1/4"	Jalten 2	34.6
1/4"	Corten	22.3
1/4"	Cast Iron	43.1
Average corrosive penetration while using inhibitor (58.3% of the time)		36.3

From Table III a comparison of Factories A and I indicates that uninhibited muriatic acid is twice as corrosive as inhibited muriatic acid under open boiling conditions.

Watts and Wipple (3) have indicated that salts of arsenic retard the corrosion rate of iron in hydrochloric acid "very materially" since iron displaces metallic arsenic from the solution. The arsenic is deposited on the iron surface and, "because of its high over voltage, causes polarization by hydrogen to take place." This seems to retard the speed of hydrogen evolution and the rate of corrosion. About 0.1% of Na_2 AsO_4 would reduce the corrosion for iron to approximately 1/20 of what it would have been without the salt inhibiting it, when measured at 3 percent acid concentration and 100°F. Unfortunately, arsenic is toxic, "its effectiveness decreases with temperature and induces pitting". This same statement is true of most inhibitors which are commercially available at the present time. Manufacturers' literature and test results indicate that most inhibitors rapidly loose their effectiveness at temperatures in excess of 180°F.

Inhibitors of the "Rosin Amine" type seem to overcoe some of the objections to arsenic inhibitors and are stated to be more effective on a weight per weight basis.

F. *Effects of Vapours vs. Solutions*

Table VI illustrates the slightly higher corrosivity of samples located in the bottoms of the bodies when compared with the ones placed just above the upper tube sheet level, the data which was presented in Table I. Table VII shows that corrosive conditions encountered in the dome or separators of the evaporator bodies are very slight. The samples exposed in these areas were subject only to the action of water and acid vapours.

SUMMARY AND CONCLUSIONS

Data obtained as a result of a study of cleaning conditions in a representative group of Louisiana sugar factories indicates that corrosion of equipment is quite severe in many of the factories studied. It is particularly severe in those cases where plants are using evaporators made of mild steel or some of the low alloy steels.

TABLE VI

AVERAGE CORROSIVE PENETRATION, IN INCHES PER YEAR OF EXPOSURE, FOR METAL SAMPLES LOCATED BELOW THE LOWER TUBE SHEET LEVEL IN EACH BODY OF THE MULTIPLE EFFECT EVAPORATOR OF TWO FACTORIES

	Representative Metal Type Exposed		Factory Providing Tests		
			E	F	Average
1/8″	Electrolytic Copper	mdd	28.82	15.34	22.05
		ipy	0.00464	0.00247	0.00355
3/16″	ASTM-A7 Mild Steel	mdd	677.0	2082.0	1380.0
		ipy	0.12390	0.38100	0.25245
1/4″	ASTM-A7 Copper Bearing Steel	mdd	418.0	919.7	668.9
		ipy	0.07650	0.16830	0.12240
1/4″	Jalten 2	mdd	600.0	1918.0	1259.0
		ipy	0.10980	0.35100	0.23040
1/4″	Corten	mdd	502.2		
		ipy	0.09190		
1/4″	Cast Iron	mdd	1137.0		
		ipy	0.22740		
Ferrous Alloy Average		mdd	666.8	1308.8	1102.3
		ipy	0.11650	0.29970	0.20760
Overall Average		mdd	560.5	983.8	832.5
		ipy	0.09785	0.22539	0.16162

TABLE VII

AVERAGE CORROSIVE PENETRATION, IN INCHES PER YEAR OF EXPOSURE, FOR METAL SAMPLES LOCATED IN THE DOME OF EACH BODY OF THE MULTIPLE EFFECT EVAPORATOR OF TWO FACTORIES

	Representative Metal Type Exposed		Factory Providing Tests		
			E	F	Average
1/8″	Electrolytic Copper	mdd	39.13	19.44	29.25
		ipy	0.00630	0.00313	0.00471
3/16″	ASTM-A7 Mild Steel	mdd	172.2	12.02	92.13
		ipy	0.03152	0.00220	0.01686
1/4″	ASTM-A7 Copper Bearing Steel	mdd	154.6	22.19	88.96
		ipy	0.02850	0.00406	0.01628
1/4″	Jalten 2	mdd	126.0	18.85	71.31
		ipy	0.02306	0.00245	0.01325
1/4″	Corten	mdd	257.2	17.71	137.4
		ipy	0.04705	0.00324	0.02514
1/4″	Cast Iron	mdd	73.50	17.40	45.55
		ipy	0.01470	0.00348	0.00911
Ferrous Alloy Average		mdd	156.7	17.65	80.34
		ipy	0.2897	0.00328	0.01612
Overall Average		mdd	135.4	17.93	71.82
		ipy	0.02519	0.00326	0.01422

Analyses of acid solutions used for cleaning both before and after the cleaning operation indicate that much greater attention should be paid to the concentration of acid used for cleaning purposes. Tests in which clean metal specimens were subjected to the action of the acid cleaning solution in the evaporators of one factory show extremely high corrosion rates. This would indicate that either the strength of acid used for cleaning must be much more carefully adjusted or else the cleaning not carried to the point of exposing the bare metal surface. Factories should study the question of the type and amount of acid used for cleaning so as to regulate more closely the acid supplied to each vessel to the amount required to remove the scale deposits. The indications are that inhibited acid is considerably less corrosive than is uninhibited acid. The inhibitors while not entirely effective do, at least, reduce the amount of corrosion experienced.

Of the alloys tested, Toncan seems to be the most satisfactory low alloy steel. This finding is also in accord with general industrial experience in the Louisiana industry with this alloy. Pure iron also appears to be quite satisfactory as a construction material followed by copper bearing steel. An examination of the typical analyses of the various alloys which will be found in the Appendix, shows that the most resistant alloys are those which are extremely low in phosphorus, carbon and silica and which contain about 0.20% or more of copper. The excellent corrosion resistance of nickel and stainless steel make them attractive as construction materials particularly in the form known as clad steels. The very high cost of such material is a serious deterrent to its extensive use in the sugar industry.

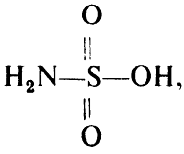
A. *Rosin Amine Type.*

Product of Naval Stores Department. Hercules Powder Company, Wilmington 99, Delaware, U.S.A.

Product used was Polyrad 0515. This material is a reaction product of Hercules Rosin Amine D (technical grade dehydroabietylamine), with ethylene oxide.

Polyrad 0515 is the product obtained by reacting five moles of ethylene oxide with one mole of Rosin Amine D. It contains 15% by weight of free Rosin Amine D.

B. *Inhibitor used with Sulfamic Acid.*

Sulfamic acid,  $H_2N-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OH$, technical grade is a product of the Grasselli Chemicals Department , E.I. Du Pont de Nemours and Company, Wilmington 98, Delaware, U.S.A. The inhibitor employed with this acid is based on their experience and recommendations.

The inhibitor employed is made up of Rodine 20 plus a wetting agent. The usual inhibited commercial acid (a dry powder) is 97.5% sulfamic acid (technical), 2% wetting agent and 0.5% Rodine 20 (by weight sulfamic acid). The wetting agent employed is a product of the Sharples Chemicals Inc., 1100 Widener Building, Philadelphia, Pa., and designated by them as Nonic 218. This is technical grade, polyethylene-glycol. tertdodecyl-thioether.

The inhibitor Rodine 20 is a proprietary product of the American Chemical Paint Company, Ambler, Pennsylvania, U.S.A. It is described as being the salt of a thioamide reaction product.

Bartlett Inhibitor.

This is an amine type inhibitor manufactured by the Barrett Division, Allied Chemical and Dye Corporation, 40 Rector Street, New York, N.Y. The manufacturer was unwilling to furnish further information.

APPENDIX

ANALYSES OF FERROUS ALLOY SAMPLES

1. *Byers Wrought Iron*

Carbon —	0.02%	Silicon —	0.15%
Manganese —	0.03%	Sulphur —	0.02%
Phosphorus —	0.12%	Slag, by weight —	3.00%

2. *ASTM A-7, Mild Steel*

Carbon —	0.25%	Sulphur —	0.05%
Phosphorus —	0.04%		

3. *ASTM A-7, Copper Bearing Steel*

Carbon —	0.25%	Sulphur —	0.05%
Phosphorus —	0.04%	Copper —	0.20%

4. *Jalten 2*

Carbon —	0.14%	Sulphur —	0.04%
Manganese —	0.35%	Silicon —	0.09%
Phosphorus —	0.13%	Copper —	0.28%

5. *Corten*

Carbon —	0.10%	Silicon —	0.48%
Manganese —	0.40%	Copper —	0.41%
Phosphorus —	0.09%	Chromium —	0.84%
Sulphur —	0.035%	Nickel —	0.45%

6. *Triten*

Carbon —	0.19%	Sulphur —	0.036%
Manganese —	0.120%	Silicon —	0.21%
Phosphorus —	0.020%	Copper —	0.41%
	Nickel—	0.60%	

7. *Toncan*

Carbon —	0.03%	Phosphorus —	0.005%
Manganese —	0.12%	Sulphur —	0.035%
Molybdenum —	0.07%	Silicon —	0.005%
	Copper —	0.45%	

—Data on Inhibitors Employed—

REFERENCES

1. American Society Testing Materials. 1949. "*Standards, Part I*, 865-873."
2. Rabald, E. 1951. "*Corrosion Guide*", p. 268, Elsevier Pub. Co., Inc., N. Y.
3. Watts, O. P. and Whipple, N. D. 1917. "The Corrosion of Metals by Acids," *Trans. Am. Electrochem. Soc.*, v. 32, p. 259.

DISCUSSION

Dr. Kerr stated that in India the general practice was to rely on mechanical cleaning of evaporator tubes. In Australia, however, the tendency was towards chemical cleaning of the tubes. To be successful with the method discussed in the paper it was necessary to have a knowledge of the composition of the scales. The first vessel of an evaporator set usually contained scales consisting mainly of calcium and magnesium phosphates. These were removed by the use of a buffered acid solution such as "alumina ferric" which had no serious effect on the metal of the evaporator. A solution of lactic acid obtained by fermentation of diluted molasses was also useful for dissolving that type of scale. The scales from the last vessel of the evaporator usually contained silica and calcium sulphate, and for these scales caustic soda was a more effective dissolving agent. Mr. Parashar commented that the scales on the steam side of the evaporator tubes consisted mainly of zinc oxide and copper oxide. Experiments at the National Sugar Institute, Kanpur have shown that sulphuric acid was very effective in removing that type of scale. Hydrochloric acid was not as effective as sulphuric acid and resulted in a greater degree of corrosion of mild steel. Investigations on this subject were being continued.

Dr. Doss stated that the chemical methods of cleaning evaporators were used in India but when scales were very heavy mechanical methods were found more effective. Doss suggested that calgon might be more useful for scale removal.

Dr. Kerr informed that Prof. Wiggins had also tried using gluconic acid and arabonic acid, but found these acids ineffective. Mr. Gundu Rao said that calgon was only a scale preventer. Dr. Doss stated that calgon can dissolve calcium carbonate and calcium sulphate.

Session III—Friday, 27th January, 2-30 P.M.

Dr. K.S.G.Doss, *Chairman*

Mr. J.P.Shukla presented the following paper.

Paper

ASSESSMENT OF MILL HOUSE SANITATION IN CANE SUGAR FACTORIES

J.P. Shukla and B.D. Kapoor
National Sugar Institute, Kanpur

The extracted juices from cane sugar mills as they come out contain epiphytic microflora along with varied contaminations from the yard soil and surroundings and are highly contaminated. It is assumed that except for the presence of polysaccharide-forming (dextran and levan) type of bacteria the concentration of micro-organisms in the mill house is of no great economic importance under normal operations. The consequence of such contamination, however, can be quite real in the event of shutdowns, cleaning periods and persistant bad sanitation of mill house in sugar factories.

It is difficult to say as to what should be considered as a normal microbiological concentration of microflora in the mill house juices. From the point of view of manufacturing it is not the qualitative species or their quantitative number that matters so much as the loss in sucrose caused by them during the short time interval in which the juices are exposed in the mill house. It still remains debatable as to whether under normal working conditions microbial activities cause any material losses. McAllip (1), Carpenter and Bomonti (2) show losses in purity during the stay of juices during 13 hours to 42 hours. It will, therefore, be only proper to correlate the mill house sanitation with the actual behaviour of the juices in regard to the rate of deterioration and maintain a definite standard by taking properly effective routine precautions.

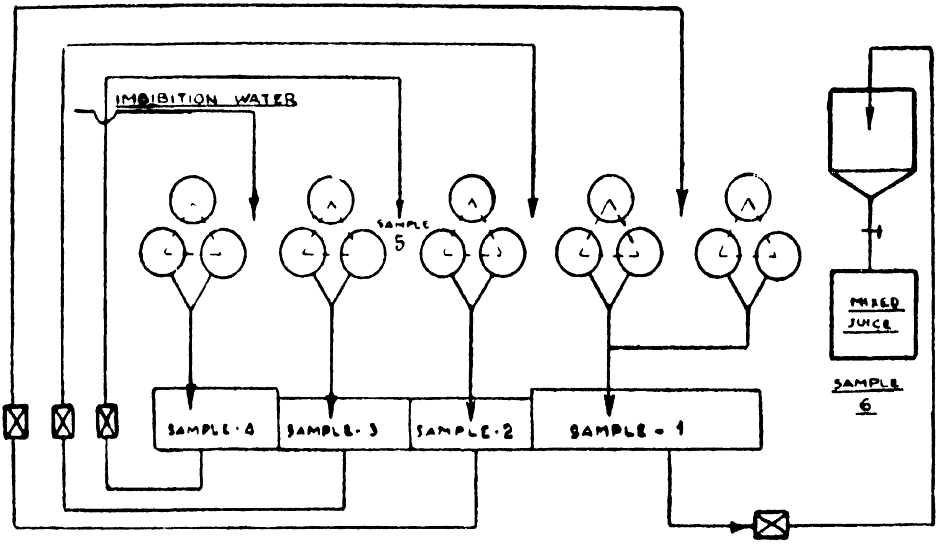
The behaviour of juices in the mill house is judged by the drop in purity between the crusher and the mixed juice. This drop in purity does not only depend upon the losses caused due to micro-organic infection but the working and setting of the mills and their extraction. The other criteria arrived at for judging the mill house losses due to the micro-organic infection is the equivalent ratio quotient value (E.R.Q.V.) which is 1.4 x purity last mill juice-40/1.4 x purity primary juice-40. It should be near 80. If the figure is high extraction is low. If the figure is low there may be either heavy inversion due to acidity or microbiological contamination or high extraction of non-sugars. Whilst it is possible to assess the losses the above procedure does not serve to either locate the pockets of infection or the effectiveness of the disinfectants used.

In the present work a comparison has been made between the methylene blue reduction method as described by Owen (3), whereby the colour of the methylene blue is discharged by the reductase from the microflora in the raw cane juice, and noting the two hourly fall in the juices pol value and purities, left for incubation at room temperature, collected in sterilised glassware. It seems safe to assume that conditions of staying of raw juices and their infection from microflora are fully represented if juices are allowed to deteriorate due to organic and biochemical agencies by staying and are not in any way influenced by factors like non-sugars or extraction of the mills. The juices from the mills can be regarded as ideal media where growth and multiplication of the organisms take place at the optimum conditions and are not influenced by slight variation in the purity or sucrose concentration caused by non-sugars.

EXPERIMENTAL

The juices from the different places were collected as shown in Figure 1.

FIG. – 1



The following juices were taken for tests :—

1. 1st Mill mixed juice.
2. 2nd Mill juice.
3. 3rd Mill juice.
4. 3rd Mill imbibition juice.
5. Last Mill imbibition juice.
6. Mixed juice from storage tank.
7. Dorr juice.

Aliquot portions of the juices were collected and stored in sterile conical flasks plugged with cotton and left over for deterioration at room temperature. The pol and methylene blue reduction were observed on the same samples at two hour intervals.

For the determination of methylene blue reduction time, an electric thermostatic bath was set up at 37±0.5°C. having enough number of sterile serological test tubes of equal dimensions and glass cover. Different juices as collected were transferred by sterile pipettes, 5 c.c. each in 5 tubes. Increasing quantities of methylene blue solution were added so as to finally reach a concentration of 1 part of methylene blue per 30,000 parts juice in the 5th tube. A blank juice tube was also left for incubation in each case. The tubes were examined for disappearance of colour after six to eight hours at progressive intervals of two hours. The volumes were equalised in each tube with sterile distilled water. The disappearance of blue colour trace against white light visually was attributed to the contamination.

FACTORY No. 1

INCUBATION TIME 6 HOURS
INCUBATION TEMP. 36-37°C. (BEFORE CLEANING)

	Methylene blue test					Pol loss
Particulars	C.C. of standard methylene blue per 5 c.c. juice					Pol loss on incubation
	0.1	0.2	0.3	0.4	0.5	
1st Mill mixed juice	—	—	—	+	+	1.2
2nd Mill juice	—	—	—	—	+	1.3
3rd Mill juice	—	—	—	—	—	0.9
1st Mill imbibition juice	—	—	—	—	—	4.8
Last Mill imbibition juice	—	—	—	—	+	1.4
Mixed juice from storage tank	—	—	—	—	+	1.3
Dorr juice	+	+	+	+	+	0.8

From the above it will be seen that the pol losses on the mills are from 1.2 - 1.4. The methylene blue test shows 3rd Mill juice and 1st mill imbibition juice highly contaminated. The pocket for contamination can therefore be located to be the underground pits which had no access to proper cleaning.

AFTER CLEANING

INCUBATION TIME—6 HOURS
INCUBATION TEMP. 35-37°C.

	C.C. Standard methylene blue per 5 c.c. juice				
Particulars	0.1	0.2	0.3	0.4	0.5
1st Mill juice	—	—	—	+	+
2nd Mill juice	—	—	—	—	+
3rd Mill juice	—	—	—	—	—
1st Mill imbibition juice	—	—	—	—	+
Last Mill imbibition juice	—	+	+	+	+
Mixed juice	—	—	—	+	+

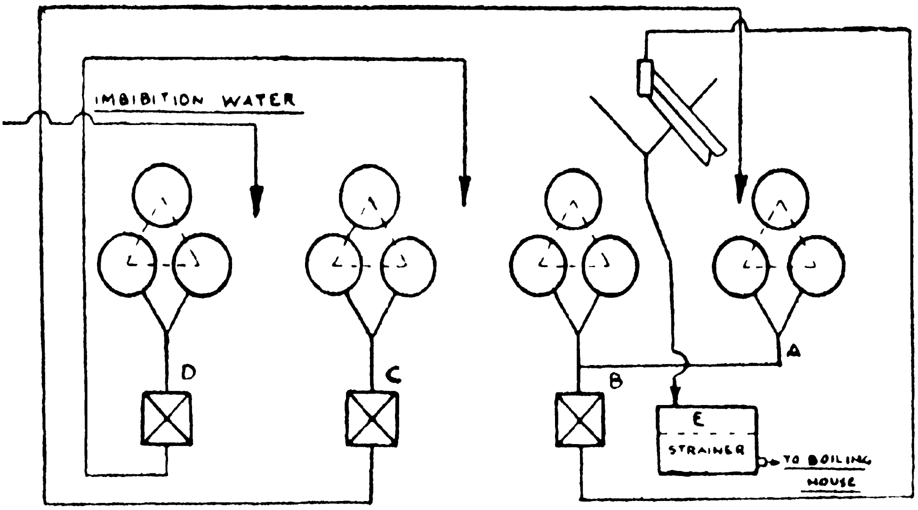
After cleaning, first, second and third mill juices behave similarly. There is no improvement in the 1st Mill imbibition juice which carried infection to the mixed juice and thence to the boiling house. The last mill imbibition juice as also the mixed juice show slight improvement. The cleaning was poor and effective only on the last mill.

The pol data in the above case could not be obtained as the juices were infected with levan type of micro-organisms, became viscous and could not be filtered on clarification.

FACTORY No. 2

In this factory there were no underground pits and the juices were handled by chokeless pumps for imbibition or sending to boiling house directly.

FIG.-2



The following samples were taken for tests :—

(1) Crusher, fore-rollers and gutter of 1st Mill juice

(2) 1st and 2nd Mill juice

(3) 3rd Mill juice

(4) 4th Mill juice

(5) Mixed juice

INCUBATION TIME—6 HOURS
INCUBATION TEMP. 35-37°C.

Particulars	C.C. of standard methylene blue per 5 c.c. juice.					Pol lost on incubation
	0.1	0.2	0.3	0.4	0.5	
1. Crusher, fore-rollers and gutter 1st Mill juice	—	—	—	+	+	0.2
2. 1st and 2nd Mill juice	—	—	—	+	+	1.3
3. 3rd Mill juice	—	—	—	—	+	0.3
4. 4th Mill juice	—	+	+	+	+	0.0
5. Mixed juice	—	—	+	+	+	0.2

DETERIORATION OF JUICE WITH TIME

Time	Hours	Crusher			1st Mill			2nd Mill			3rd Mill		
		Brix	Pol	Purity	Brix	Pol	Purity	Brix	Pol	Purity	Brix	Pol	Purity
9.2.55													
2-0 P.M.	—	18.4	15.7	85.1	16.4	13.8	84.5	5.8	4.5	79.2	4.3	3.2	75.2
4-0 P.M.	2	18.4	15.7	85.2	16.4	13.8	84.2	5.8	4.5	77.3	4.3	3.2	73.7
6-0 P.M.	4	18.4	15.6	84.9	16.4	13.6	83.0	5.8	4.4	75.9	4.3	3.2	74.5
8-30 P.M.	6-30	18.4	15.4	83.9	16.3	12.8	78.6	5.9	4.2	71.1	4.4	3.2	72.2
10.2.55													
2-0 A.M.	12-0	Does not filter			15.6	—	—	5.6	3.0	53.0	4.2	2.9	69.5
8-0 A.M.	18	18.2	—	—	15.6	—	—	4.9	1.1	22.7	4.2	2.5	58.9
11-0 A.M.	21	18.1	—	—	15.3	—	—	4.6	0.1	2.2	4.3	2.4	55.9
2-0 p.M.	24	18.0	—	—	14.6	—	—	4.2	3.1	—	4.2	1.9	45.7

Time	Hours	Mixed juice heated to 95°C.			Mixed juice with $HgCl_2$ 0.5 gm. per litre			Mixed juice with NaF 0.5 gm. / litre			Mixed juice without preservative		
		Brix	Pol	Purity	Brix	Pol	Purity	Brix	Pol	Purity	Brix	Pol	Purity
2-0 P.M.	—	16.9	14.4	85.2	16.2	13.7	84.8	16.2	13.7	84.5	16.1	13.9	86.2
4-0 P.M.	2	16.9	14.4	85.1	16.2	13.7	84.2	16.2	13.7	84.2	16.2	13.8	85.5
6-0 P.M.	4	16.8	14.3	85.2	16.3	13.7	84.4	16.3	13.7	83.8	16.1	13.8	85.1
6-30 P.M.	6-30	16.8	14.2	84.6	16.2	13.7	84.6	16.3	13.6	83.3	16.2	13.6	83.3
2-0 A.M.	12-0	16.7	14.1	84.4	16.2	13.7	84.2	16.3	13.0	80.1	16.0	12.7	79.8
8-0 A.M.	18-0	16.7	13.2	79.4	16.3	13.7	84.3	16.3	12.5	76.8	15.7	11.3	71.7
11-0 A.M.	21-0	16.6	Does not filter		16.2	13.6	83.6	16.3	11.9	72.9	15.4	10.3	66.8
2-0 P.M.	24-0	16.6	—	—	16.2	13.5	83.6	16.3	11.5	70.3	15.1	9.2	61.1

As may be seen the average pol loss in this factory is much less. The methylene blue test also shows that reduction time is prolonged indicating that this factory had much better sanitation as compared to Factory No. 1.

The variation in the pol reading or pol value can be taken as a comparative measure against methylene blue test. In order, however, to decide as to which of the factors Brix, Pol or Purity gave maximum variation during incubation with time, the deterioration was seen for 24 hours and is given in the preceding table.

From the data in the above table, brixes show very small variation and in some cases high values are indicated. Next comes the pol. The maximum differences are recorded by the purity of the juices, being 8.18 in case of 2nd Mill juice and least with mercuric chloride as preservative. The pol loss is high in 1st Mill juice which later developed rancidity and became unfiltrable.

It will, therefore, be proper to check the mill house sanitation by taking juices from different places from time to time during a run and performing the methylene blue test and noting its purity progressively every two hours for six to eight hours.

CONCLUSION

1. Methylene blue test gives an indication of contamination of the juices and can be used for routine check of the mill house sanitation or effect of disinfectants used.
2. Running juices and data of differences in 1st and Last Mill or E.R.Q.V. can be more usefully substituted by noting pol and purity losses of the juices collected and incubated for purposes of judging mill house sanitation and unknown losses.

The present data are too meagre and have to be multiplied for full season in several sugar factories with different mill tandems to arrive at the standards for a proper hygiene of the mill house.

ACKNOWLEDGEMENTS

The authors wish to express their thanks for the help rendered by the sugar factories and their staff and Shri J.M. Saha, Ex-Director and Professor K.S.G. Doss, D.Sc., F.R.I.C., F. Inst. P., F.A.Sc., Director, National Sugar Institute, Kanpur for valuable suggestions and taking keen interest in the work.

REFERENCES

1. Mc. Allep, W.R. 1920. *Report of the 18th Annual Meeting of the Hawaiian C. Assoc. Nov.*
2. Carpenter, C. S. and Bomonti, H.W. 1920. Report of the Com. on Juice Deterioration, *Hawaiian Planters Record* Vol. 24, No. 5, 198-203.
3. Owen, W.L. *The Microbiology of Sugars, Syrups and Molasses* p. 50-55.

DISCUSSION

Mr. Davis asked Mr. Shukla if there was any other method of judging mill sanitation apar from those based on (a) lactic acid formation, (b) methylene blue test and (c) pol loss on incubation, and if he had tried the effect of disinfectants.

Mr. Shukla replied that he was not aware of any other method.

Mr. Clayton said that polarisation reducing sugar ratio was often used. But organisms might consume sucrose or consume the reducing sugar. The ratio also might be affected by the innate inhomogenity of juice in cane.

Mr. Parashar stated that the difference between the purity of primary juice and last mill juice gave an idea of the mill sanitation.

Dr. Dekker replied that purity difference depended on many factors such as variety, degree of milling etc. and hence was not reliable.

Dr. Doss said that Prof. Shukla had developed the method based on the idea that the juice would get microbial contamination more or less proportional to that existing in the bagasse being crushed. That appeared to be a more reliable assumption than the others suggested till then The pol loss on incubation could be correlated so as to get an objective idea of sugar lost by microbial action.

Mr. S.V.Parthasarathy then presented the following paper.

Paper

PROBLEMS OF GUR IN INDIA

S.V. Parthasarathy

Sugarcane Specialist, Madras State

IMPORTANCE OF 'GUR'

Sugarcane had been under cultivation in this country for many centuries now while the modern white sugar manufacture on factory scale is of comparatively recent origin. In tropical India, 'gur' is produced not only from sugarcane but also from palms (such as *Borassus flabellifer*, *Cocosnucifera* and *Phoenix sylvestris*). The final form of the crude product is generally moulded to hard mass, but some times it is rendered powdery or syrupy. Researches all over the country generally pertained to improve the colour, make the gur hard and crystalline in structure and remove such of the constituents that cause rapid deterioration in colour and quality during storage. Yet, on account of its poor preserving quality it has not entered the distant markets. It has a strong hold on the rural folk and when market prices are favourable, it strangles sugar production by diversion of cane from sugar factories. 'Khandsari' sugar is the crystalline sugar made on cottage industry basis but it could not compete with White sugar industry on account of poor recovery of sugar from cane. Production statistics for sugar, Khandsari sugar, gur from cane and gur from other sources are furnished below.

TABLE I

YEARWISE PRODUCTION IN TONS FROM 1949-50 TO 1951-52

		Tons.	
	1949-50	1950-51	1951-52
White sugar	9,78,600	11,00,500	14,83,100
Khandsari sugar	1,35,000	1,25,000	1,00,000
Cane-gur	27,43,000	31,32,000	31,00,000
Palm-gur	—	—	1,73,500*

*Average for 1933-37

In 1951-52, of the total cane produced in India, 52.6% were diverted to gur, 2.8% for Khandsari sugar, 26.3% for white sugar and 18.3% for seed and chewing (5).

In the process of gur manufacture sugar in cane is lost to a greater extent than in white sugar manufacture and this is brought out in Table II.

TABLE II

LOSSES IN GUR MANUFACTURE

	In sugar manufacture	In gur manufacture
Sugar in cane	11.45%	11.45%
Mill extraction	92.0%	—
Juice extraction	—	60.0%
Recovery percent	9.5	10.5
Purity of final product	99.5%	75.0%
Overall efficiency	83.0%	68.3%
Yield of cane in tons per acre	30.0	30.0
Total sugar in cane in tons per acre	3.43	3.43
Sugar recovered in final product tons per acre	2.85	2.33
Loss of sugar in tons per ton of cane	0.0195	0.0369
Extra loss in gur manufacture tons sugar per ton of cane	—	0.0174
Total loss of sugar in India for 1951-52 in tons	—	19,14,310

In spite of heavy loss in sugar by inefficient extraction and its burning in the 'gur' furnace as fuel, the gur industry in India has a strong hold in rural economics. 'Gur' is specially required for certain religious ceremonies and also in the preparation of 'sweet meats' for which white sugar is not suited. It is also widely believed that 'gur' is more nutritious than sugar on account of its mineral contents. The analysis of cane-gur and palm-gur are presented in Table III. (Nutrition Res. Lab., Coonoor.)

	Sugarcane-gur	Palm-gur
Moisture percent	3.9	8.14
Protein percent	0.4	0.35
Fat percent	0.1	0.17
Mineral matter percent	0.6	0.74
Carbohydrate percent	95.0	90.6
Ca percent	0.08	0.06
P percent	0.04	0.06
Fe in mgs. per 1000 grams	11.4	2.50
Calorific value per 100 gm.	383	365
Carotene (International vitamin A units per 100 gm.)	280	—
Nicotinic acid mgm. per 100 gm.	1.0	5.24
Vitamin B_1 (microgrames per 100 gm.)	20	21
Riboflavin (microgrames per 100 gm.)	—	432
Vitamin C mgm./ 100 gm.	Nil	11

The two 'gurs' are considered to be more or less of the same nutritive value. The comparative data on analysis of juices from sugarcane and palm are also furnished below :—

TABLE III

JUICE ANALYSIS DATA FROM SUGARCANE AND PALM

		Palm juice	Sugarcane juice
1.	Specific gravity	1.07	1.07
2.	pH	6.7 to 6.9	5.8 to 6.4
3.	Nitrogen (gm. per 100 c.c. juice)	0.056	0.019
4.	Protein (gm. per 100 c.c. juice)	0.35	--
5.	Total sugars (gm. per 100 c.c. juice)	10.93	13.00
6.	Ash (minerals) (gm. per 100 c.c. juice)	0.54	0.37
7.	Calcium	Trace	0.021
8.	Phosphorus (gm. per 100 c.c. juice)	0.14	0.032
9.	Iron (gm. per 100 c.c. juice)	0.04	—
10.	Titratable acidity (c.c. of N/10 alkali)	8.75	12.00
11.	Vitamin C (mg. per 100 c.c.)	13.25	—
12.	Vitamin B_1 per 100 c.c.	3.9	—

Manufacture of 'gur' is suited to peasant farming and to the decentralised cottage rural industry and it will continue in the field for a long time.

PROBLEMS OF GUR MANUFACTURE

The problems of gur industry and research work done in the country were reviewed already (1, 9). As in any modern white sugar factory, the problems in gur manufacture mainly concern efficiency in milling, furnace for boiling, clarification, moulding, packing and storage. In India, three roller iron mills worked by bullocks or power are in use and they yield upto 66 percent juice extraction on cane weight. The grooving in the iron rollers wear out in one or two seasons when extraction go below 50 percent. The various types of mills now in the market differ in the size and set up of the three rollers. They differ mainly in their crushing capacities per hour. The leading one have not increased the milling efficiency to that comparable in a sugar factory. In the absence of imbibition, there is little scope to increase efficiency in milling. Future research in improving milling efficiency must be directed towards imbibition techniques suited to these small mills. The utilisation of steam from the open pans must be explored for this purpose and if necessary, the open pan process must be given up.

The large majority of cultivators two decades ago were adopting open furnaces which needed extra fuel to boil down the juice to hard mass. Various designs of furnaces, suited to local tastes, have beer introduced in recent times to save fuel. Air dry bagasse forms nearly 35-40 percent on weight of extracted juice and dry trash another 10-15 percent. In open furnaces, additional jungle fuel will be required, whereas in the furnaces introduced by the Agricultural Department, the total fuel consumption varies from 35 to 40 percent on juice weight and bagasse or trash is generally saved. There is considerable loss of heat through the fuel feeding holes, flue for hot air and by loss of steam. Multiple pan system has been evolved to save the heat in flue gas, but it is not popular due to other reasons. In areas like Bombay and Madras, where acre yields are high, in addition to economy in fuel, the speed of boiling is important. In some of these centres, as much as 1200-1500 lbs. of juice are converted to gur in about 1½ hours. A good gur sets to hard crystalline mass in a shorter time than the bad one (16).

Clarification of juice is an important aspect. A good juice from mature cane is easier to handle and most of the impurities are removed by heat (15). The clarificants in use may be broadly classified as vegetable material and inorganic salts. Of the many materials tested, water extract of Bhindi (Hibiscus esculentus) and Sukkalai (Kydia calycina) are common. Of the inorganic clarificants hydrated lime $Ca(OH)_2$ is common. In some places $NaHCO_3$ ard $NaHSO_3$ are in use. The sodium hydrosulphite is efficient in bleaching the colouring matter, but it imparts a sulphur taste, affects keeping quality of gur and the light colour fades away soon. Excess of lime imparts dark colour to gur. The browning of colour is suspected to be due to the soluble nitrogen in juice, which is mostly amino nitrogen. At present, clarification is not perfect enough to remove and to prevent the formation of colouring matter in the open pan boiling process.

In different research stations analysis of the juice and gur were carried out to detect the correlating factors for good and bad gurs. Earliest workers first reported that the colour of gur is most probably due to chlorine (2, 6, 7) and later to interaction between the amino acids and the reducing sugars of the juice (3). Significant difference in respect of purity percent and reducing sugars, while other constituents like total nitrogen, P_2O_5 and colloids being not significant, was reported from Coimbatore (4). Pusa first reported low colloid content, low ash and high phosphate content as characteristics of good juice yielding good gur and later (1949) (8) added low levels in respect of (i) ash in colloidal matter, total ash (ii) harmful nitrogen (iii) harmful nitrogen per total organic nitrogen (iv) soluble SiO_2 (v) $Fe_2O_3+Al_2O_3$ (vi) CaO (vii) MgO as characteristics of good juice (13). Reports from Bombay indicated low nitrogen, high P_2O_5, low K_2O and low CaO contents as characteristics of good juice (10). Reports from Anakapalle recorded low non-protein nitrogen, colloidal matter and high phosphate as characteristics of good juice. The analytical data of Anakapalle in respect of juice and gur from two varieties are reproduced below.

COMPARISON OF JUICE OF CO.419 AND CO.527

	Co.419	Co.527
Brix percent	20.6	19.7
Sucrose percent	18.4	17.9
Purity percent	89.3	90.1
Glucose percent	1.10	0.34
Ash (gms. per 100 c.c. juice)	0.350	0.324
Phosphoric acid (gm. per 100 c.c.)	0.032	0.042
Chloride (per 100 c.c.)	0.103	0.105
Total Colloids (per 100 c.c.)	0.48	0.37
Total Nitrogen (mg. per 100 c.c. juice)	19.0	16.2
Non protein Nitrogen (mg. per 100 c.c. juice)	15.6	12.8
Amino nitrogen (mg. per 100 c.c. juice)	7.0	5.6

The gur from Co. 527 is superior to that from Co. 419 variety. The gur samples from the corresponding juices were analysed and data reported below in Table IV.

TABLE IV

ANALYSIS OF GUR

	Gur from Co. 419	Gur from Co.527
Moisture percent	8.5	7.2
Sucrose percent	72.8	80.3
Glucose percent	9.5	6.8
Glucose ratio	13.1	8.4
Total non-sugars percent	9.2	5.7
Nitrogen (mg. per 100 gm. of gur)		
i. Total Nitrogen	56.6	36.2
ii. Non-protein Nitrogen	42.9	19.6
iii. Protein Nitrogen	13.7	17.6
Non protein Nitrogen % on total Nitrogen	75.8	53.7
Colloids percent	5.5	3.5
Physical features :		
Colour	Brown	Yellowish
Hardness	Hard	Very hard
Structure	Moderate crystals	Good crystals

Colloids and non-protein nitrogen are confirmed to be important factors in qualities of juice and gur.

Of the manures applied to the crop, the nitrogenous ones are universally known to affect the quality of juice and gur by increasing the soluble nitrogen fraction in juice. The advantages of phosphate fertilizers is not universally useful, though high phosphate content of juice is known to improve the quality of juice.

PACKING AND STORAGE

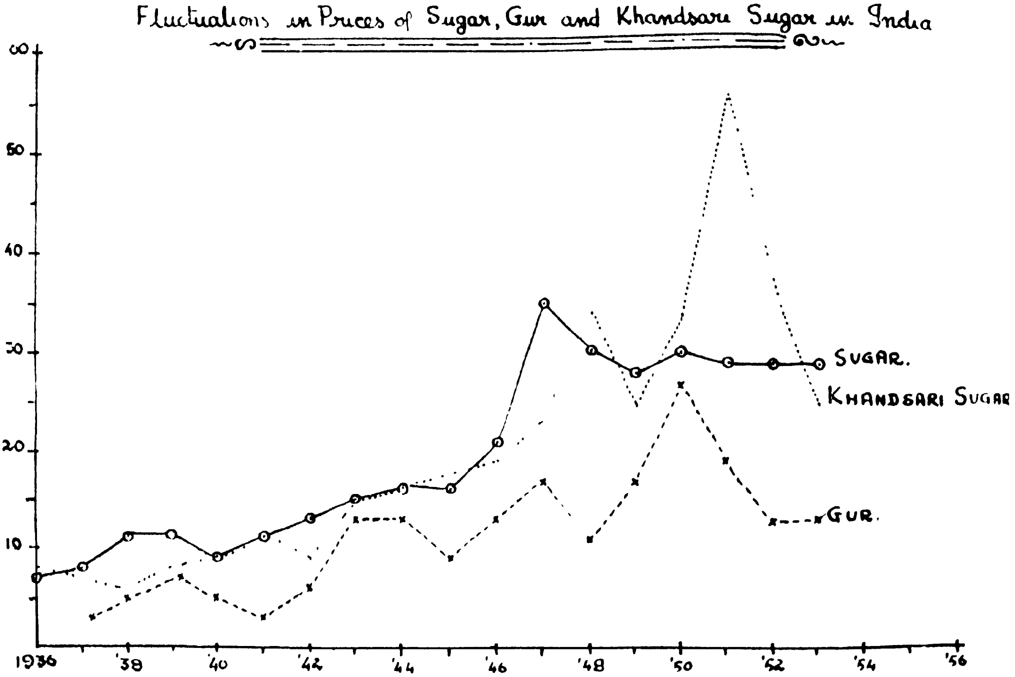
The good quality gur is moulded to a hard mass of different shapes and sizes depending upon the market concerned. Powdery or molassine gur have only limited market. For long distance transport the materials commonly used are hessian cloth, bagasse and date palm mats. The gur moulds are packed in gunnies with lining of date palm mats or bagasse. In many centres, no adequate packing is done and there is considerable loss. Recently investigations in different centres did not lead to any tangible results. Furnace ash coating to gur, alkathene lined gunny, asphalt coated gunny, paddy husk, cotton seed were suggested as preserving or packing materials for gur. Preservation in air tight drums is recommended from U.P. and in paddy husk from Bombay. In Kolhapur market the gur moulds are packed in cotton seed for preservation of gur.

In the preservation of gur atmospheric humidity is the most potent factor. A perfect method of preserving gur in large markets is in vogue in the Andhra State (12). The storage godowns are de-humidified by a system of smoking with rice husk smouldering on the floor. The only defect in this system is that the smoke imparts a blackening colour to a depth of 1/10—1/20 inch on the mould, inspite of the latter being packed in dry cane trash and date palm mats. The many local methods detailed previously aim at keeping the gur mould out of contact with humid atmosphere. The detailed behaviour of gur at different humidity levels as related to its composition and structure have not been studied. The commercial experience in Godavari belt has shown that gur from mature cane only can be preserved without risk and that humidity of the atmosphere is the only factor to be considered. However, scientific investigations are lacking to confirm these experiences.

GUR VS. SUGAR

On average only 25 percent of cane produced in the country is consumed in white sugar factories. In U.P. the percentage may go upto 50 while in Madras it is only 14 percent. In very few centres only, the cane is totally diverted to sugar factories while in others gur and sugar zones overlap and co-exist. Sugar being the product of one of the most important industries of the country, it is controlled or regulated to different degrees, while gur being a cottage industry product, is free and decentralised. The fluctuations in price of gur are wide and in some seasons very low and quite uneconomic (Fig. 1) (Tariff Board 1950). When gur prices are high cane supply to many sugar factories is affected due to diversion of cane to gur making. Dr. T.S. Venkataraman pronounced that gur and sugar cannot possibly co-exist in the same area. Except where cane plantations are owned by the sugar factories or in the hands of plantation farmers, supplies from peasant farmers could not be steady in the face of better returns from gur making. In view of some special advantages offered by gur to small farmers, it will continue in the field for many decades more and may not possibly be replaced by white sugar altogether in this country.

FIGURE 1.



SUMMARY

Gur is prepared from sugarcane or palms in India. On account of inefficient milling, considerable quantity of sugar in cane is lost in bagasse and is burnt in the furnace. Approximately 0.0174 ton of sugar is lost per ton of sugarcane. Due to the presence of minerals in gur, it is believed to be more nutritious than sugar. Milling efficiency of the present three roller iron mills may not very much improve, unless imbibition techniques are adopted. The furnaces are mainly designed to save fuel, but in Madras and Bombay speed of boiling is an important criterion. Clarification of juice is a difficult problem. Chloride interaction of amino acids with reducing sugars, soluble protein, colloids, low ash and nitrogen , high P were recorded as criteria for good juice. Nitrogenous manures are known to affect the qualities of juice and gur to largest extent. Varieties differ characteristically in the quality constituents of juice. The vegetable or inorganic clarificants that are now in use, have not been of universal benefit.

Preservation of gur is yet another problem. Gur from mature canes only preserve well on storage and the atmospheric humidity plays the largest role in

deteriorating the stored gur. Of the various suggestions made, the godowns of Godavari tract present the best model and here the atmosphere is de-humidified by periodical heating with smouldering rice husk on the floor.

Gur prices fluctuate widely. When high prices prevail, much of factory cane is diverted to gur making. In spite of many drawbacks in gur, it will continue to be an important cottage industry product. The cultivation of cane, trade and economics of gur fundamentally differ from that of sugar and possibly the manufacture of these two alternative products cannot co-exist in the same zone.

ACKNOWLEDGEMENT

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REFERENCES

1. Dutt, N. L. 1950. Report on Survey on Sugarcane Research in India Published by Indian Central Sugarcane Committee, New Delhi.
2. Ganapathi Iyer, G. 1947. *Indian Journal Agri. Sc 17*, p 341.
3. Ganapathi Iyer, G. and Bhushanam, K. 1939. *Madras Agri. Journal, XXVII*, p. 161.
4. Gopala Iyer, K.V. 1953. *Annual Report—Sugarcane Breeding Institute—* page 48.
5. Indian Sugar Manual 1952. *Published by Sugar Techn. Assn. India*, Kanpur
6. Krishnamurthy Rao, K. 1919. *Agri. Journal India*, 14, p. 476.
7. Krishnamurthy Rao, K. and Iyer, G.G. 1923. *Madras Agricultural Journal* 11, p. 266.
8. Khanna, K.L. 1948, 1949. *Annual Report. Sugarcane Research Station, Pusa, Bihar State.*
9. Khanna, K.L and Chakravarti, A. S. 1951. *Biennal Conference of Sug Res and Dev. workers in India*, p. 74.
10. Parthasarathy, .S. V. 1951. *Annual Report—Sugarcane Research Station, Anakapalle, Madras State*
11. Parthasarathy, S. V. 1954. *Proc. Sug. Techn. Assn. of Ind.* p.71.
12. Parthasarathy, S.V. and Lakshmikanthan, M. 1950. *Madras Agri. Journal, XXXVII*, p. 499.
13. Rege, R. D. 1951. *Annual Report of Sugarcane Research Station Padegaon, Bombay State.* p. 12.
14. Report of Indian Tariff Board 1950. *Published by Government of India.*
15. Varahalu, T. 1935. *Madras Agri. Journal, XXIII*, p. 389.
16. Varahalu, T. 1937. *Madras Agri. Journal, XXV*, p. 377.

DISCUSSION

Dr. Doss stated that Mr. Parthasarathy had given an idea of the problems facing the Gur Industry in India. Before inviting discussions he wanted to draw the attention of the members to the following limitations under which research on Gur has to be conducted : -

(i) It is a cottage industry and carrying any new idea to all the numerous small cultivators is a stupendous problem ; extension of cooperatives and community projects is likely to improve the position.

(ii) Any improvement should not involve technical complications such as cannot be understood and given effect by the common man.

Regarding the design of godowns, he said that he had seen some of the best ones at Dankaur, near Meerut. The Gur was stocked on the 1st floor to avoid ingress of moisture through the floor ; there was provision for air drying during the dry season ; the walls of the rooms were protected from exposure to rain ; the principle of double door was adopted for minimising entry of humid air during monsoon months. That was convenient for medium scale storage. He suggested that a de-humidifier would be of immense help in the more humid regions.

He further added that the development of gur industry should focus its attention on minimising the large scale losses by having central manufacturing stations for Gur. That would also help in standardising the quality of Gur which was so important for a direct edible commodity such as Gur. Qaiyum Ahmad (Pakistan) stated that confectionery type of vacuum pans were worthy of being considered for preparing gur.

In the absence of the authors the following paper was taken as read.

Paper

THE DESIGN AND PERFORMANCE OF A NEW TEST FILTER

R.I. Nicholson *and* (Miss) M. Horsley
The Colonial Sugar Refining Co. Ltd., Sydney

INTRODUCTION

During investigations into the nature of the filter impeding impurities in raw sugar, which have been in progress in the Company's Research Department for a number of years, the necessity was felt for a small filter as the basis of a simple and accurate filterability test.

Considerations in the design of the filter were that it should function with small quantities of sugar, and allow for the collection and analysis of the filter cakes for the presence of certain constituents considered to be filter impeding.

Other considerations in the design of the filter were that it should be simple, portable and independent of services such as steam, electricity and air pressure lines. These points were desirable since we had in mind using such a filter in the mills and refineries of the Company where a further study of filtration problems could be made in any part of the factory.

A most important requirement of the filterability test was that the results should be real in that they should correlate with, and serve as a prediction of, the actual behaviour of the sugar in a refinery.

A survey of existing methods of test filtration procedures showed that none were wholly suitable for our purposes. They were either too crude or too elaborate, or required samples larger than we could conveniently handle on a research basis. The tests available ranged from the simplest, which depended on the flow of a sugar solution through a filter paper by gravity, through the well-known Elliott test employing vacuum, and to several more complex tests employing either incremental or constant pressure. The Colonial Sugar Refining Company's standard filtration test is an example of one of the last types. The test was introduced in 1927 and employed incremental pressure with rather large sugar samples in a 4 compartment pressure vessel. This test is described in "Laboratory Manual for Queensland Sugar Mills", 3rd Edition, page 109 (1954).

With these facts in mind, it was decided that a new test filter would have to be developed.

REQUIREMENTS SOUGHT IN FILTER DESIGN AND OPERATION

The general object was to design a filter of great simplicity and portability, unencumbered by much ancillary equipment. Simplicity in operation and the provision of readily standardizable test conditions were also required.

The following points, therefore, were considered desirable in the design and operation of the filter and in the overall test procedure.

1. *Filter Design.*
   - (a) Filter body to be of a simple cylindrical design of about 450 ml. capacity.
   - (b) Horizontal filter disc.
   - (c) The filter disc to be of a simple design without a complexity of wire gauzes and groovings of the disc, as in the Elliott filter.
   - (d) The filter septum over a single wire gauze to be a standard size filter paper which could be easily changed between runs, obviating the necessity of fitting filter cloths.
2. *Filter Operation.*
   - (a) Filtration at constant pressure
   - (b) Abolition of stirring during filtration.
   - (c) Filtration at ambient temperature requiring only a record of the temperature and not control.
   - (d) The compressed gas for actuating the filter to be supplied from cylinders and not from permanent installations supplied from a compressor.
3. *Test Procedure.*
   - (a) The use of the readily available filter aid, such as Super-Cel (Johns Manville Corp.)
   - (b) The use of a buffer to obtain the desired pH.
   - (c) Standardization of the filter using at 60° Brix refined sugar solution.

DESCRIPTION OF THE FILTER

Two photographs of the original filter are shown.

It consisted of the following parts :

- (a) The body was a piece of brass tubing 2″ I.D., about 9″ long and threaded at each end.
- (b) The base was a brass casting machined and threaded. In it were placed the filter plate, retaining ring, rubber gaskets, etc.
- (c) The head of the filter carried a gauge, pressure relief valve and a threaded inlet gas connection.
- (d) The filter disc was a circular brass plate drilled with 45 × 3/32″ holes. A piece of 120 mesh Monel gauze was edge-soldered in a recess.

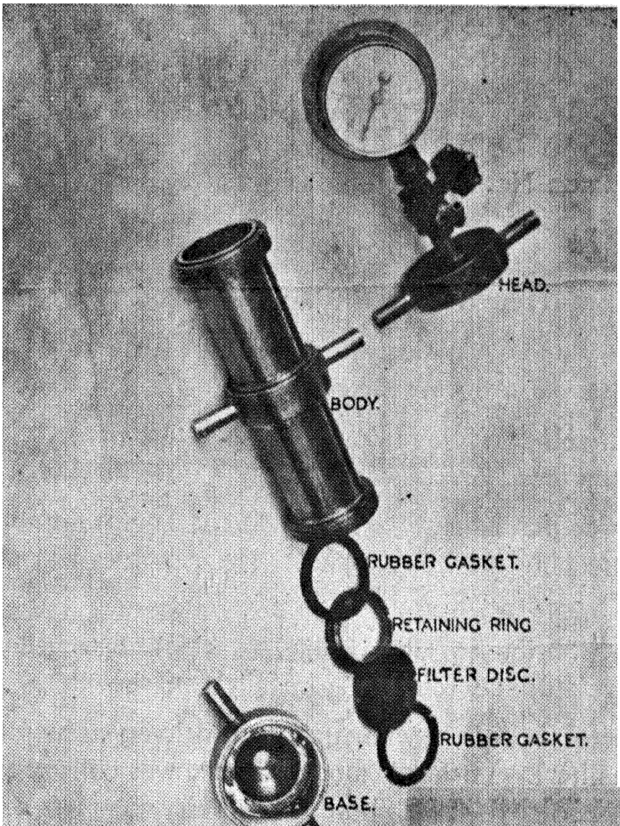


Photo 1.
Original Model Filter.
— Exploded view.—

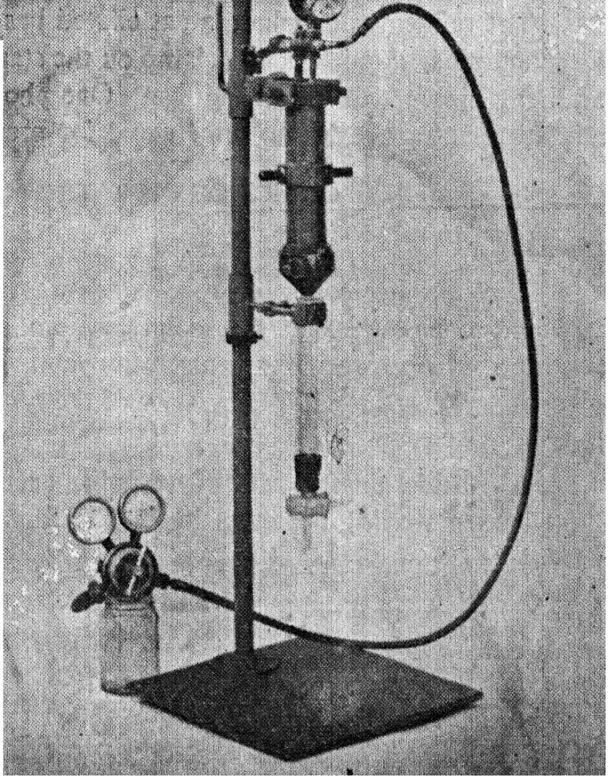


Photo 2.
Original Model Filter.
—Assembled.—

To assemble the filter ready for use the various units are placed in the base in the following order :

(a) rubber gasket,
(b) filter disc,
(c) filter septum (Whatman No. 1 paper , 5.5 cm.),
(d) brass retaining ring,
(e) rubber gasket.

The body of the filter is then screwed on to the base and tightened.

Rotation of the filter-disc and retaining ring during tightening was prevented by pins, which also served to locate the paper.

After addition of the sugar solution to be filtered, temperature observation, etc., the body is screwed into the head on its stand.

The head in this model was permanently attached to the stand but could be angled forward to make attaching the body easier. The gas inlet was also left permanently attached.

Control of pressure at 50 lbs./sq. in. (gauge) is achieved by using a commercial type welding gas regulator between the gas cylinder and the filter.

Fore-run and filtrate collectors could be swung under the delivery as required (see photograph of new model filter). In the old model, filtrate was collected in a modified 100 ml. cylinder fitted with a wide-bore tap. This was left open and the fore-run run to waste, and closed for collection. This system has advantages where a large number of samples are handled.

The new model filter is similar to the prototype except that certain refinements have been incorporated. These are shown in the accompanying photographs.

The refinements include a castellated base, some modifications to the filter disc and pins, a quick-acting clamp on the stand, a safety valve and a valve for applying pressure or blowing down. One photograph also shows a small motor and stirrer attached to the same stand for preparing the solution.

CHOICE OF OPERATING CONDITIONS

1. *Filter Aid.*

The initial selection of a filter aid was arbitrary. Firstly, the filtration rate had to be such that a reasonable quantity of filtrate was passed both for the pure syrup used for calibration and for the raw sugars investigated subsequently. Secondly, the clarity of the filtrate had to be acceptable to our industry.

A considerable amount of work has been carried out on various filter aids, the effect of varying the quantity of filter aid and the effect of pH.

It is not necessary to discuss the results here, but it should be remembered that as well as choosing a filter aid suitable to the requirements of this particular

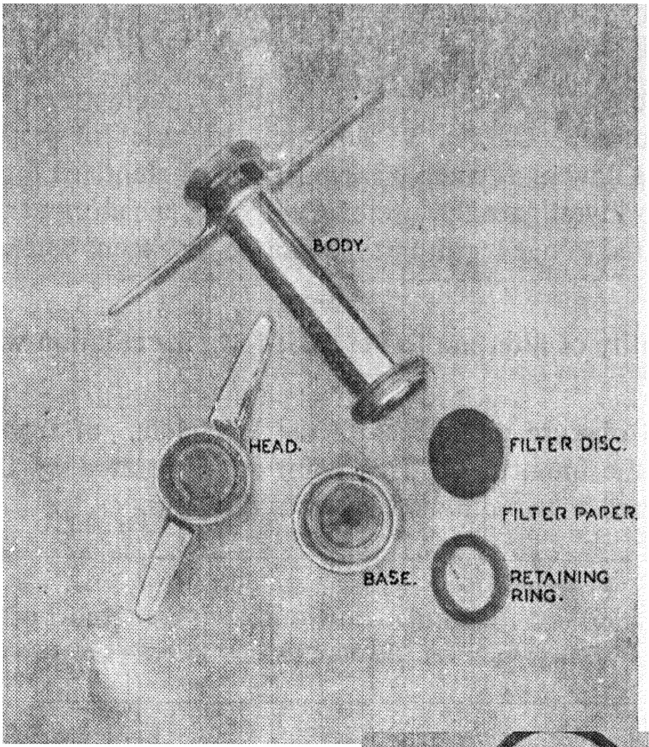


Photo 3.
New Model Filter.
—Exploded View.—

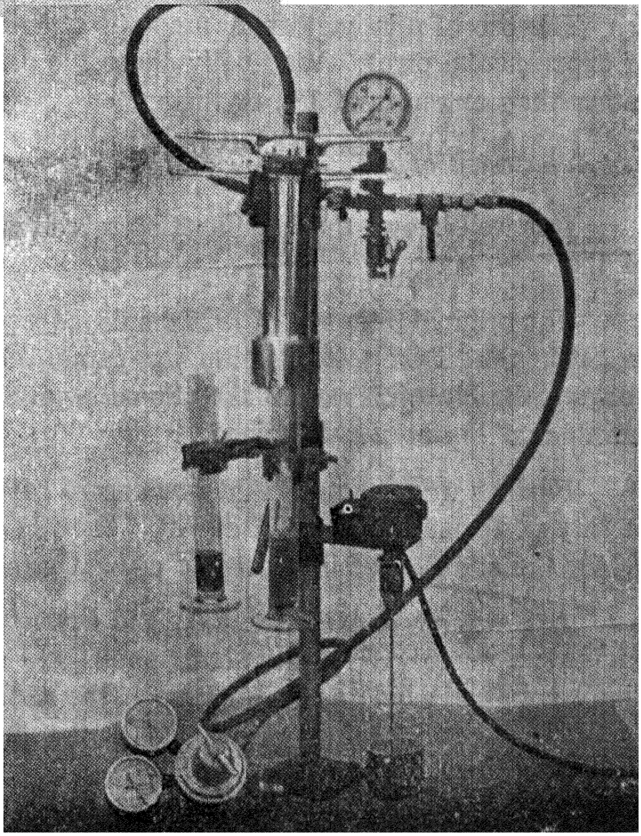


Photo 4.
New Model Filter.
Assembled.—

model filter we required a test that would predict the behaviour of the sugar under certain refinery conditions.

We have found that the old type of Standard Super-Cel manufactured by the Johns Manville Corporation, U.S.A., is suitable. Material of recent manufacture has a rather faster flow and, when a fresh supply of standard filter aid is required, we propose to investigate the use of Celite 505, which appears to have characteristics more suited to our requirements than do the recent batches of Standard Super-Cel.

The selection of the quantity of filter aid to be added to the solution was also more or less arbitrary.

Large quantities tend to obscure differences in the behaviour of sugars by "swamping" the effect of the impurities. This point is illustrated by the filterability of three sugars filtered at two different levels of filter aid.

Quantity of Filter Aid	Filterability Sugar A	 Sugar B	 Sugar C	Ratio of Rates
0.5% on sugar	7.5%	13.6%	24.5%	1:1.8:3.3
1.2% on sugar	44.5%	51.5%	56.5%	1:1.2:1.3

The use of relatively small amounts undoubtedly increases the likelihood of experimental error. We finally chose the addition of 0.4 to 0.6% on sugar rather than amounts of 1% or higher.

2. *Adjustment of pH.*

It is well known that the filtration rate of a raw sugar is affected by the pH of the solution.

The original filter test of 1927 employed a pH of 8.0. We found, however, in 1952, that if the test filtration was conducted at pH 9.7 a better correlation between the filtration rate of the affined sugar solution and that of the refinery carbonated liquor was obtained.

Further work showed that raw sugars gave the best correlation with their factory performance at a pH of 9.0. The pH of the solution was adjusted to 9.0 by the addition of lime-sucrose using a glass electrode.

As it was our intention to make the new test procedure as simple as possible, trials were made with various compounds and mixtures to act as buffers. The aim was to find a liquid, for preference, the addition of a fixed amount of which to the raw sugar solution would give a reasonably constant pH of 9.0 without need for actual measurement.

A mixture of triethanolamine and calcium acetate in 50% glycerol was finally chosen, and was found to be satisfactory, except for some deteriorated raw sugars which were more acid than normal.

(The solvent, 50% glycerol, was chosen as having approximately the same viscosity as 60° Brix sucrose).

USE OF THE FILTER

In this section a brief description of the test filtration procedure is given. Full details are included in an Appendix.

1. *Standard Conditions.*

The standard conditions for determining the filterability of a raw sugar are as follows :

Concentration of sugar solution : 60.0° Brix±0.1° Bx.

pH of sugar solution : 9.0±0.1.

Weight of standard filter aid : 0.5% on solids±0.001 gm.

Temperature of the test : Room temperature. The temperature of the solution before and after the test must not differ by more than 1°C.

Pressure : Pressure must be kept constant at 50 lbs./sq. in. (gauge).

Duration of test run : 8 minutes. The filtrate is discarded for the first 2 minutes of the run, and collected for the remaining 6 minutes.

2. *Procedure.*

The 60° Brix solution to which both buffer and filter aid have been added is poured into the partly assembled filter and its temperature taken. The head of the filter is screwed on and 50 lbs./sq. in. pressure applied. For the first two minutes the filtrate is allowed to run to waste. The volume of filtrate passing in minute intervals over a period of 6 minutes is then noted. The pressure is released and the temperature of the residual contents of the filter taken.

3. *Calibration.*

The filter, i.e., the filter disc, is calibrated by determining the rate of filtration of a pure 60° Bx sugar syrup using the standard quantity of selected filter aid. The rate is determined over a temperature range likely to be encountered under laboratory conditions, viz. 15-31°C.

Figure No. 1 shows the volume of filtrate at the end of each minute plotted against temperature. Over a restricted range of temperature the graphs may be represented by straight lines. (This is not strictly correct since viscosity, the main rate-controlling factor, is not quite linear with temperature, Figure No. 2, but straight lines are sufficiently accurate for our purposes).

Figure 1.

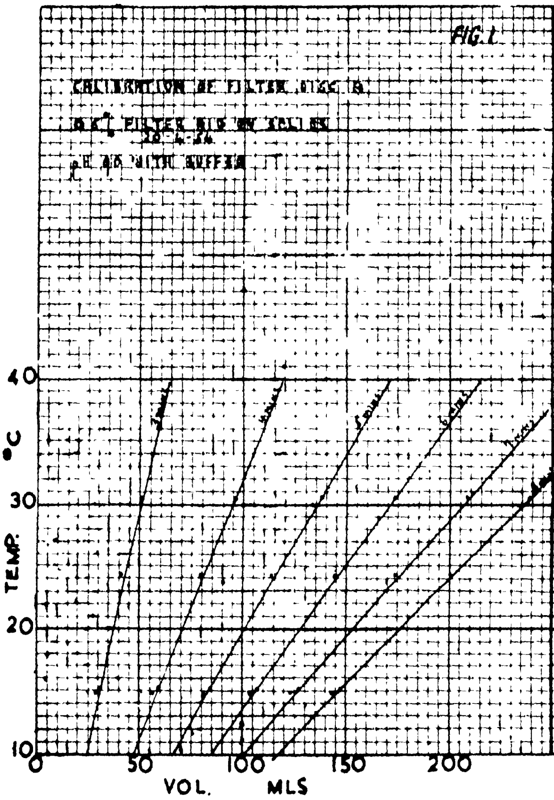
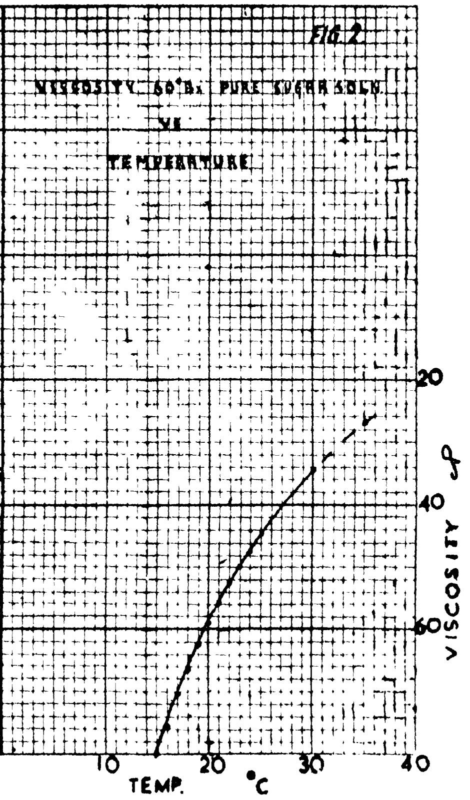


Figure 2.



From these straight lines the volumes of pure sugar syrup filtered at the end of 3-8 minutes can be read at any temperature within the range.

The relevant volumes at each 0.1°C. interval can be conveniently recorded in tables.

4. *Expressions of Results.*

The filterability of a raw sugar is obtained by expressing the volume of filtrate collected as a percentage of the corresponding volume of pure sugar solution collected at the same temperature read from the calibration graph.

It is convenient to take the volume of filtrate at the end of three different periods, divide them by the corresponding pure syrup volumes and average the results to obtain the filterability figure.

An example will make this procedure clear.

TABLE I

DATA FROM A FILTRATION RUN

Time	Volume of Filtrate	Filterability	Temp. (°C.)
End of 3 min.	9.0 ml.	9/37×100=24.3%	Initial 19.6
„ „ 4 „	17.8 „	17.8/70 „ 25.4%	Final 19.8
„ „ 5 „	25.3 „	25.3/100 „=25.3%	Average 19.7
„ „ 6 „	31.5 „	31.5/126 „=25.0%	
„ „ 7 „	37.8 „	37.8/151 „=25.0%	
„ „ 8 „	42.8 „	42.8/173 „=24.7%	

The 6,7,8 minute figures are averaged to give a figure of 24.9%. This is the filterability value of the raw sugar.

The rate figures for the shorter times are not usually used since errors of observation may be considerable. They are useful however sometimes during investigational work when a miscalculation of the necessary quantity of a sugar, or the fact that only a small sample is available, results in a short filter run.

5. *Investigation of Filter Cakes.*

The use of a horizontal filter plate instead of a vertical plate has great advantages for investigating filter cake impurities. A filtration may be done, then the filter blown dry and the cake washed with water or other reagent if desired. The sugar-free cake can be quantitatively transferred and analyses made. The results of these analyses can be accurately referred to the sugar initially taken since no wastage of syrup has occurred.

PERFORMANCE OF THE FILTER

There are a number of factors which can affect the accuracy of the result obtained with this filter. These factors will now be discussed, and an estimate made of the reproductibility of the filterability value obtained for a given sugar.

The factors can be divided into two groups—those relating to the filter and accessories, and those relating to the solution.

1. *Factors relating to the filter include* :

(a) Area of filter discs,

(b) Rate of application of pressure,

(c) Variations in pressure,

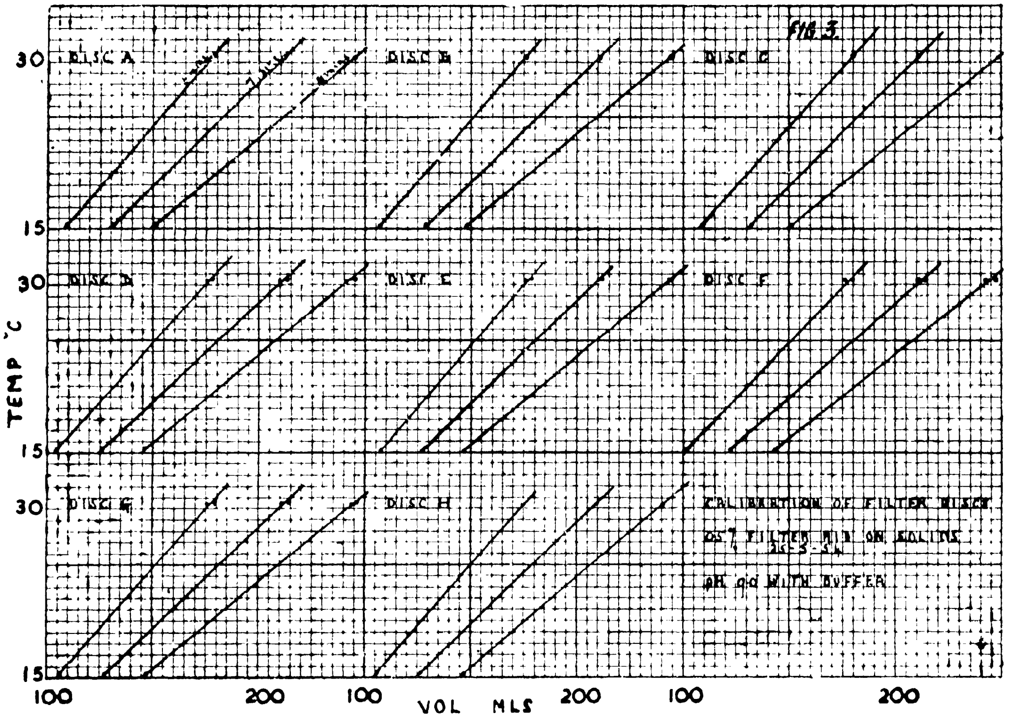
(d) Measurement of filtrate volume.

(a) *Variations in Area of Filter Discs.*

We have satisfied ourselves that filter discs manufactured to careful tolerances give consistent results. This uniformity of manufacture has been achieved by crimping the gauze and soldering only where the solder cannot creep on to the filtering surface of the gauze and so affect the area.

Figure No. 3 shows the calibration of 9 filter discs. (The averaged figures from these runs were used in drawing up our standard tables). Having established that the graphs may be drawn as approximate straight lines we have relied on duplicate determinations at two temperatures, approximately 15°C. and 31°C., to locate them.

Figure 3.



A check on the calibration of the filter and/or the accuracy of the pressure gauge may be made at any time at a mill or refinery. This is done by determining the filtration rate for a pure syrup as above at ambient temperature. If agreement within 6% of the calibration table is not obtained, further checks on the disc and pressure gauge have to be made.

After prolonged use the calibration of a disc may vary due to the accumulation of some debris behind the gauze. This may be removed by a short immersion in hot chromic acid.

There is one point where our new model filter is unsatisfactory. Its total capacity due to a reduction of diameter (1.83″ instead of the original 2″) is 370 ml. This is insufficient for calibration at : 30°C. above 6 minutes, 27°C. above 7 minutes and 25°C. above 8 minutes.

The original filter had a capacity of 435 ml. which would give an 8 minutes run on pure syrup up to 30°C.

It consequently appears desirable to have a filter of from 435 to 450 ml. capacity which may be done by reverting to the 2″ inner diameter or increasing the length of the filter body.

(b) *Rate of Application of Pressure.*

No error has yet been attributed to this factor, but undoubtedly the rate of application should be standardised.

The rate has been different in our old and new model filters. In the old model the pressure was raised by screwing in the reducing valve handle. In the new, full pressure is applied instantaneously by turning a cock.

(c) *Variations in Pressure.*

Control of pressure has been satisfactory with the regulator described.

Error introduced by an inaccurate gauge is proportional to pressure. A gauge reading 50 lbs. instead of 49 should introduce a 2% error. Filtrations deliberately conducted at 49 and 51 lbs./sq. in. gauge gave the following results, which differ from one another by less than the expected 4%.

Pressure	Filterability
49 lbs./sq. in.	37.2%
51 lbs./sq. in.	38.1%

(d) *Measurement of Filtrate Volume.*

The main error here occurs where readings are taken on a fast running filtrate i.e., pure syrup at high temperatures. The error is difficult to assess, as the 2-3% variation in volume between replicate runs during calibration is more likely to be associated with variations in temperature.

2. *Factors relating to the solution include* :

(a) Brix and pH.
(b) Temperature.
(c) Standing of solutions.

(a) *Brix and pH.*

To study these factors duplicate runs were made at pH 8.8, 9.0 and 9.2 and Brix of 59.5, 60.0 and 60.5.°

An analysis of variance was done on the results to determine the significance of the differences. A change of 0.4 unit of pH (from pH 8.8 to pH 9.2) introduced a total difference in filterability of 4.8%. Thus the permitted pH variation of ±0.1 pH could introduce an error of approximately 2.5%. This figure will vary with the type of sugar since the sensitivity of sugars to pH changes differs.

A Brix variation of 1° Brix was found to introduce a 15% error : thus ±0.1° Brix could yield a 3% error.

(b) *Temperature.*

The effect of temperature on a filtration rate is due to changes in viscosity. We have specified a tolerance±0.5°C.

This specification was laid down after an estimate of the effect of temperature had been made. This was done by taking the viscosities equivalent to the maximum allowed variations of Brix and finding what temperatures gave the same viscosities. This is made clear in the following table.

ESTIMATED EFFECT OF TEMPERATURE

Brix	Corresponding Viscosity	Corresponding Temperature of 60° Bx. Solution giving that Viscosity	Difference in Temperature
59.9°	58.00 cP.	20.30°C.	0.55°C.
60.1°	59.85 cP.	19.75°C.	

It was found that twenty laboratory filtration runs at round 20°C. showed an average range of 0.56°C., and 20 runs at around 25°C. an average range of 0.49°C. Thus it appears reasonable to claim that the effect of temperature variations could introduce an error of the same magnitude as a± 0.1° Brix variation viz , 3%.

If during a whole filtration run the temperature was 1°C different from that observed (a condition unlikely to occur) the error could amount to twice the above, viz., 6%.

(c) *Standing of Solutions.*

The filterability of a sugar solution is always lowered by standing at a high pH such as 9.0 or 9.7.

We have sought to overcome this source of error by emphasising that the time of standing and the speed of stirring should be standardised.

3. *Reproducibility of Results.*

The sum of the effects of these factors shows that the reproducibility of the results obtained is of the order of 10% $\left[\frac{\text{difference between duplicates}}{\text{average of duplicates}} \times 100\right]$. For operators working at speed we have tentatively allowed a 15% difference between duplicates.

The variations between duplicates appear to be due rather to interactions between filter aid, impurities and buffer than to the filter itself. For this reason standardised working conditions should be adhered to as closely as possible. Duplicate determinations on a stable material such as carbonatated liquor agree within 5% or better.

Two operators supplied with the necessary stirring equipment etc. are able to carry out from 20 to 25 determinations per day. During the 1954 crushing season three filters were in almost constant use in the Research Department when well over 2000 determinations were made.

DISCUSSION

The design and operation of this filter has departed considerably from previous practice. However consideration of the following points shows some justification for the changes.

1. *Lack of stirring.*

It will have been realised that the success of this filter in obviating stirring, and hence achieving a great simplification, has depended on the relatively high viscosity of 60° Brix syrup at room temperature in suspending the filter aid.

If the filter aid is successfully suspended and does not settle out during the filtration then the equation for constant pressure filtration must be obeyed.

$$\text{i.e., } t = \frac{nrc}{2PA^2} V^2 + \frac{nr}{PA} V$$

$$\text{or } \frac{t}{V} = \frac{nrc}{2PA^2} V + \frac{nr}{PA}$$

Where, t = Time (secs.)

n = Viscosity (poises)

c = Concentration of insoluble solids (gm./ml.)

P = Pressure (dynes/sq. cm.)

A = Area of cake ($cm.^2$)

V = Vol. of filtrate (ml.)

r = Specific resistance of filter cake (cm./gm.)

R = Initial resistance of filter septum.

This equation is directly derived from D'Arcy's equation (1856) and Poiseuille's Law (1844) for the flow of water through sand and the flow of a viscous liquid in a capillary respectively, with the introduction of the initial resistance term due to Sperry (1916).

From the second form of the equation given above it is seen that on plotting $\frac{t}{V}$ versus V a straight line should be obtained if c remains constant (i.e. no sedimentation of filter aid).

Straight lines were in fact obtained within the limits of experimental error for pure syrups. Hence we conclude that under the conditions studied (temperatures up to 32°C. and times up to 15 minutes), no settling of the filter aid sufficient to interfere with orderly filtration takes place. Impure sugars tend to drop off in rate with increasing time and hence depart from the straight line relationship. This departure from linearity is due to compressibility of the filter cake and not to settling of the filter aid.

2. *Temperature.*

Filtration of sugar syrups at ambient temperature is avoided in manufacturing operations for obvious reasons. It is also frequently avoided in test filtrations for the following reasons :-

(a) High viscosity of syrup gives smaller volume of filtrate.

(b) Rapid changes in viscosity with changes in temperature may lessen accuracy.

(c) The possibility that a different behaviour of the filtration—retarding impurities might be encountered at low contrasted to high temperatures.

With the filter designed here it is easy to measure small volumes of filtrate with reasonable accuracy, and the high viscosity of the syrup has the advantage discussed above, viz., elimination of the need for stirring.

The last point is of course a possibility. Changes in colloid flocculation could affect filterability in different ways at different temperatures. We can say at this stage that no real interference with the usefulness of the test filtration procedure finally adopted can be attributed to its being carried out at room instead of high temperatures.

3. *Pilot Plant Evaluation of Test.*

Fifteen ton lots of each of 3 brands of raw sugar were obtained. After affination, the melter liquors were carbonatated at 0.2%, 0.4% and 0.8% CaO on solids and 75% and 90% Degrees of Carbonatation in the first tower. Each trial was duplicated making a total of 36 trials.

For each trial, samples of raw sugar, melter liquor and carbonatated liquor were taken. The filterability of the raw sugar was determined by the new filter test. The slurry resistance of the carbonatated liquor, which is directly related to filter station performance, was determined.

It was found that there was a relationship (significant at the 5% level) between the raw sugar filterabilities and the slurry resistances of carbonatated liquors.

The results of the pilot plant trials indicated that the new filter test was of value in picking a sugar that is likely to filter badly in a carbonatation process.

ACKNOWLEDGEMENT

The authors would like to express their appreciation to the management of the Colonial Sugar Refining Co. Ltd. for permission to publish this paper.

They would also like to thank Mr. D.R. Beiers and Mr. J.G. Paynter of the Engineering Staff of the Company for valuable suggestions in the design of the filter.

APPENDIX

RAPID FILTERABILITY TEST FOR RAW SUGAR

1. *Standard Conditions for the Test.*

As described in the paper.

2. *Preparation of the Sugar Solution.*

Take the required weight (W) of sugar in a tared beaker. Add 2/3 W gm. of filtered water and dissolve by stirring at room temperature.

Adjust to 60°±0.1° Bx using a refractometer. Weigh the syrup. For a single determination 250 gm. is sufficient.

3. *Addition of Standard Filter Aid.*

Weigh out a quantity of standard filter aid equal to 0.5% of the weight of solids. Transfer to a small beaker. Add a small quantity of the syrup, allow it to wet the filter aid. then mix into a smooth paste with a rubber-tipped rod. Transfer to the main bulk of syrup and rinse with some of the original syrup.

4. *Addition of Buffer.*

Place the syrup under the stirrer and pipette in 2 ml. of buffer for 250 gm. of syrup.

5. *Filtration.*

Pour the freshly stirred syrup into the assembled filter. Stir gently with a 50°C. thermometer until the temperature is steady. Record this to 0.1°C. Transfer filter to the stand and immediately apply pressure (50 lbs. gauge).

Run the filtrate to waste for exactly 2 minutes then collect in a 100 ml. measuring cylinder. Continue to collect the filtrate for 6 minutes, noting the volume at the end of each minute. After noting the 8 minute figure, release the pressure and immediately record the final temperature in the same manner as the initial temperature.

6. *Calculation of the Results.*

Record and work out as below.

Sample	Run No.	Date
Time	Volume of Filtrate	Temperature
End of 3 min.	10.0 ml.	Initial 20.8°C.
,, 4 ,,	19.0 ,,	Final 20.5°C.
,, 5 ,,	26 0 ,,	Average 20.7°C.
,, 6 ,,	32.5 ,,	
,, 7 ,,	38.5 ,,	
,, 8 ,,	44.0 ,,	

From the calibration graph (specific for filter aid used) read the volumes of pure syrup filtered at 20.7 °C.

Thus 6 min.—131 ml.; 7 min.—157 ml.; 8 min.—183 ml. The percentage rates of the impure syrup are calculated and averaged.

6 min.	7 min.	8 min.
$\frac{32.5}{131} \times \frac{100}{1} = 24.8\%$	$\frac{38.5}{157} \times \frac{100}{1} = 24.5\%$	$\frac{44.0}{183} \times \frac{100}{1} = 24.0\%$

Average Filterability 24.4%.

7. *Working Check of Filter Disc.*

This may be carried out to check the performance of the filter.

Prepare about 500 gm. of approximately 60° Bx. syrup refined sugar and filtered water.

Add $2\frac{1}{2}\%$ Super-Cel on Brix and filter on a wide Buchner funnel. Adjust filtrate to 60°Bx.±0.1°. Add standard Super-Cel—0.5% on solids as described in Section 3. Add buffer—1.4 ml. per 500 gm. of syrup. Filter as described in section 5.

The volumes filtered should agree within 6% of the original calibration.

8. *Preparation of Triethanolamine Buffer.*

Triethanolamine	40 gm.
Calcium acetate	1.5 gm.

Make up to 100 ml. with 50% *w/w* glycerol.

Method:—Dissolve the calcium acetate by heating with some of the 50% glycerol. Weigh the triethanolamine separately. Transfer each to the 100 ml. flask, washing in and making up to volume, after cooling, with more of the 50% glycerol solution.

9. *Special Precautions.*

(a) Mix the sample of sugar thoroughly before weighing out the quantity required for the test.

(b) Carry out all tests on syrups prepared on the day of the test.

(c) Filter immediately after stirring in the buffer. Make sure that the syrup and filter are near room temperature all the time. Avoid conditions which would cause temperature changes in the syrup during filtration, e.g., do not prepare the syrups or filter near ovens, muffles or in direct sunlight or draughts.

(d) Do not wash the filter with hot water between runs ; handle the beakers and filter as little as possible during a test.

(e) Keep filter and gaskets clean.

(f) Protect mating surfaces of filter disc and retaining ring from injury.

(g) Check for gas leaks.

SUMMARY

A new test filter has been designed with the object of facilitating the routine esting of raw sugars. The filter is operated at ambient temperatures and equires no thermostatic or stirring devices. Further simplification has been chieved by the use of filter paper, and of a buffer to obtain the required pH. as pressure for actuating the filter from cylinders of nitrogen, oxygen or ompressed air has resulted in a high degree of portability.

The filter is also convenient to use for research work as it requires only mall samples of sugar and allows easy collection of the filter cake for analysis.

The reproducibility of results for one operator is of the order of 10% Difference between duplicates over average of duplicates times 100). For a umber of operators working at speed we have tentatively allowed a 15% ifference between duplicates. Duplicate determinations on a stable material uch as a carbonatated liquor agree within 5% or better.

Two operators supplied with the necessary stirring equipment etc. are able o carry out from 20 to 25 determinations in 6 working hours. During the 1954 rushing season three filters were in almost constant use in the Research epartment when well over 2000 determinations were made.

DISCUSSION

Mr. Venkatiah enquired if the sparkler filter had been tried. Mr. Davis replied that parkler filter was an industrial filter ; that discussed in the paper was a laboratory filter for orking under controlled conditions.

Mr. B. C. Joshi then presented the following paper.

Paper

SUGAR YIELDING PALMS AS A POTENTIAL SOURCE OF SUGAR SUPPLY

B. C. JOSHI AND N. GOPINATHAN
Bhartiya Tad Gud Shilpa Bhawan, Dahanu

At present the two main sources of sugar supply in the world are the sugarcane nd the beet. Both these are extensively cultivated in different countries nd it is estimated that together they produce about 40 to 42 million metric tons f sugar annually. With the increasing consumption of sugar as an article f diet and the new avenues that are being opened by modern scientific research or its use as a source for other useful products, it is expected that the demand or sugar will shoot up considerably in the very near future. This will necessitate ither a marked increase in the present acreage of sugarcane and beet or to ap alternative sources of sugar supply. It is well known that both sugarcane nd beet require fertile lands for growth with plenty of irrigation and heavy manuring. Under the present circumstances, when the human population is rapidly increasing all over the world, it may become impracticable to bring under plough more fertile lands for the cultivation of sugarcane or beet. On the other hand, due to the impact of this over population-rightly called the 'O' Bomb—it may become imperative in due course to release a part of the land already locked up under cane or beet cultivation for the production of essential food-crops.

SUGAR YIELDING PALMS

There are about 1100 known species of palms distributed among 131 genera. The palm belt as shown in the following map extends roughly from 45° S Lat. to 45° N Lat.

Palms are essentially tropical and partly sub-tropical plants capable of growing on waste lands without any apparent manuring or irrigation.

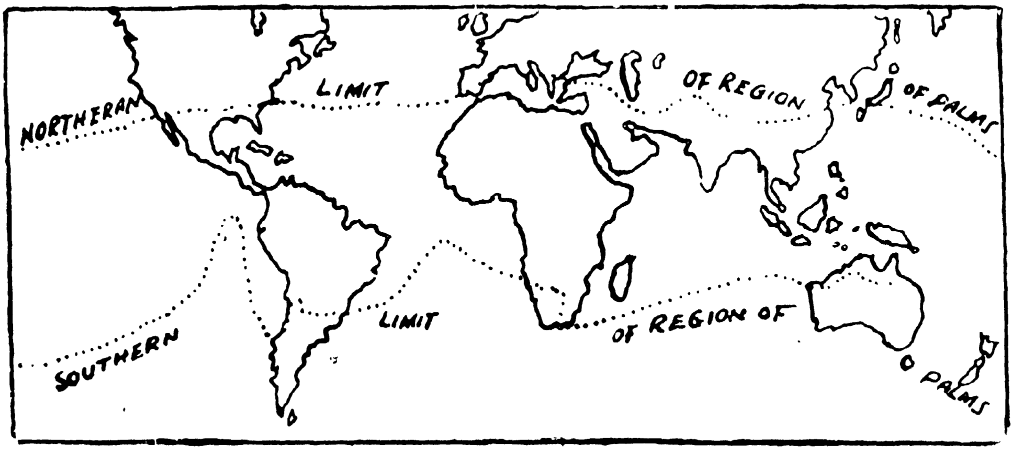


Table I gives the genera of sugar yielding palms along with the particular species found in India :—

TABLE I

Tribe I—Coryphinoe
1. *Phoeniceoe*
(i) Phoenix
2. *Sabaleoe*
(i) Trachycarpus
(ii) Corypha
Tribe II—Borassinoe
3. *Borasseoe*
(i) Borassus
Tribe III—Ceroxylinoe
4. *Arenicaoe*
(i) Caryota
(ii) Arenga
(iii) Areca
5. *Cocoineoe*
(i) Cocos
Tribe IV
6. *Phytelephantinoe*
(i) Nipa

The importance of the above palms is clearly indicated from the figures given in Table II below :—

TABLE II

	Date (Phoenix Sylvestris)	Palmyra (Borassus Flabilliformis)	Coconut (Cocos nucifera)	Sago (Caryota urens)
1. Life of the tree (years)	50 to 60	90 to 120	60 to 80	35 to 45
2. Commencement of tapping from	8th year	15th year	8th year	10th year
3. Tappable part of the tree.	Crown base	Spadix or fruit	Spadix	Spadix
4. Tapping season	Oct. to May	Jan. to July	Throughout the year	
5. Overall tapping period of a tree (years)	25 to 40	70 to 95	25 to 35	15 to 20
6. Tapping period in a season (months)	4 to 6	Male-2 Female-4 to 6	4	6
7. Average yield of juice per tree per day	5 lbs.	6 lbs.	4 lbs.	20 lbs.
8. Seasonal yield of gur per tree Max.	50 lbs.	150 lbs.	80 lbs.	400 lbs.
Min.	15 lbs.	40 lbs.	60 lbs.	200 lbs.
9. Average sucrose % in juice	10	12	14	10
10. No. of trees tapped by one tapper per day Max.	40	80	30	10
Min.	20	10	10	5
11. No. of trees grown in one acre	500	500	80	100
12. Mode of tapping	One day's tapping followed by three days' rest	Twice a day	Twice or thrice a day	Twice or thrice a day

Tables III and IV give an idea of the yield of sugar from palms as compared with sugarcane :—

TABLE III

	Average yield per acre in terms of gur	Average cost of cultivation for gur per acre
Sugar cane ...	3550 lbs.	Rs. 350/-to 400/-
Palm ...	6160 lbs.	Almost Nil

TABLE IV

			Yield of gur
1.	Coconut palm	...	12 to 18% on weight of juice
2.	Date palm	...	10 to 15% -do-
3.	Palmyra palm	...	10 to 16% -do-
4.	Sago palm	...	8 to 11% -do-
5.	Sugar cane	...	18 to 20% -do-

At present, as per statistics, about 36 lakhs acres of good fertile land is under sugarcane cultivation in India. Sixty five percent of this crop, grown in about 23 lakhs acres goes for the manufacture of 3 to 4 million tons of cane gur (raw sugar) per year. The only alternative, therefore, to save fertile land and prevent national waste is the utilisation of the untapped wealth of palms.

PALM GUR (RAW SUGAR) INDUSTRY IN INDIA

The manufacture of gur (unrefined form of sugar) is an age old industry in India. The sap of the palm furnished the material for sweetening purposes, but the beginning of the knowledge of the palm as a sugar producer lies hidden in the unrecorded files of antiquity. Mr. Noel Paton in his notes on "Sugar in India (1911)" gives an estimate of palm gur produced in India as 4 lakhs and 80 thousand tons forming about 17% of the then total production of sugar. The Industry was mainly confined to the provinces of Bengal, Madras and the States of Travancore-Cochin and there is every reason to believe from available informations that it was a flourishing industry in those parts during the 17th 18th and the earlier days of the 19th century.

The first industrialisation of sugar in India was associated with the palm sugar and it was in 1837 that the first sugar factory was started by Mr. Blake at Dhobah near Burdwan.

This was soon followed by two more factories. These factories were sugar refineries making use of palm gur purchased from the local markets. By this time two other refineries sprang up in Madras province also. But the history of these refineries is a very short one as they could not flourish due to factors like equalisation of duties, free-trade policy, increasing cost of labour etc. The upheavels in the refining industry however, surprisingly did not much affect the indigenous palm gur industry, and it survived in spite of lack of proper encouragement and help from the Government.

RECENT GROWTH AND DEVELOPMENT OF THE INDUSTRY

With the advent of freedom and the formation of a National Government in the country, the once neglected palm gur and sugar industry soon found its rightful place in the national development schemes. The avowed Government policy of prohibition created the enormous problem of rehabilitating the thousands of ex-toddy tappers thrown out of employment and this gave a new impetus to the development of the industry. A Palm Gur Section was attached to the Central

Ministry of Food and Agriculture with a Palm Gur Adviser to the Government of India as its head in 1947; since then, the development of the industry was spectacular. A Central Palm Gur Training School was started for conducting research work and imparting training in the art of tapping palm trees and manufacturing superior quality gur and sugar on cottage industry scale. Within a few years time, besides reorganising the industry, which was already existing in some of the States, it was introduced as a new experiment in most of the remaining states. Today the section and the school are working under the All India Khadi & Village Industries Board under the Central Ministry of Production. The Palm Gur Development Scheme is now operative in 17 States in the Indian Union.

THE TECHNIQUE OF GUR AND SUGAR MANUFACTURE

The gur and sugar manufacture from palms is practised essentially as a village industry in India.

The wide and irregular distribution of palms throughout the country and the impossibility of pooling large quantities of juice at a central place for utilisation in the mills have made it essentially a decentralised industry.

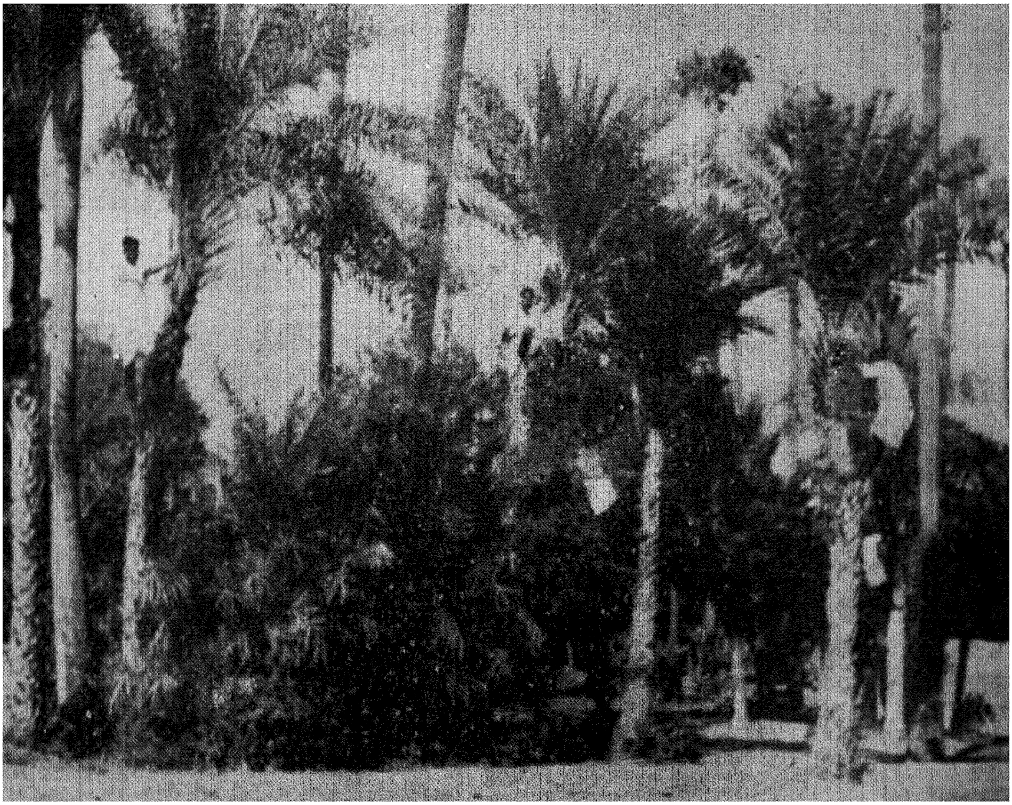


Fig. 1. Tapping of date palms.

(*a*) *Tapping of palms* :—The art of collecting juice from palm trees through slicing the trunk or the inflorescence is called "tapping." It is generally done by means of incision cuts or slicing the respective parts of the palm tree. In the case of coconut, palmyra and the sago palms, juice is extracted from the spathes forming the inflorescence. The date palm trees are tapped through cuts or incision at the tender topmost part of the tree just below the crown of the leaves.

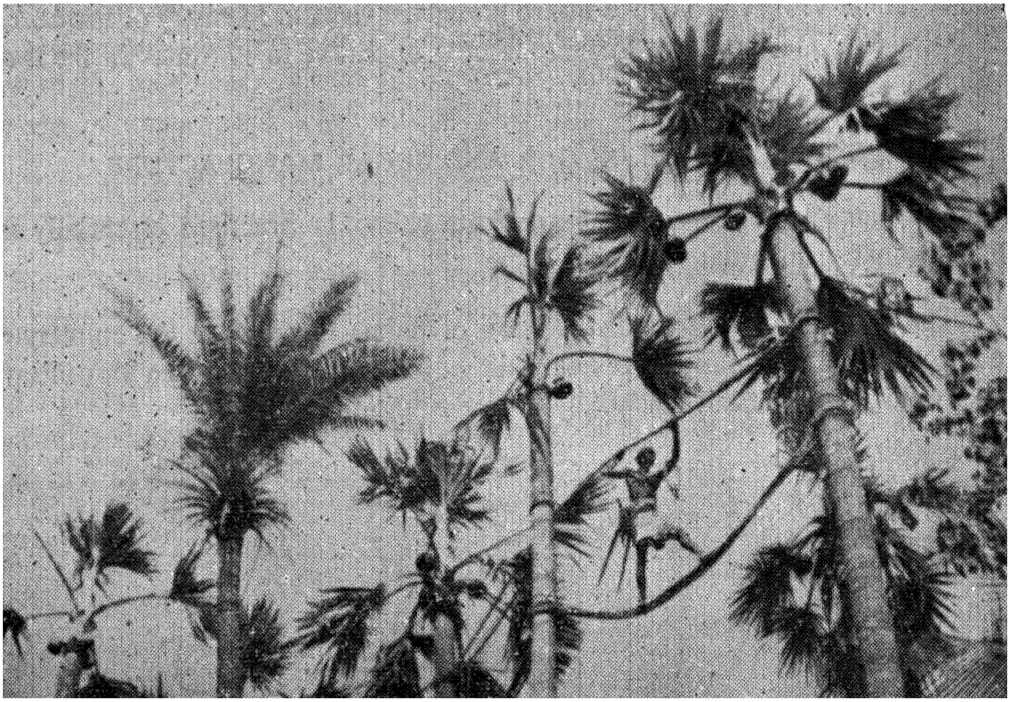


Fig. 2. Aerial rope ways for tapping palmyra palm.

The present day tapping methods as practised by the tappers are the results of their long experience and knowledge. Though quite scientific in technique, tapping remains as a very hard and laborious operation especially due to the hazardous climbing process required to reach the tree top.

(*b*) *Nature and composition of palm juices*:—The sweet juice obtained by tapping any sugar-yielding palm is called 'neera.' It is a transparent liquid with a sweet taste and pleasant flavour. When freshly drawn from the tree, it is almost neutral and water-like ; but exposure to the atmosphere makes it easily susceptible to the action of micro-organisms which ferment it to form the intoxicant beverage toddy with an acidic reaction and a foul smell. For the preparation of gur and sugar it is of vital importance that the juice must be preserved fresh by

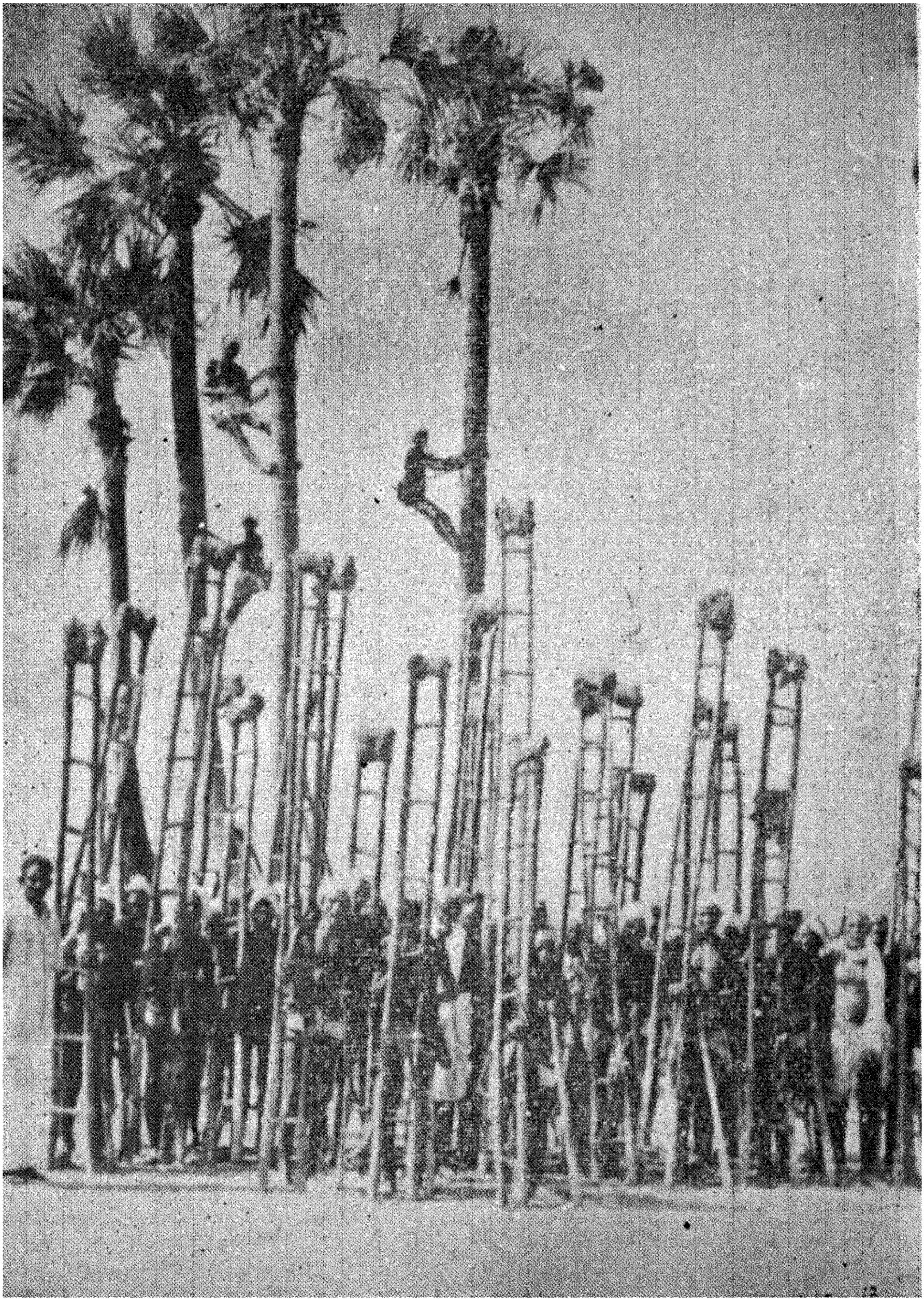


Fig. 3. A group of palm tappers.

the addition of a proper preservative. Lime has been and is still being used universally for this purpose. The addition of lime prevents the fermentation of the juice by imparting to it a strong alkaline reaction which inhibits the action of

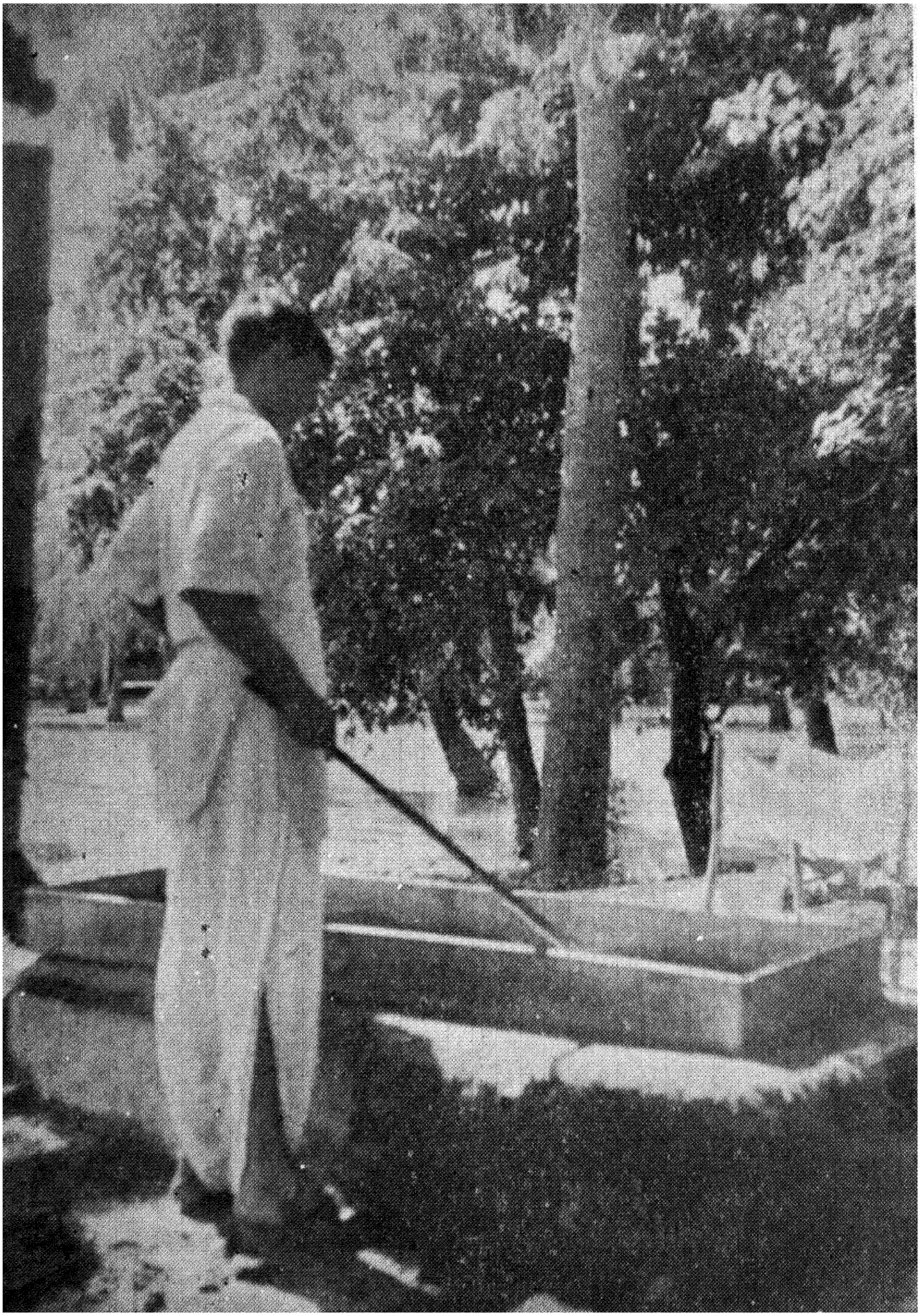


Fig. 4. Boiling of palm juice.

yeast and other micro-organisms. The juice so collected is rich in sucrose content and its importance as an invaluable source of sugar may be gauged from the following typical analytical data collected at our research laboratory.

TABLE V

	Palmyra Juice	Coconut Juice	Date palm Juice	Sago palm Juice
Solids as Brix %	13.5	18.7	14.6	10.9
Pol %	11.8	15.9	12.2	9.7
Purity	87.4	85.0	83.6	89.0
Sucrose	11.7	15.8	12.0	9.7
Reducing Sugars %	0.2	0.5	0.3	0.1
Pectins and gums %	0.2	0.3	0.1	0.03
Ash %	0.3	0.5	0.6	0.3

(*c*) *Process of gur and sugar manufacture* :—For the manufacture of gur and sugar, the juice collected from a number of trees is pooled at a central place, clarified and boiled directly into gur or 'rab' (massecuite) as the case may be by open pan boiling methods. The clarification is effected by first straining the juice through wire-mesh to remove the suspended foreign matters and then deliming in hot using phosphoric acid or triple superphosphate solution. The tricalcium phosphate precipitate so formed along with other impurities is removed by either settling and decantation or direct filtration through a drill-cloth or a hand-operated filter press. A very simple and efficient method of clarification standardised recently gave very promising results. The purity rise is as follows :—

TABLE VI

	(Limed) raw juice				Clarified juice					
	Brix %	Pol %	Purity	Red. Sugar	Brix %	Pol %	Purity	Red. Sugar	Mud %	Pol% Mud
Sample I	11.7	9.2	78.6	0.39	13.2	11.0	83.3	0.40	6.0	5.8
,, II	13.3	10.6	79.7	0.25	13.7	11.4	83.2	0.30	7.5	6.3

The clarified juice is directly boiled into gur or rab. The boiling is carried out in open rectangular G.I. pans or in aluminium pans of 22 gauge and size 6′ x 2′ x 8″. A very economical furnace called 'Kifayat Bhatti' recently introduced gives a fuel consumption of 30 to 35% light fuel on juice weight for gur boiling. Another better and more economical furnace using aluminium pans introduced recently and known as the 'Mufeed Bhatti' consumes 25 to 28% fuel only. In the case of gur, strike point reaches at about 118° to 120°C. and rab at about 112°C. Gur is moulded into desired shapes according to requirement and the rab is transferred into small crystallisers for further crystallisation. The sugar is separated by using hand driven centrifugal machines.

(*d*) *Composition of palm gur and sugar*:—The composition of the different varieties of palm gurs is given in the following Table:—

TABLE VII

	Palmyra gur	Date palm gur	Coconut gur	Sago palm gur
Pol %	77.2	68.8	79.6	82.2
Sucrose %	76.0	69.7	79.4	81.2
Reducing Sugar %	4.0	8.1	2.6	0.8
Moisture %	10.5	9.9	8.7	11.2
Ash %	3.6	—	4.1	3.4

Nutritional analysis of palm gur as analysed by the Director, Nutritional Research Laboratories, Coonoor, is as follows:—

Moisture %	8.14
Protein %	0.35
Fat %	0.17
Minerals %	0.74
Carbo-hydrates %	90.60
Calcium %	0.06
Phosphorus (P) %	0.06
Iron (Fe) (mgms. per 100 gms.)	2.50
Calorific value per 100 gms.	365
Nicotinic Acid mgms./100 gms.	5.24
Vitamin B_1 mgms./100 gms.	21
Riboflavin ,,	432
Vitamin C ,,	11

ANALYSIS OF PALM SUGAR (CENTRAL PALM GUR TRAINING SCHOOL, CUDDALORE)

	1st sugar	2nd sugar
Sucrose %	98.7	96.2
Reducing Sugar %	0.1	0.6
Moisture %	0.05	0.09
Ash %	0.16	0.20

POTENTIALITIES OF DEVELOPMENT FOR THE PALM SUGAR INDUSTRY IN INDIA AND ABROAD

According to the recent estimates the total palm population of the Indian Union is over 19 crores. Of these, at least 7 crores may be considered tappable. It is expected that these seven crores of trees, if tapped properly, will produce about 2 million tons of palm jaggery and this 2 million tons of palm jaggery will release 14 lakhs acres of fertile land at present devoted to sugarcane cultivation.

The present stage of development and the potentialities of the industry are shown below :—

		Present stage (1952)	Potentialities on 7 crores palms population basis
(a)	Annual gur production ...	59,104 tons	20,00,000 Tons
(b)	Total seasonal employment :		
	(i) Direct beneficiaries (tappers) ...	1,50,000	26,00,000
	(ii) Indirect beneficiaries (auxilary rural artisan)		
	(1) Pan boilers ...	75,000	5,60,000
	(2) Potters and brick layers ...	5,000	1,40,000
	(3) Smiths and others ...	5,000	1,05,000
(c)	Relaxation of pressure on fertile land ...	33,100 acres	14,00,000 acres

In addition to the above, well planned schemes of planting more palms, throughout the country utilising all possible waste lands are under way. And in fact lakhs of palms have already been planted in selected areas . These palms when matured will serve as a steady source of our future sugar supply.

What has been said about India is also true of the other palm growing countries of the world. Palms are known to grow in abundance in Burma, Indo-China, Siam, Malaya, Indonesia, different parts of Africa, South America and Mexico. In Chile (South America) these palms are tapped for the manufacture of palm syrups. In Ceylon, Burma, Cambodia and parts of Philippines sugar making from palm juices is a very old industry. With the rapidly increasing population of the world the need for producing more and more food crops is being keenly felt every where. Before it is too late, well thought out plans to curtail the use of fertile lands for raising cash crops shall have to be chalked out and this will bring the uncared for, the unmanured palm trees growing wild all over the world into due importance. Moreover extensive and large scale plantations of sugar yielding palms will have to be undertaken and this will probably be only a matter of time.

SUGAR FROM PALMS, A NEW EXPERIMENT IN DECENTRALISING INDUSTRY

The history of the palm sugar industry in India as discussed above shows that in spite of the attempts to centralise it in the past, the industry has remained essentially a village industry throughout. There are certain inherent difficulties in centralising it and these may also probably be real blessings in disguise. For, in this age of heavy mechanisation increase in production has no meaning unless there is increase in purchasing power. This requires adequate employment.

Only a decentralised industry can assure job for a surplus population. But to survive competition with centralised industry requires great efficiency. This is what is required in particular for the palm sugar industry. It is a challenge to the modern science to devise ways and means and adopt its immense resources to suit a decentralised economy with a high degree of efficiency. There are a number of problems facing the industry, but these have to be solved with all patience and perseverence.

There are bound to be difficulties and disappointments in the initial stages as there had always been in the case of the cane and beet sugar industries which were once heavily subsidised by Governments. It may be recognised that India is the first country to realise on a national level the so far dormant potentialities of the palms as 'tube wells' of sugar supply. She has launched on a great experiment and it may well inspire other palm growing countries of the world, to follow suit and make real "wealth from waste."

REFERENCES

1. Gajanan Naik. 1949. "Palm Gur." Published by the All India Village Industries Association, Wardha.
2. "Tad Gur Parichaya." Published by the Palm Gur Section, All India Khadi and Village Industries Board, Bombay.
3. Joshi, B.C. 1952. "Development of Palm Gur Industry in India." *Proc. of* 21*st Conv. of the Sug. Tech. Assoc.*, India, p. 90-103.
4. Joshi, B.C. 1954. "Tapping of Palms and Composition of Palm Juices." *Proc. of* 11*th Conv. of the Deccan Sug. Tech. Assoc.*, p. 164-174.
5. Blatter. 1926. "Palms of British India and Ceylon."

DISCUSSION

In reply to a question Dr. Doss said that he did not think that a considerable part of the demand for sugar would be met with by tapping the palms. He added that Mr. Joshi was trying his best to make that a possibility, and if one succeeds in (a) tapping the palms continuously, (b) avoiding microbial action and (c) growing dwarfed palms having the same growth qualities as natural palms, palm sugar might become a competitor to cane.

In the absence of the authors the following paper was taken as read.

STUDIES ON THE SURFACE AREAS AND THE REFINING QUALITIES OF CHARS

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and

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Refining a sugar solution with Darco S-51 rapidly destroys the surface area of the char ; but in the decolourization of a final molasses solution with an A-service char the surface area of a bonechar was not affected even after three successive treatments with fresh molasses solutions.

Vegetable carbons adsorb more colour from a raw sugar solution than a bonechar. Avot (1) reported that in some cases the adsorption of colour by the former may be more than one hundred times the colour adsorbed by the latter. The active decolourizing principle of a bonechar is carbon (2), which forms about 10 percent by weight of the char. But in a vegetable carbon, where the element carbon may be present to the extent of about 90 percent, the decolourizing power is not dependent upon its carbon content (3). For example, the decolourizing power of a vegetable carbon without any activation is inferior to that of a bonechar. Thus, the carbon content of the two chars fails to explain the difference in their decolourizing powers. Adsorption being a surface phenomenon, it is probable that this difference arises mainly from a difference in their specific surface areas.

The work of Horton and Sengson (4) showed that, weight for weight, a bonechar and Norit adsorb almost the same percentage of ash from a sugar solution of 15° Brix or higher. Blowski and Bon (5) found that some vegetable carbons are better ash adsorbers than a bonechar. The ash removal property of a bonechar is attributed to its mineral constituents which comprise about 90 percent of its weight. Vegetable carbons contain only about 5 percent mineral matters. Therefore, the equal or higher ash removal property of the vegetable carbons may be due, in part, to their higher specific surface area compared to that of a bonechar.

Unlike a bonechar, vegetable carbons are not efficiently regenerated by a simple heat treatment. This may suggest that the usual refining operations of a raw sugar solution do not affect the surface area of the two adsorbents in the same way. This was investigated in the present work by the following analytical procedures recommended by the Tenth Session of the International Commission for Uniform Methods of Sugar Analysis (1949), and by making the experimental conditions simulate the factory practice as far as possible. However, the bonechar used in this work produced a "blue" colouration with a raw sugar solution ; and comparative effects of refining a raw sugar on the surface areas of a vegetable carbon and a bonechar were not available. Studies were made on the effects of refining a raw sugar solution with Darco S-51 and a final molasses solution with an A-service char.

PROCEDURE

A turbinado sugar solution of 60° Brix was used to study the decolourizing power of Darco S-51. The carbon was thoroughly washed with distilled water and dried. A weighed quantity of sugar was dissolved in a measured volume of distilled water and was heated to the required temperature in a water-bath. After the desired amount of Darco was added to the solution, it was stirred at intervals of every five minutes; and, at the end of the required period of treatment, it was filtered through a thick layer of Dicalite.

In the filtration of the raw and refined solutions, Reeve Angel No. 202 filter papers were arranged one by one on the base of a Buchner funnel covering the circular base of the funnel. Dicalite Speedex filteraid was stirred with hot distilled water and was poured on the funnel applying a suction. Sufficient Dicalite was used to form a layer of about half-inch thickness. Boiled distilled water was repeatedly passed through this layer to wash out any soluble salts which might be present in the filteraid. A small amount of the sugar solution was poured into the funnel under suction, and the water enmeshed in the layer of Dicalite was thus displaced. This was repeated thrice, and the filtrates were rejected before the final filtrate was collected for the tests.

The bonechar used in this work was an A-service char purchased from a refinery in Louisiana. It was screened into six different parts and the nitrogen adsorption surface area of each was measured. The decolourizing powei of this char was studied on a final molasses solution with only three different fractions. A Louisiana final molasses was diluted with cold distilled water and filtered through Dicalite Speedex. Procedures for decolourizing and filtering were the same as those described under the experimental conditions with Darco.

The ash content of a solution was determined by the Double Sulphitation method, as recommended by the Tenth Session of the International Commission for Uniform Methods of Sugar Analysis. A measured volume of the solution, containing about 5 to 10 grams of solids, was pipetted into a platinum dish and evaporated by infra-red rays. The total solids content of this measured volume of solution was estimated using Plato's tables and refractometric solids. A Bausch and Lomb Precision Sugar Refractometer was used to determine the latter. The deduction of 10 percent ash was omitted, and the term "gravimetric ash" was substituted for "sulphated ash."

Invert sugar was determined by Kraisy's method. In all cases the total invert sugar was calculated using the factor 0.435 mgm. invert sugar per milligram of copper. The total solids corresponding to an estimated amount of invert sugar were found from Plato's tables and refractometric solids.

The colour of solution was determined by measuring its transmittancy and calculating its adsorbency index, as recommended by the Tenth Session of the International Commission for Uniform Methods of Sugar Analysis. Using a pH of 7 in all cases, the transmittancies at a few selected wave lengths were measured in the visible spectrum. A Coleman Model 11 Universal spectrophotometer was used, and all measurements employed the null method which allows a precision of about 0.5 percent. Distilled water was adopted as the reference sample. The percent colour adsorbed at a particular wave length was calculated from the adsorbency index at this wave length of the raw and refined solutions having the same Brix and pH. When necessary, the Brix was adjusted with a white sugar, and the pH was adjusted with hydrochloric acid and ammonium hydroxide.

The nitrogen adsorption surface area of the adsorbents was measured by the Esso Laboratories, Baton Rouge, Louisiana, using a modified BET method due to Shell.

TABLE I

EFFECTS OF INCREASING AMOUNTS OF DARCO S-51 IN THE REFINING OF RAW CANE SUGAR

Specific surface area of Darco S-51, sq. m./gm. = 550
Percent total solids in solution = 60
Time of treatment, hour = 1
Temperature, °C. = 90

	Raw	Refined Percent	Darco on	Solids
		0.33	0.67	1.50
Percent gravimetric ash on solids	0.129	0.109	0.107	0.103
Percent ash removal on raws		15.50	17.05	20.16
Percent invert sugar on solids	0.064	0.139	0.171	0.200
Percent increase of invert sugar on raws		117.2	167.2	212.5
Percent colour adsorbed at 560 mμ		59.8	81.8	93.7

TABLE II

EFFECTS OF TEMPERATURE IN THE REFINING OF A RAW CANE SUGAR BY DARCO S-51

Specific surface area of Darco S-51, sq. m./gm. = 550
Percent total solids in solution = 60
Percent Darco on total solids = 0.67
Time of treatment, hour = 1

	Raw	Refined Temperature, °C.		
		30	60	90
Percent gravimetric ash on solids	0.129	0.108	0.107	0.107
Percent ash removal on raws		16.28	17.05	17.05
Percent invert sugar on solids	0.064	0.085	0.091	0.171
Percent increase on invert sugar on raws		32.8	42.2	167.2
Percent colour adsorbed at 560 mμ		47.3	74.0	81.8

TABLE III

EFFECTS OF TIME IN THE REFINING OF A RAW CANE SUGAR BY DARCO S-51

Specific surface area of Darco S-51, sq. m./gm. = 550
Percent total solids in solution = 60
Percent Darco on total solids = 0.67
Temperature, °C. = 90

	Raw	Refined Time, hour 1/4	 1	 2
Percent gravimetric ash on solids	0.129	0.107	0.107	0.103
Percent ash removal on raws		17.05	17.05	20.16
Percent invert sugar on solids	0.064	0.110	0.171	0.192
Percent increase of invert sugar on raws		71.9	167.2	200.0
Percent colour adsorbed at 560 mμ		74.4	81.8	85.7

TABLE IV

REFINING QUALITIES OF ONCE-USED DARCO S-51

Percent total solids in solution = 60
Percent Darco on solids = 0.67
Time of each treatment, hour = 1/4
Temperature, °C. = 90

	Raw	Refined Unused Darco	 Once-Used Darco
Percent gravimétric ash on solids	0.129	0.107	0.115
Percent ash removal on raws		17.05	10.85
Percent invert sugar on solids	0.064	0.110	0.081
Percent increase of invert sugar on raws		71.9	26.6
Percent colour adsorbed at 560 mμ		74.4	58.6

TABLE V

REFINING A RAW CANE SUGAR SOLUTION WITH DARCO S-51 ADDED IN STEPS

Specific surface area of Darco S-51, sq. m./gm. — 550
Percent total solids in solution — 60
Percent Darco on solids — 1.50
Total time of treatment, hour — 1
Temperature, °C. — 90

	Refined Solution Darco added in one step	 Darco added in four steps
Percent ash removal on raws	20.16	19.38
Percent increase of invert sugar on raws	212.5	148.4
Percent colour adsorbed at 560 mμ	93.7	91.2

DISCUSSION I. DARCO S-51

Ash and Colour Removal. In the refining of a cane sugar solution with a vegetable carbon like Darco S-51, adsorption does not take place over the entire surface of the carbon. Thus, in Table I, corresponding to 0.33 percent Darco on solids, 550 sq. m. surface area adsorbed only 15.5 percent ash and 59.8 percent colour from a sugar solution containing a total of 0.387 gm. gravimetric ash and 37.8 Peters and Phelps colour units at 560 mμ (6). The results also show that an increase in the amount of Darco does not proportionately increase the amount of ash and colour adsorbed.

A reduction in the amount of Darco from, say, 1.50 percent to 0.67 percent reduces the ash adsorption only slightly (Table I); but the colour adsorption is appreciably affected both in wave length and in quantity (Fig. 1). The smaller the amount of Darco, the lower the percentage of colour adsorbed ; but this loss in colour adsorbed is greater at longer than at shorter wave lengths. Amounts of Darco affect also the wave length at which a maximum adsorption occurs (Fig. 1). An increase in the amount of Darco appears to shift this wave length from the violet to the red end of the spectrum. Thus, with 0.33, 0.67 and 1·50 percent Darco on solids, the maximum adsorption occurred at about 500 mμ (green), 560 mμ (greenish-yellow) and 720 mμ (red), respectively.

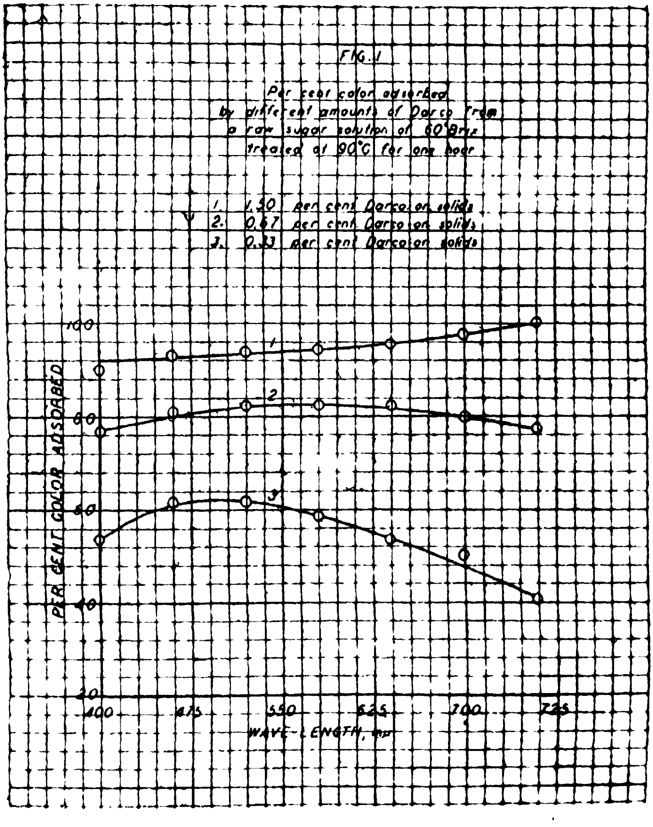

Fig. 1.

Effects of Temperature. An increase in the refining temperature from room temperature to 90°C. was found to increase the adsorption of colour at all wave lengths (Fig. 2) but the ash removal was not affected appreciably (Table II). A decrease in temperature reduces the percentage of colour adsorbed more at longer than at shorter waves (Fig. 2).

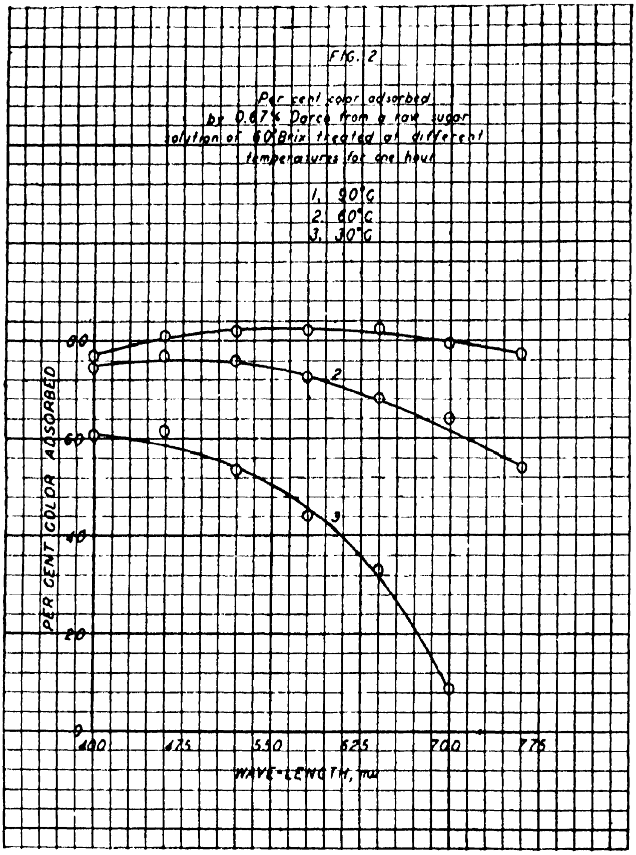

Fig. 2.

Effects of Time. In the refining of a raw sugar with Darco at 90°C., a contact time of 15 minutes is unsatisfactory. During this period, the adsorption of colour approaches an equilibrium only at shorter wave lengths ; but a much longer time is necessary for an equilibrium at longer wave lengths (Fig. 3). Thus, using 0.67 percent Darco, 75.3 and 56.5 percent colours were removed in 15 minutes at 400 mμ and 760 mμ, respectively. But when the time of treatment was increased to two hours, the same amount of Darco adsorbed 80.4 and 92.3 percent colours at 400 mμ and 760 mμ, respectively. An increase in the time of treatment does not increase the ash removal by any appreciable amount (Table III).

A measurement of the nitrogen adsorption surface area of two Darco samples, one treated for 15 minutes with a 60° Brix sugar solution at 90°C. and the other for two hours, showed that both the samples had the same specific surface area, namely, 282 sq. m. per gm. An increase in the time of treatment from 15 minutes to two hours increased the percentage of colour adsorbed from 74.4 to 85.7 at 560 mμ (Fig. 3). Since, however, the ash adsorbtion attains equilibrium within a few minutes, it is probable that the loss of surface area by Darco is mainly due to the mineral matters of the sugar solution, which clog the pores of the carbon and thus reduce the surface area. This should explain why a simple heat treatment fails to regenerate a vegetable carbon satisfactorily, and treatments are necessary with water, acids and alkalies.

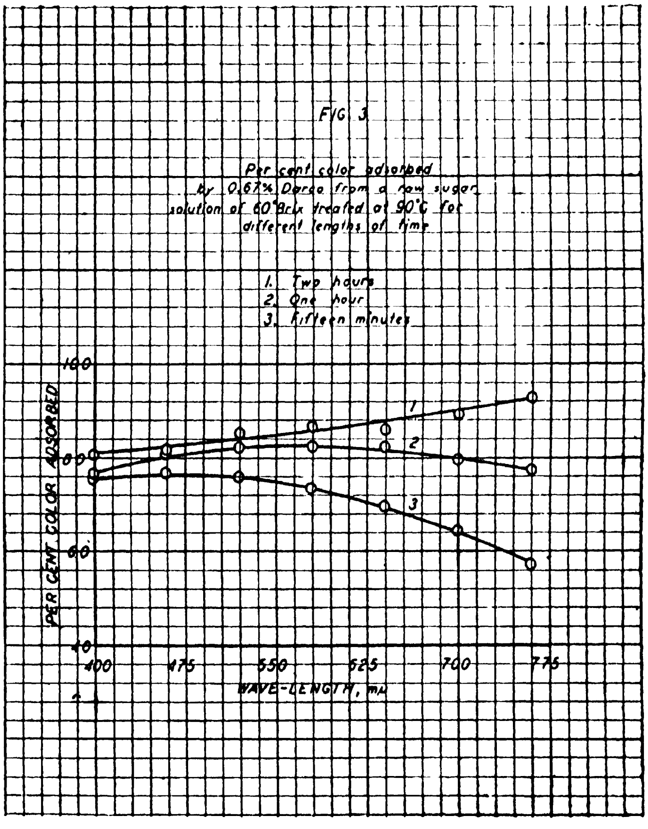

Fig. 3.

Effects on Refining Qualities With Use. Each refining operation markedly affects the surface area of Darco S-51. For example, 0.67 percent Darco on raws adsorbed 17.05 percent ash and 74.4 percent colour at 560 mμ. The same sample of Darco, without any regeneration, adsorbed 10.85 percent ash and 58.6 percent colour at 560 mμ from a fresh sample of the sugar solution. A measurement of the nitrogen adsorption surface area showed that the specific surface area of Darco was reduced from 550 to 282 and then to 167 sq. m. per gm. in the two successive treatments. Thus, Darco lost 48.7 precent of its total area in the first treatment and 37.7 percent in the second treatment.

Effects of Step-wise Addition. Sipyagin and Serkin (7) found that a step-wise addition of vegetable carbons to sugar solutions increased the decolourizing effect from 13.3 to 25.7 percent. In the present work, adding 0.33 percent Darco at every quarter of an hour three times and finally adding 0.50 percent in the last quarter of an hour, it was found that for a total time of one hour treatment the step-wise addition of 1.50 percent Darco does not remove any more colour from a cane sugar solution than the same amount of Darco added all at once. However, the step-wise addition reduced the amount of invert sugar by reducing the period of time during which the amount of Darco and the acidity of the solution were highest (Table V).

Inversion Loss. Tables I-V show that in the refining of a raw sugar by Darco, there is an appreciable inversion loss. Using 0.67 percent Darco and a temperature of 90°C. for 15 minutes, an increase of 71.0 percent invert was observed (Table III). This is explained by the acidic nature of Darco S-51. Inversion losses were smaller with a used Darco (Table IV).

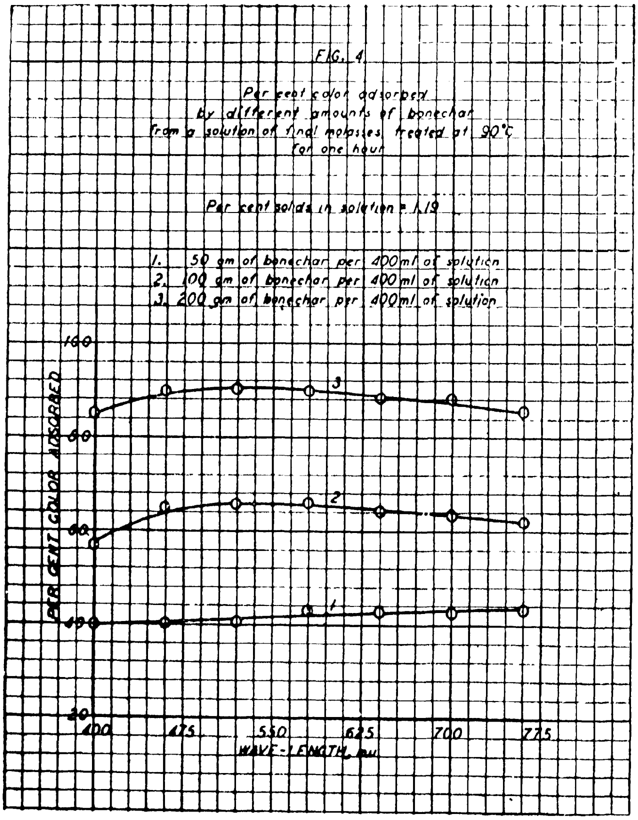

Fig. 4

II. BONECHAR

Surface Area. The specific surface area of an A-service char was found to be 46 sq. m. per gm. Darco S-51 has a specific surface area of 550 sq. m. per gm. This difference in the specific surface area of the two adsorbents partially explains the observations of Horton and Sengson (4) and of Blowski and Bon (5) that vegetable carbons may adsorb as much as an equal weight of bonechar. In the case of a bonechar, the ash adsorption is dependent upon both the surface area and its mineral constituents ; but in the vegetable carbons it depends mainly upon the surface area. A bonechar has more mineral constituents and less specific surface area ; whereas a vegetable carbon has less mineral matters and more specific surface area.

Effects of Time and Temperature. The standard method adopted by the Ninth Session of the International Commission for Uniform Methods of Sugar Analysis on tests for decolourizing powers of chars was that of a one hour contact of the adsorbent at 80°C. Lowy (8) recommended the use of 90°C. and Payne (9) suggested that one hour contact time might be insufficient for an equilibrium.

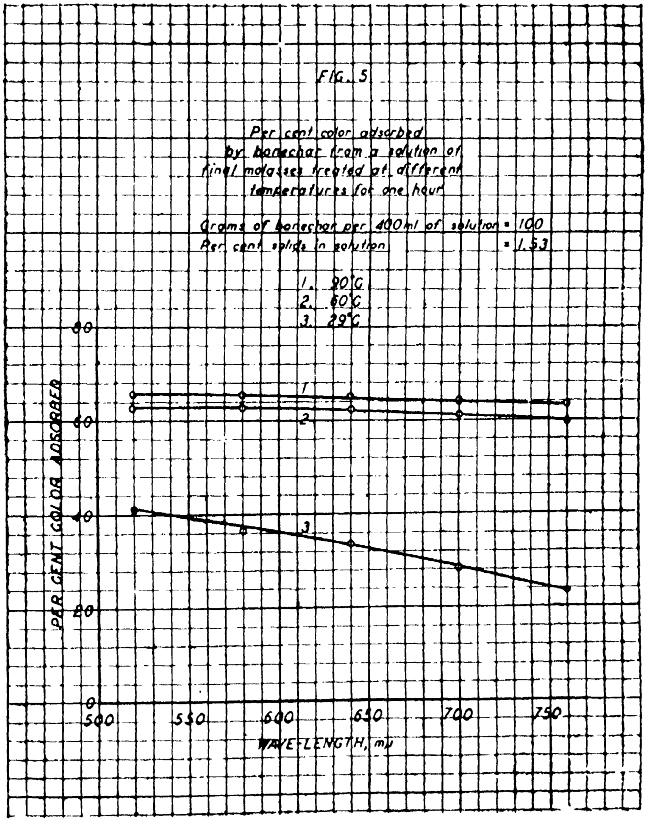

Fig. 5.

Figure 5 shows that in the decolourization of a molasses solution by bonechar using 10-20 mesh particles, not much difference in the adsorption of colour was observed at 60°C. and 90°C. Thus, at 560 mμ the percentage of colour adsorbed by a bonechar at 60°C. and 90°C. were, respectively, 62.7 and 65.5. Comparing, however, the effects of time, an equilibrium on the adsorption of colour was not observed in the decolourization of a molasses solution by a bonechar of 10-20 mesh particles using a temperature of 90°C. and a contact time of two hours. Thus, at 560 mμ and 90°C., the percentages of colour adsorbed by the char during contact periods of one, two and three hours were 65.4, 76.3 and 89.7, respectively (Fig. 6). As with Darco, the reduction of temperature below a certain value affects the colour adsorbing capacity of a bonechar both in wave length and in amount (Fig. 5). The lower the temperature, the greater the reduction in the adsorption of colours at longer waves.

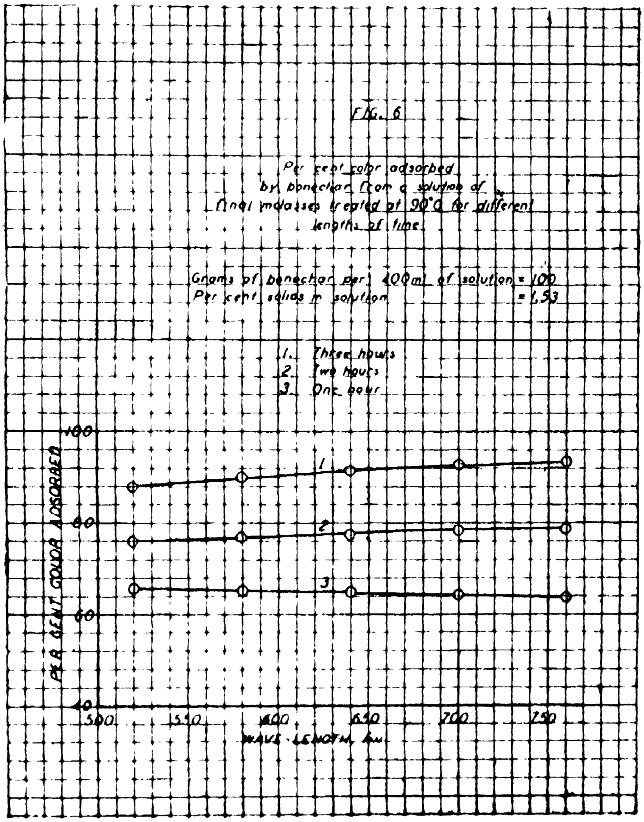

Fig. 6.

Effects of Particle Size. Attritions of a bonechar do not increase its specific surface area appreciably. A measurement of the nitrogen adsorption surface area of an A-service char consisting of particles between 10-20, 28-38, 48-65 and

100-200 mesh sizes as well as of particles passing through a 270 mesh screen gave the same specific surface area, namely, 46 sq. m. per gm. But the larger particles of the bonechar were found to decolourize a molasses solution better than the smaller particles. Thus a bonechar of 10-20 mesh particles adsorbed 66.4 percent colour from a molasses solution at 560 mμ, but the same char consisting of 48-65 mesh particles adsorbed only 29.0 percent colour (Fig. 7). Furthermore,

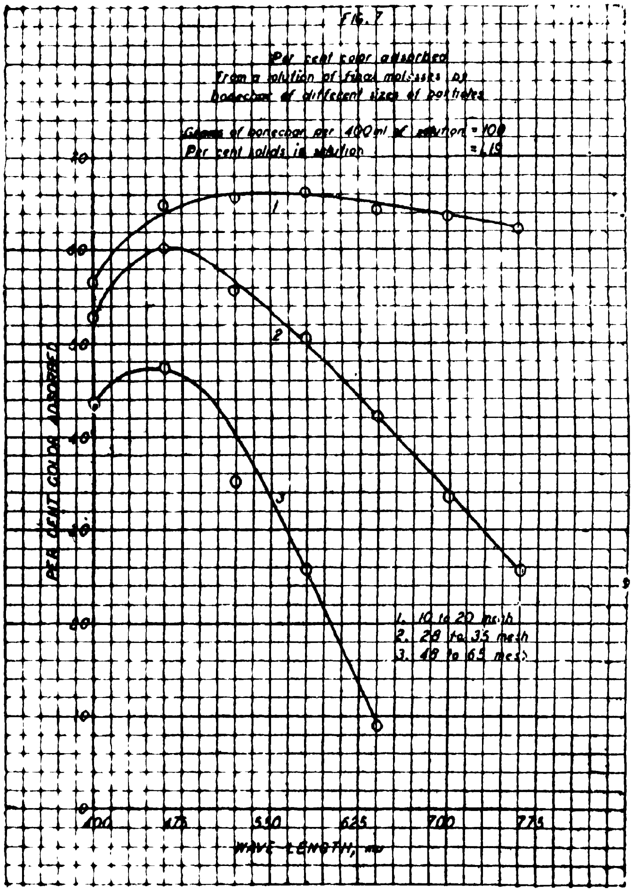

Fig. 7.

the grain size seems to effect the type of colour adsorbed ; that is, the smaller the size of the particles the greater the reduction in the percentage of colour adsorbed at the longer rather than at the shorter waves. The lower percentage of colour adsorbed by the smaller particles of a char is explained by a poor circulation of the solution through the more compact mass of the finer particles and by the creation of a larger number of colloidal particles.

Effects on Refining Qualities With Use. The adsorption of colour and ash from a molasses solution has no marked effect on the surface area of a bonechar.

Thus, when three samples of a final molasses solution, each containing 12,070 Peters and Phelps colour units at 560 mμ and 0.6932 gm. of gravimetric ash, were treated at 90°C. for one hour with 100 gm. of a bonechar having a total surface area of 4,600 sq. m., 95.2, 85.9 and 72.3 percent colour were adsorbed by the bonechar in three successive treatments, without any regeneration. A measurement of the nitrogen adsorption surface area showed that the surface area of the bonechar was unaffected even after the third treatment. Therefore, the adsorbed materials are deposited on the surface of the char without clogging the pores. This contradicts theory that the decolourizing action of a bonechar is due to the entanglement of the large molecules of colloidal colouring matter in the fine cellular structure of the char.

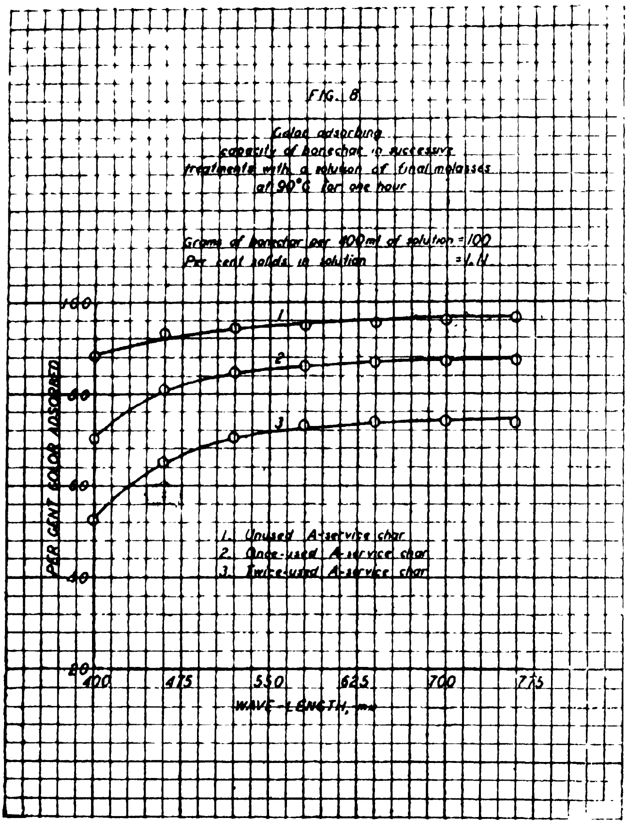

Fig. 8.

Cause of "Blue" Colouration. Harman (10) observed that the cause of turbid liquors of char lies fundamentally with the raw sugar, but the trouble may be aggravated by the condition of the char. The char used in this work imparted a "blue" colouration to a raw cane sugar solution. Following the refinery practice, where this trouble is eliminated by covering the filters of such a char with nearly water-white liquors, the char was treated with a 60° Brix solution of a white sugar at 90°C. for one hour. A colourless solution was obtained on filtration through a layer of Dicalite. It was also observed that this bonechar would decolourize a final molasses solution containing about one percent refractometric solids. A composite "raw" sugar solution 60° Brix was made by dissolving a white sugar in the molasses solution. On treatment of this solution with the char at 90°C., the "blue" colour developed rapidly. This suggests that neither sucrose nor the impurities of a raw sugar solution alone produce the "smoky" liquor of a bonechar refinery. Some constituents of the raw sugar impurities seem to cause this trouble by "peptizing" the colloidal particles of the char in the presence of an excess of sucrose.

SUMMARY

The specific surface area of Darco S-51 is about twelve times that of an A-service char. Each refining operation of a sugar solution rapidly destroys the surface area of Darco, but in three successive decolourizing operations of a molasses solution with a bonechar no appreciable effect was observed on its surface area.

At a certain optimum temperature, the decolourization of a raw cane sugar solution by Darco and that of a molasses solution by bonechar removes about the same percentage of colour at all waves of the visible spectrum. Below this value, a greater percentage of violet than red is adsorbed. Darco behaves similarly with respect to the time of treatment and to the amount.

Attrition of a bonechar does not create any measureable surface area. Finer particles of a bonechar adsorb less colour than the larger particles, the reduction being greater at longer than at shorter waves.

ACKNOWLEDGMENT

Grateful thanks are due to the Engineering Experiment Station of the Louisiana State University and to Sir Dorabji Tata Trust for grants and to Esso Laboratories, Baton Rouge, for measuring the nitrogen adsorption surface area of the adsorbents.

REFERENCES

1. Avote, G. 1923. Intern. Sugar J., 25, 196-8.
2. Horton, P.M. 1923. Ind. Eng. Chem., 15, 519-20.
3. Bradley, A.B. 1921 Intern. Sugar J., 23, 25-32.
4. Horton, P.M. and Sengson, P.T. 1924. Ind. Eng. Chem., 16, 165-7.
5. Blowski, A.A. and Bon, J.H. 1926. Ind. Eng. Chem., 18, 32-42.
6. Peters, H.H. and Phelps F.P. 1927. Bur. Standards Tech. Paper, 338.
7. Sipyagin, A.S. and Serkin, E.S. 1929. Trans. Central Sci. Research Inst. Sugar Ind. (U.S.S.R.) No. 3, 39-42.

8. Lowy, K. 1949. Report of the Proceedings of the Tenth Session of the International Commission of Uniform Methods of Sugar Analysis, Brussels, 12.
9. Payne, G. 1949. Ibid., 13.
10. Harman, R.W. 1935. Intern. Sugar J., 37, 471-3.

DISCUSSION

Dr. Doss remarked that the ash adsorbing power of vegetable carbon is a very interesting feature. Normally we would not expect carbon to adsorb much of simple ions. The mechanism is perhaps the same as happens with bauxite. Earlier work at my Institute (Doss and Jain) has shown that the positively charged bauxite can adsorb Ca^{++} only in presence of a polyvalent anion like phosphate. The latter when taken up by bauxite acts as a centre for adsorbing cations such as Ca^{++}. Similarly in the present case, some amphiphatic anions in sugar solutions are getting adsorbed on charcoal by the attraction between the hydrophobic group of the anion and the carbon atoms charcoal ; this adsorbed anion acts as a centre for adsorbing cations such as Ca^{++}. This explains the extraordinary behaviour that increase of Darco from 0.67% to 1.5% increases the ash adsorption only slightly ; once the anions helping adsorption are removed completely by the 1st lot of carbon, the remaining mineral constituents cannot get adsorbed in carbon.

Mr. F.H.C. Kelly presented the following paper.

Paper

MELASSEGENESIS

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INTRODUCTION

The purpose of this paper is to examine theories of melassegenesis and to discuss their relationship to observations of samples of "synthetic molasses."

The term melassegenesis is used to refer to processes bringing about the formation of molasses in the manufacture of sugar. The combination of the two portions of the word as a mixture of etymons is considered justified on grounds of comparative philology (cf. "television") and is euphonious. Some latitude might be considered in the spelling of the first portion in that "melassi" has been adopted by Geerligs (1) when describing the "melassegenic power of substances." The Oxford dictionary however describes "melasses" as an obsolete form of the word molasses, and it may be difficult to justify perpetuating the obsolete form in the combined word. The spelling adopted here follows fairly recent usage of the word "Melassegenic" by Van Hook (2) and in the opinion of experimental groups of people the author has found it to have advantages from the point of view of euphony.

Molasses is a material common to the refinery worker, the raw cane sugar manufacturer or the producer of beet sugar. The composition varies over a wide range not only from one type of material to another, but also from place to place and season to season within any single type. The fact that it varies significantly with growing conditions has been well recognised within the industries themselves, but difficulties experienced in specifying exactly the complete range of factors contributing to growing conditions have appeared to exercise a far greater influence on the quantity of sugar leaving the factory in molasses than any chemical or mechanical factor under the control of the sugar mill operator.

Some workers (1, 3, 4, 5) have endeavoured to apply the observations made on simple two or three-component systems to the complex multi-component system which constitutes factory molasses whilst others (6, 7, 8) have endeavoured to analyse statistically the compositions of molasses and relate purity values to the more readily determined constituents such as reducing sugar and ash.

Recently experiments have been conducted in the Chemistry Department of the University of Tasmania, Australia, which included study of the influence of various substances on the solubility of sucrose and also on its ability to crystallise. Whilst these systems have not reached the multi-component complexity of a sugar cane molasses, up to five components in a system have been studied in association with natural molasses (9). Several four-component systems have also been studied (10) as well as supporting and allied three-component systems (3). Also the author has described conditions under which very small amounts of amino acids (particularly aspartic acid and tyrosine) can exercise a controlling influence on the crystallisation of sucrose when they themselves reach saturation (12), particularly as fifth or sixth-component in complex systems.

Micheli and de Gyulay (13) discounted the possibility of obtaining useful information regarding the limitation of sucrose crystallisation in molasses from a phase rule approach, suggesting that under factory conditions sufficient time is not available for the molasses and crystal in a low grade massecuite to reach equilibrium at the end of cooling in the crystallisers. In the author's experience such conditions have been observed in factory practice, but observations have also been made when crystallisation had been completed under factory conditions and no further crystallisation could be obtained (14). Even with both of these conditions observed in practice, it is possible to discuss theories of melassegenic properties of substances from phase equilibria data accumulated during the course of the present researches.

THEORIES OF MELASSEGENESIS

Geerligs (1) has defined molasses as a "hydrated syrupy-liquid combination of sucrose and its salts." He seems generally to use the term "melassegenic power" to refer to the manner in which substances other than sucrose "salt-in" or "salt-out" sucrose from solution, and a fairly wide range of data is available from the work of Shukow (15) and Kohler (16) on the effect of inorganic salts on the solubility of sucrose ; whilst Jackson and Silsbee (17) have described the effect of "invert sugar" on the solubility of sucrose.

From a survey of data the author generalised in observing that solutes which form a hydrate have a "salting-out" effect on sucrose i.e., decrease the solubility of sucrose ; whereas those which do not form a hydrate increase the solubility of sucrose. This generalisation might be better if qualified by considering conditions of hydration of the second solute in the solution itself. Where the concentrations of ionisable solutes are small there would be ionisation and it is known that ions in solution are hydrated. Reduction in the solubility of sucrose could well be taken as a measure of the effectiveness with which these ions compete for water molecules. Salts such as KCl and NaCl have a salting-out influence at low concentration. Also the reducing sugars are able to salt-out sucrose. Endeavours have been made to calculate coefficients to represent the salting-in or salting-out influence, but at the concentrations which are of interest for a study of melassegenesis no success has been experienced.

Salts like $CaCl_2$, $MgSO_4$ and $CuSO_4$ were found to continue to exercise a salting-out influence until they themselves saturated the solution. At saturating concentrations these solutions were in equilibrium with their own appreciably hydrated crystalline salts. It is likely, therefore, that unionised fractions of these solutes would themselves be hydrated in solution which would be consistent with their salting-out influence.

The property of salting-in of sucrose was considered by Geerligs (1) to be associated with the ability for sucrose and the particular salting-in compound to form double compounds themselves.

Cochrane (18) following Gill (19) reported that he could prepare fairly easily a hydrated compound between sucrose and sodium iodide ; and with sodium bromide when evaporation was allowed to proceed slowly over a period of months. Success was also claimed for a compound between sucrose and sodium chloride, but mixed with crystals of varying composition from almost pure sugar to pure salt. In the author's experiments with the sucrose-sodium chloride mixtures no double compound formation was observed after a period of two weeks. The direct effect of double compound formation is not believed by the author to be important under conditions experienced in the commercial production of sucrose. Indirectly, however, substances which only under certain favourable circumstances may form a double compound with sucrose might exercise a salting-in effect at suitable concentration conditions.

From a study of phase equilibria systems (12) it is considered unusual for sugar cane molasses to be concentrated to the stage at which it is saturated with either dextrose or levulose. If saturation is not reached, then reducing sugar as such can only have a beneficial effect in reducing the solubility of sucrose but will not of itself limit crystallisation.

Geerligs observed that "after boiling up mixtures of sucrose, reducing sugars and salts with water the amount of sucrose crystallising out increased in proportion as the liquid contained more R.S. for the same amount of salts." From phase equilibria studies (9, 10) the author believes that Geerligs observation really amounts to a successive dilution of the system water-sucrose-salts with reducing sugar. The added reducing sugar would certainly have some salting-out effect on the sucrose, but the main effect on the "purity" of the solution would be one of dilution with another non-sucrose substance. The author has also carried out the converse procedure of adding KCl to the water-sucrose-reducing sugar system with the same effect i.e., reducing "purity" in spite of a salting-in influence of KCl. The interpretation is simply one of dilution. Thus a solution of sucrose and "invert sugar" with minimum purity of 48% was progressively reduced to 33% purity by addition of KCl. At this stage the solution was also saturated with KCl.

From a study of the four and five-component systems it appeared that there need be no theoretical limit to the amount of non-sucrose material which could be retained in solution within their own solubility limits. In other words, the greater the *variety* of solutes the lower the purity which could be obtained synthetically.

It is submitted that Geerligs wrongly interpreted this simple diluting effect which he apparently observed correctly but did not describe in these terms. The author recognises that salting-in or salting-out effects of solutes other than sucrose exercise an influence on the ease with which crystallisation proceeds in a factory, but fails to see how these influences limit *per se* the amount of sucrose which can be crystallised.

SECONDARY SOLUTE SATURATION

The possibility of substances other than sucrose reaching saturation in a molasses, and the effect of this on the crystallisation of sucrose has been examined. When two solutes reach a condition of saturation in the same solution, continued cooling and or evaporation will result in one of three things happening: (1) Both solutes will crystallise either as individual entities, as a solid solution or as a double compound. (2) One of the solutes will crystallise leaving the other in a meta-stable state of supersaturation. (3) The solutes will interfere with each other in the solution in such a way that neither will crystallise.

It is well known that substances of low solubility such as calcium sulphate and calcium aconitate reach saturation at an early stage of raw sugar production and co-crystallise with sucrose generally in the form of crystallites most of which remain in the molasses. The fact of these saturating molasses does not appear to influence sucrose crystallisation. From analyses of the inorganic constituents of molasses there appears the possibility of KCl reaching saturation under certain conditions and of K_2SO_4 reaching saturation when the sulphate concentration is particularly high and lime and chloride are lower than usual. Hughes (20) has actually observed KCl co-crystallising with sucrose from molasses. In this case exceptionally high molasses purities were experienced and it would appear that co-crystallisation continued for only a limited range. From observation of analyses of some samples of Queensland molasses which seemed to be saturated with K_2SO_4 the author believes that at least a limited amount of co-crystallisation of K_2SO_4 and sucrose is possible, although no crystals of K_2SO_4 have as yet been identified in the molasses. Its presence has however been indicated as likely in some raw sugars (21). Limited co-crystallisation may be permissible in the crystallisation of raw sugar but not refined sugar.

Neither KCl nor K_2SO_4 is isomorphous with sucrose which is believed to limit the possiblity of co-crystallisation in solid solution. The possibility of double compound formation is considered to be unlikely as sucrose concentrations are generally 5-7.5 molal whereas KCl in Spencer-Meade's Louisiana molasses (22) is little more than 0.5 molal, although with the molasses reported by Hughes (20) it is more nearly 3.25 molal, and in the latter case separate crystals of KCl were identified.

The author has observed synthetic solutions of sucrose and NH_4NO_3 (11), the inorganic solute crystallising separately from the solution supersaturated with respect to sucrose. The converse conditions were not observed, but could possibly be produced by careful control of systems provided only with sucrose crystal surface.

When studying the effects of the reducing sugars it is essential to differentiate between dextrose and levulose because of their widely differing solubilities. These names are preferred by the author particularly to avoid perpetuating the confusing reference to "glucose" when total reducing sugars are intended to be described. An analytical method was developed by the author (23) for the separate identification of dextrose and levulose in molasses using a chemical technique.

The stability of supersaturated sucrose solutions saturated also with dextrose and/or levulose has been observed to have been appreciably increased. However, the possibility of levulose reaching saturating conditions in a molasses is very unlikely, but it would appear that conditions approaching saturation for dextrose are not infrequent with molasses of high reducing sugar content and approximately equal proportions of the two reducing sugars.

The most effective solution stabilisers of those tested from the range of possible substances in molasses were found to be the amino acids, aspartic acid and tyrosine (12). These were more effective in the presence of reducing sugars in the concentrations normally experienced in molasses.

REDUCING SUGAR-ASH RATIO

A direct examination of the "R. S./Ash" ratio has been described for the four-component synthetic system water-sucrose-levulose-KCl (10). This was chosen in preference to the system with dextrose because the greater solubility of levulose enabled examination to be extended over a wider range of conditions. The salting-out effect on sucrose of dextrose and levulose was very similar and the difference of no practical significance. A levulose/KCl ratio of 19 had only a slightly greater salting-out effect for sucrose than a levulose/KCl ratio of 3 ; thus the solubility co-efficient was 0.86 for the former conditions compared with 1.0 for the latter. However, the purity at which the second solute also saturated the solution was 26.4% in the first case and 50% in the second. The rate of change of limiting purity was not linearly related to the rate of change of levulose/KCl ratio but virtually constant at 26.4% as the ratio changed from ∞ to 4.87. After this the purity rose rapidly to 84.3% when the ratio was zero. In the system with dextrose instead of levulose the salting-in or salting-out effect was very similar, but due to the much lower solubility of dextrose, the purity at which the second solute saturated the solution fell from 64·9% for a dextrose/KCl ratio of ∞ to 42.8% for a ratio of 2.7, and then rose rapidly to 84.3% for a ratio of zero.

Thus it is not sufficient only to know the reducing sugar/inorganic salt ratio, but it is also essential to know the proportions of the two reducing sugars. The nature of the inorganic solutes also varies in natural molasses and exercises correspondingly varying influences.

It would be convenient to assume that at least in the majority of molasses samples the dextrose/levulose ratio approaches unity. Under these conditions the purity in the synthetic system at which a second solute reached saturation fell from 48% to 32.7% as the R.S./Ash ratio fell from ∞ to 4.2. The purity then rose rapidly to 84.3% for a ratio of zero. The combined salting-out influence of the two reducing sugars was very strong in the absence of KCl, having a solubility coefficient of 0.65 which rose to 1.3 for the R. S./ KCl ratio of 4.2 and then fell again to 1.21.

This simplifying assumption has been shown to be frequently untenable, as the author has found the dextrose/levulose ratio to vary from 1:0.84 to 1:3.5 (12,23).

A simplifying assumption that the combined effect of inorganic solutes may be interpreted in terms of a single solute such as KCl or K_2SO_4 would be convenient, but this also is untenable owing to different solubility relationships of the various combinations of inorganic ions as well as possible combinations of organic and inorganic ions.

A THEORETICAL MELASSEGENIC FORMULA

Formulae can be deduced from the phase equilibria relationships of the synthetic mixtures to represent the limit to which sucrose crystallisation may be carried before a second solute reaches saturating conditions. Unfortunately no single simple formula will do this, but possibly most types of molasses might come within the range of one of them. Even this, however, requires for its use a detailed analysis of the molasses thus making it somewhat unworkable for day to day control.

$$P = [65.4 - e^{-(1.1)\,b}] \times \frac{\text{sucrose} + \text{dextrose} + \text{KCl}}{\text{total solids}} \times C \qquad \ldots(1)$$

where $b = \text{KCl} : \text{dextrose}$, and when

$$\text{dextrose} : \text{KCl} > 2.7$$

$$\text{and levulose} : \text{dextrose} < 3$$

e = base of natural system of logarithms (= 2.72)

P = true purity of molasses.

Sucrose, dextrose, levulose and KCl are the percentage concentrations of these solutes in the molasses.

$$C = \frac{\text{solubility coefficient for sucrose in molasses as determined}}{\text{solubility coefficient from appropriate position in sucrose-dextrose-KCl-water system}}$$

When an examination of the ash analysis of molasses shows that it is more likely to be saturated with K_2SO_4 before it is saturated with KCl; then this formula would apply over a wider range of dextrose : K_2SO_4 than for dextrose : KCl, although this relationship would not necessarily be of the same mathematical type as for KCl. However, as a first approximation it might well be accepted as such. A graphical analysis of the composition of the molasses using phase equilibria diagrams for sucrose and reducing sugars with or without KCl would probably be more informative.

This formula does not include the influence of specific constituents of the O.O.M. group of substances. Such a limitation is not believed to be serious from the point of view of their salting-in or salting-out effects on sucrose. However, it is believed to be a serious deficiency from the point of view of observations on the inhibiting influences of amino acid or such other constituents affecting the crystallisation of sucrose (12). Sufficient information is not available from equilibrium data to cover this aspect in detail.

The formula is not shown as being temperature dependent. This is approximately correct from the point of view of most of the constants, but is not strictly correct from the point of view of the solubility coefficients. It is known that solubility coefficients for sucrose increase with temperature under all conditions but the rate of change with temperature is known to vary. Corrections for these variations are not included in the above formula as insufficient data is available for precise treatment. Solubility data from the work of Shukow (15) or Jackson and Silsbee (17) may be used to provide temperature corrections for the denominator of C, and the value for the numerator may be determined at the factory temperature of operation.

The Louisiana molasses tabulated by Spencer-Meade (22) falls into the group to which this formula might be applied. For a value of C equal to unity the calculated value of P becomes 36, whereas the actual true purity quoted is

40. To obtain agreement between these two values it would be necessary to assume a solubility coefficient of 0.98 at 30°C. if the molasses of "theoretical purity" is to equal the actual purity quoted. Such a value is by no means unreasonable.

MECHANICAL CONTROLLING FACTORS

"Mechanical factors" limiting the crystallisation of sucrose in molasses have been the basis upon which most actual improvements in molasses exhaustion have been effected in factory practice. Also such factors must be important for study when molasses of the Micheli and de Gyulay type are experienced (13).

A summary is presented of the author's examination of factory molasses from the point of view of purely mechanical factors influencing exhaustion (24). These were considered as follows :—

(1) Rate of increase of viscosity of molasses with decreasing purity.

(2) Rate of change of solubility coefficients with decreasing purity.

(3) Effect of crystal content on viscosity of massecuite.

(4) Growth of sucrose crystals at low purities.

(5) Decrease of crystal growth rate with decrease in purity. For true purity values below 60 it was found that at a saturation temperature of 55°C. the change of viscosity with purity could be represented by an equation of the type

$$\log \eta = 10^{k}\ P^{-m} \qquad \ldots(2)$$

where η = viscosity of molasses in poises.

P = true purity of molasses

and ^{k} and ^{m} are constants.

Molasses types which indicate values for ^{k} and ^{m} of the order of 5 and 3 respectively or higher were described as having an unfavourable viscosity characteristic, and increased in viscosity very rapidly as the true purity decreased. Those which indicate values for ^{k} and ^{m} of the order of 3 and 1.5 respectively or lower, were considered to have a rather more favourable viscosity characteristic, with a much lower rate of viscosity increase.

The solubility coefficient (S. C.) of sucrose was found to vary with purity in different ways with different types of molasses. If the S. C. decreased with decrease in purity this behaviour was considered favourable from the point of view of exhaustion, whereas when it increased with decrease in purity this behaviour was considered unfavourable. The view has already been expressed that it is fallacious to assume an unfavourable S.C. establishes, *per se*, a limit to the crystallisation of sucrose. It was observed that lower temperatures were invariably associated with lower values for S.C. ; and for saturation temperatures of 45°C. or less the S.C. characteristic was invariably of the favourable type.

Davies (22, p. 216) when discussing crystallisation in motion states that low purity and high viscosity of the massecuite retard the growth and development of the crystals. The author examined the effect of crystal content on the viscosity of massecuites (25) but was unable to observe a fundamental relationship between massecuite viscosity and ultimate limitation of sucrose crystallisation.

The following formula has been deduced from the author's experimental results (25) to illustrate the effects of crystal content and crystal size in increasing the viscosity of molasses (suitable for crystal contents of 10-45%).

$$\eta_{sp}=267.l.V^{2.55} \qquad \ldots(3)$$

where η_{sp} = specific viscosity of massecuite.

l = average length of side crystals in mm.

V = volume of crystals per unit volume of massecuite.

The manner in which crystal content and crystal size of a massecuite and the viscosity characteristic can limit the exhaustion of molasses from the point of view of a particular set of mechanical equipment has been discussed by the author (24). An "exhaustion criterion" (k) was suggested as a means of rating centrifugal operation to take into account molasses quantity and viscosity as well as crystal size.

$$k=\eta.v.\ l^{-2} \qquad \ldots(4)$$

where η = viscosity of molasses in poises at centrifugalling temperature and concentration.

v = volume of molasses handled per unit of time.

l = average length of side of sucrose crystal in mm.

On this basis it was indicated that a five-fold increase in mechanical capacity would be required for 6% reduction in the purity of molasses (e.g., from 45 to 39%) for a molasses with an unfavourable viscosity characteristic. On the other hand a molasses with a favourable viscosity characteristic would require no increase in capacity for a similar improvement if appropriate adjustments were made in crystal size and crystal content of massecuite (i.e., purity of massecuite). On the other hand a five-fold increase in mechanical capacity should be associated with a 15% reduction in purity provided crystallisation *was not hindered by other factors* from continuing to this stage. Helderman (4) used phase equilibria investigations and expressed the view that every molasses can crystallise further on evaporation, while velocity of crystallisation and size of crystals becomes very much reduced so that the last crystals may be only visible under the microscope. The author has found by experiment (24) that a relationship between the surface area of crystal per unit weight of mother liquor and purity of molasses at any particular stage of the boiling procedure has a pronounced effect on the decision which a crystallising molecule makes as to whether it will attach itself to the surface of an existing crystal or will start new crystal development. In other words it was found that fine crystal or "crystallite" development could be avoided for any specified conditions if sufficient crystallising surface per unit weight of molasses was present.

Thus to avoid crystallite formation :—

$$A=\frac{19x}{l(100-x)} \nless \frac{a\,(\text{degree of saturation}-1.0)}{P^{1.4}} \qquad \ldots(5)$$

where A = surface area of crystals in sq. ft. per lb. of mother liquor.

x = % crystal content of massecuite.

l =average length of side of crystals in mm.

P=true purity of mother liquor.

The author found that a value of approximately 3.0 x10^4 for the constant "a" satisfied conditions for certain types of molasses, but further experimental work is desirable to establish the scope of usefulness.

There have been many workers who have endeavoured to determine the possibility of the velocity of crystallisation of sucrose gradually decreasing until it becomes vanishingly small at the point at which the molasses is considered to be exhausted. Van Hook (2) has expressed the view that except during nucleation, the rate at which crystallising molecules place themselves in the crystal, is the rate controlling process rather than the rate of diffusion to the crystal surface. He also suggested that a relative melassegenic rating of juices in terms of both intensity (nature of molasses constituents) and capacity (their concentration) factors might be used for establishing the point at which rate of crystallisation would become uneconomically low. The author has, however, reported observations (24) of molasses which reached conditions of zero rate of crystallisation with unexpected suddeness from observation of rates of crystallisation at purities only slightly higher than the final purity reached.

STATISTICAL FORMULAE

A number of formulae have been reported from time to time which describe final molasses purities experienced under different sets of conditions. There would be interest in comparing them with data obtained from phase equilibria studies, but in a discussion on melassegenesis they are not considered to be germane to the issue.

REFERENCES

1. Prinsen-Geerligs, H. C. "*Cane Sugar and its Manufacture.*" Norman Rodger.
2. Van Hook, A. 1949. *S. R. F. Project* 7, p. 17.
3. van der Linden, T. 1915. *Archief Suikerindustrie*, 23, 1033, 1389.
4. Helderman, W. D. 1920 ; 1921. *Archief Suikerindustrie*, 28, 1701 and 2305 ; 29, 1167.
5. Sjilmans, C. 1934. *I.S.J.* 36, 437.
6. Thieme, S.G. 1931. *I.S.J.* 33, 244.
7. Davies, J.G. 1932. *I.S.J.* 34, 242.
8. Sjilmans, C. 1942. *Archief Suikerind.* 50, 413.
9. Kelly, F. H. C. 1955. *J. Appl. Chem.*, 5, 170.
10. Kelly, F. H. C. 1955. *J. Appl. Chem.*, 5, 66-71 and 120-124.
11. Kelly, F. H. C. 1954. *J. Appl. Chem.*, 4,401-413.
12. Kelly F. H. C. 1955. *Proc. Qld. Soc. S. C. T.*, 22, 265.
13. Micheli, L. I. A. and de Gyulay, O. S. 1935. *Proc. Fifth Cong. Int. Soc. Sugar Cane Tech.* 229.
14. Kelly, F. H. C. 1946. *Proc. Qld. Soc. S. C. T.* 13, 135.
15. Shukow, I. 1900. *Z. Ver. Dtsch. Zuckerind.* 50, 313.
16. Kohler, A. 1897. *Z. Ver. Dtsch. Zuckerind.* 47, 447.

17. Jackson, R. F. and Silsbee, C. G. 1924. *Tech. Pap. U. S. Nat. Bur. Stand.*, 18, 277, p. 259.
18. Cochrane, W. 1946. *Nature* 157, 231.
19. Gill, C. H. 1871. *J. C. S.*, 24, 269.
20. Hughes, R. H. 1952. *Rep. of Hawaiian Sugar Tech.*, 59.
21. Sugar Research Institute (Mackay, Qld.) 1955. *Tech. Rep.* No. 30.
22. Spencer, G. L. and Meade, G.P. 1952. "*Cane Sugar Handbook*." p. 248. John Wiley and Son, 8th Ed.
23. Kelly, F. H. C. 1954. *J. Appl. Chem.*, 4, 622.
24. Kelly, F. H. C. 1946. *Proc. Qld. Soc. S. C. T.*, 13, 135.
25. Kelly, F. H. C. 1942. *Proc. Qld. Soc. S. C. T.*, p. 51.

DISCUSSION

Dr. Douwes Dekker considered the work of great importance and endorsed the theoretical approach adopted. He asked whether the rate of crystal growth was related to the speed with which the crystals move through the mother liquor. Mr. Kelly said it is necessary to distinguish between the mass movement of crystals in a pan, and the effect at the immediate crystal surface. Van Hook is undertaking studies to determine how far the effect of this "viscous drag" extends beyond the surface of the crystal. Mr. Gairola said he viewed the problem rather from the physical and practical angle than from the chemical point of view. By increasing cooling as much as possible and increasing the crystal content of the massecuite, it is possible to reduce the final purity to 32-33. It seems that stickiness of the massecuite is the property which governs exhaustion and he referred to his earlier publication on the subject.

Mr. Kelly considered that so-called "stickiness" is a combined effect of surface tension and viscosity.

Dr. Doss offered his word of commendation on Mr. Kelly's approach ; he had viewed the problem similarly. He had corresponded with Van Hook, who had suggested the activity method of treatment, but it was found that the influence of the viscosity co-efficient correlated well with the rate of crystallisation. The condition of the crystal surface seems very important. Where broken pieces are used as seed instead of well developed crystals of similar size the rate of crystallisation is very much accelerated. With rough surface, rate of diffusion seems most important.

Mr. Foster said that some people in Italy had shown that calcium aspartite does not appear to influence sugar crystallisation. Would Mr. Kelly say whether the aspertic acid present in the molasses was there in the free state or as a salt ?

Mr. Kelly considered that at the pH of normal molasses it would be present as the free acid.

Mr. Gundu Rao said that Mr. Kelly had presented very interesting and valuable data. Work has shown that the R.S./Ash ratio is related to sugar loss in molasses, but this is not always true. It is possible to record high purities with a favourable ratio. Evidently other non-sugars, perhaps amino acids, are dominant in such cases and we must study these influences. The effect of impurities on purity is to reduce this but it also increases the quantity of molasses made. We are seeking to devise a formula for exhaustion, but we do not know the relative influence of each. It has been found that an off-colour seed crystal will lose its colour completely in a high purity syrup and give a favourable crystal. Does this mean that the colouring substances can diffuse from the original crystal ? This might be related to the appearance of crystal surface as revealed by the electron microscope photographs made by Tate & Lyle.

Mr. Kelly thought that the colour effect may be only a surface effect, as is eliminated by removing the surface film. Dr. Douwes Dekker considered that the colour is in part from both sources. Removal of the surface film does take away some colour ; but as the crystal is corroded, the syrup continues to remove colour, and indeed the last syrup may be most highly coloured. He stressed also that the R.S./Ash ratio is purely empirical and is recommended as a working guide, but it will not help in the solution of the problem.

Dr. Doss presented the following paper.

Paper

LABORATORY EXPERIMENTS ON RESISTANCE HEATING OF MASSECUITES

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For obtaining maximum exhaustion of molasses, it is often an advantag to cool the massecuites to a very low temperature say of the order of 40°C. Suc cooled massecuites would attain very high viscosity so much so that the curin of the massecuites in the centrifugals becomes difficult and ineffective. T obviate this difficulty it is necessary to reheat the massecuites.

Amongst the various devices for carrying out the reheating are (a) coolir and reheating elements in the crystalliser and (b) mixers with heating element The heating medium for this purpose is usually hot water. The heat transf presents a serious problem, since the film coefficient of the heat transfer on tl massecuite side is exceedingly low, owing to high viscosity of massecuites. is therefore often necessary to employ high temperature of the heating mediu in order to carry out the heating operation in a reasonable time. This resul in the redissolution of the sugar in the massecuite near the heating element.] minimise this effect, it would be necessary to aim at a comparatively lo temperature for the heating medium with the consequence that the massecuit cannot be heated to sufficiently high temperatures. Thus one cannot obtain t fullest advantage by the reheating.

The careful experiments of Gundu Rao and Sastry (1) have shown th on the average about two units of rise in purity takes place during reheating of massecuites even under most careful conditions of working. In the mixer ty of reheating unit, it is claimed by some of the manufacturers that the rise in puri is only by 0.3 unit. It is however to be seen how far this result is obtainab under the conditions in India especially when the C massecuites are of hi brixes and consequently highly viscous at low temperatures. In any ca since the heating would be slow, it would be difficult to raise the temperature the massecuites to values equal to or higher than the saturation temperatu without considerable re-dissolution of sugar.

Whenever heat transfer becomes a serious problem, one has to consic the possibility of carrying out the heating preferably by an agency not dependi on heat transfer. Amongst such agencies are

(a) infra-red heating,
(b) dielectric heating,
(c) induction heating, and
(d) resistance heating.

Induction heating is adaptable only with metallic conductors. Dielectric heatin very costly and is to be considered if cheaper methods do not work. Infra-red heating would involve getting the massecuite in very thin layers or having a very efficient arrangement for stirring the massecuite which would mean certain amount of complication in design. It is the object of the present work to examine the possibility of resistance heating for reheating of massecuites. Work of P. Honig (3) has shown that the final molasses has considerable electrical conductivity at the usual brixes and temperatures. It is to be noted in this connection that resistance heating has been a feature which has been introduced in a special type of centrifugal described in a patent (2).

EXPERIMENTAL RESULTS AND DISCUSSION

Two mild steel sheet electrodes were fixed in a small rectangular box and filled with C massecuites. An alternating field of 220 volts was applied. The massecuites took about 20 minutes to rise from 34°C. to 55°C. Later on experiments were tried with different samples of C massecuites of various sugar factories, which all showed a nearly identical behaviour. With the kind and active co-operation of the managements and staff of Godavari Sugar Mills at Sakarwadi and Lakshmiwadi a semi-large scale experiment was tried. A box with 8 to 9 compartments was got made and filled with C massecuite. The electrodes were made of galvanised iron sheet. The alternating voltage was applied from the mains. The temperature rise took place as expected. But, this experiment showed clearly that in a simple arrangement of parallel places, large differences in temperature occur in the different localities in the heating box. This is, caused by either the buckling of the plates or want of parallelism. It may also be caused by the presence of air pockets within the massecuite. The differences in temperature are found to be of the order of 20°C. in extreme cases. It was therefore decided to modify the design so as to avoid this non-uniformity.

In the new arrangement a rectangular box with a truncated pyramidal bottom was used. In the rectangular portion a grid of electrodes was introduced as described in Fig. 1. The massecuite was allowed to flow continuously from the crystalliser at the rate of 75 lbs. per hour. The applied voltage was controlled by using a variable transformer. The initial and final temperature as well as other data were noted. Typical sets of data are given in Table I.

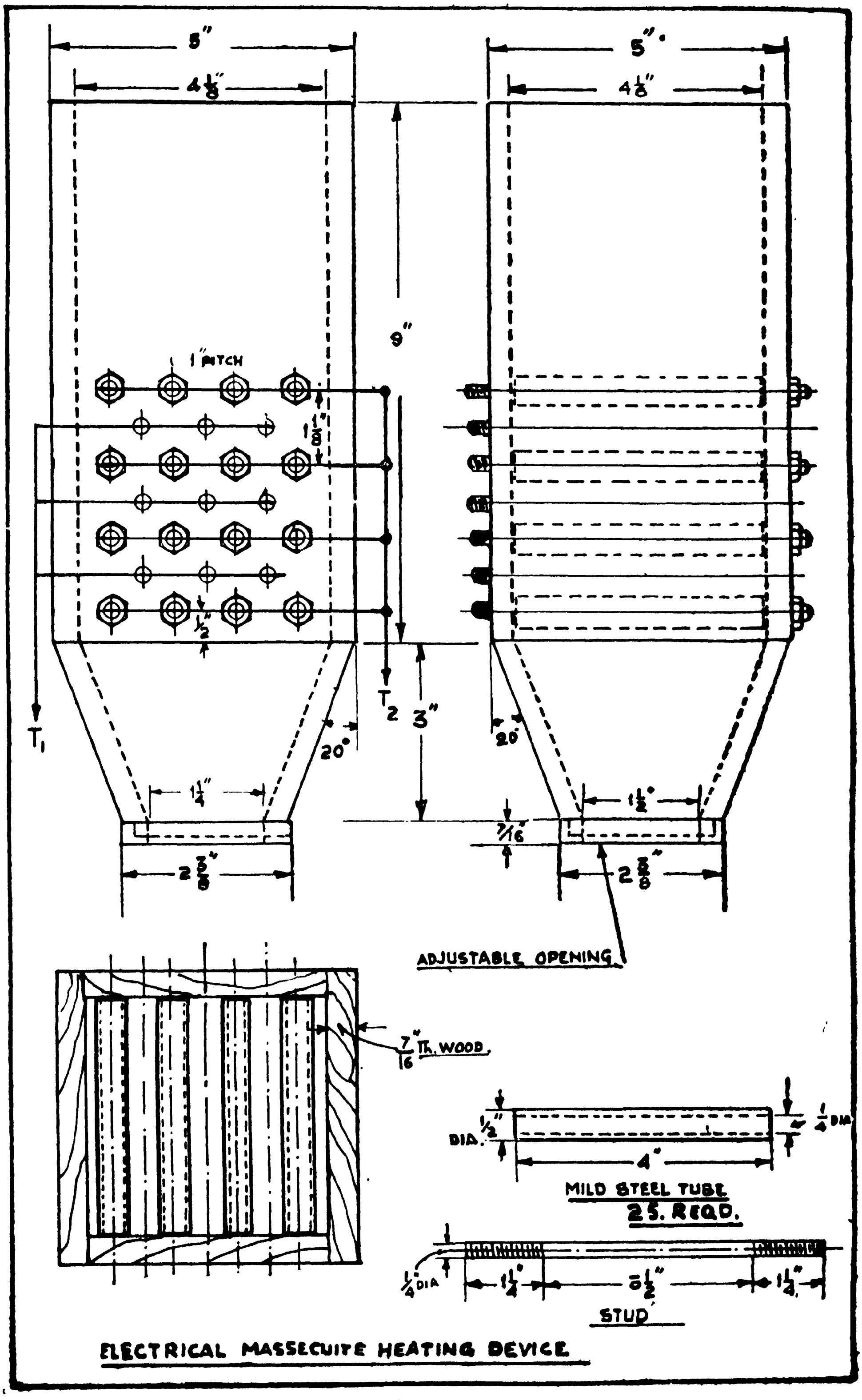
5"
4 1/8"
1" PITCH
1 1/8"
1/2"
9"
T1
T2
3"
20°
1 1/4"
2 3/8"
5"
4 1/8"
20°
1 1/2"
7/16"
2 3/8"
ADJUSTABLE OPENING
7/16" TH. WOOD.
1/2" DIA.
1/4 DIA
4"
MILD STEEL TUBE
25. REQD.
1/4" DIA
1 1/4"
5 1/2"
1 1/4"
STUD
ELECTRICAL MASSECUITE HEATING DEVICE

Fig. 1.

TABLE I

Experiment No. 1		Experiment No. 2	
Initial temp. of massecuite : 39°C. Average current kept constant at 5.2 amp.		Initial temp. of massecuite : 45°C. Average current kept constant at 9.4 amp.	
Readings of voltage applied and temp. after every minute.		Readings of voltage applied and temp. after every minute.	
Volts	°C.	Volts	°C.
65.0	48.0	100	64.0
	51.0	60	65.0
	51.0	60	64.0
66.0	54.5	70	62.5
66.0	54.5	70	66.5
66.0	54.0	70	65.5
66.0	54.5	80	68.0
66.0	55.5	74	70.0
66.0	55.0	74	70.5
66.0	54.5	74	70.0
66.0	54.5	74	70.0
		74	70.8
		74	71.0
		74	70.0
		74	68.0
		74	67.0
		80	68.5
		80	69.5
		80	70.0
		80	69.5
		80	69.5
		80	70.0
		82	70.0
		80	69.5
		82	69.5

An examination of the table shows that the heating is quick and is uniform. In the particular grid system described the terminal electrodes are all earthed and thus the danger of shock is completely eliminated. The staggered arrangement of the electrodes causes an effective mixing of the massecuite. In a large scale installation one can have also a number of spare banks of electrodes, which may be brought into action as and when desired. This can be done automatically by introducing thermostatic control. This would help in getting any desired rise in temperature and make the heating unit flexible with regard to its capacity. Furthermore if any conducting material such as nails, wire gauze etc. gets into the system and is trapped in the grid, it would affect only a particular bank of electrodes and would not bring any general breakdown. On the other hand, the thermostatic control would automatically bring into action the next bank of electrodes and thereby ensure maintenance of the final temperature of the massecuites at the desired value. A patent has been applied for covering this invention.

The power requirements as experimentally determined and as calculated comes out to be 1000 units per day for a 1000-ton factory assuming that the heating is to be done to get a temperature rise of 15°C. Since the heating is very quick and does not involve any heating surface as such, the heating is uniform and the purity rise can be completely avoided if the final temperature is not higher than saturation temperature. It is likely however that it will be possible to use the arrangement for heating to temperatures considerably above the saturation temperature, if the heated massecuite can directly pass into the centrifugals. This would greatly help in improving the curing quality of the massecuite without any appreciable rise in purity. Though the grid system invloves theoretically certain amount of non-uniformity of field as well as a more or less stationary film of massecuites, these are not of importance from the practical point of view since there is a thorough mixing of the massecuites caused by the staggered arrangement of the electrodes.

One can also think of introducing a suitable heating system inside the crystalliser. Even the factories having the reheating arrangements in the crystallisers can utilise resistance heating as an auxiliary for a final heating of the massecuite before curing.

The advantages of resistance heating would be different under different circumstances and would vary from factory to factory. Some of the possible advantages are given below :—

(a) This leads to a diminution of re-circulation;
(b) lowers considerably the centrifugal capacity requirements and appreciably the pan capacity requirements ;
(c) enables working with (i) well cooled high brix massecuite, (ii) high crystal/molasses ratio, and (iii) fine grained massecuites, thus improving the exhaustion of molasses ;
(d) enables working with low purity footings in C-boiling and thereby lowers the final molasses purity ;
(e) enables quick heating to very high temperatures facilitating efficient curing ;
(f) improves the quality of sugar ;
(g) causes overall lowering of production costs ; and
(h) can be combined with flashing method of cooling of massecuites.

ECONOMICS

Whereas a complete consideration of economics should await this technique to be adopted on a pilot plant scale, some rough calculations are made herein.

Consumption of Electricity (Theoretical).

Capacity of factory :—1000 tons cane per day.
Amount of C massecuites per day = 100 tons.
Specific heat of massecuite = 0.5
Temperature rise during reheating = 15°C.
Heat required per day

$$= \frac{100 \times 2240 \times 454 \times 0.50 \times 15 \times 4.2}{1000 \times 60 \times 60}$$

$$= 890 \text{ kWh.}$$

Consumption of Electricity (Actual).

Through put = 75 lbs./hr.
Voltage = 66V. Current = 5.2 amp. Temperature = 16°C.
Electricity for heating 75 lbs. massecuites through 16°C.

$$= \frac{66 \times 5}{1000} \text{ kWh.}$$

Electricity for heating 100 × 2240 lbs. through 15°C.

$$= \frac{66 \times 5.2}{1000} \times \frac{15}{16} \times \frac{100 \times 2240}{75} = 960 \text{ or say, 1000 kWh per day.}$$

Cost of Electricity at 2 annas per unit assuming 1000 units per day comes out to be Rs. 125/-. Taking other expenses including depreciation and interest on equipment as Rs. 25/-, the expenditure per day comes to be Rs. 150/-.

This method of heating would practically eliminate redissolution of sugar and thereby help in getting a molasses of purity lower by at least 2 units.

Increase in recovery is about 0.7 ton of sugar per day, which corresponds to about Rs. 560/-.
Increase in net profit per day = Rs. 410/-.
Net gain per season of 100 days
= Rs. 41,000/- or $8,600.

If hydroelectric grid is available the cost of electricity would be

$$1000 \times \frac{1}{32} \cong \text{Rs. } 31/\text{- per day.}$$

ACKNOWLEDGEMENT

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REFERENCES

1. Gundu Rao, S.N. and Sastry P.V.S. 1951. *Proc. D.S.T.A. (India), 8th Annual Convention,* p. 183-194.
2. Hoyt, S. T. Assr. to Castle and Cooke, Ltd., (U.S.P. 2, 613, 230. Appl., 25-5-51. (divided out of an original appl., 14-12-48 ; Granted, 25-11-52).
3. **Honig.,** P. *Private Communication.*

DISCUSSION

Mr. Gundu Rao commented that normally in factory practice it was customary to cool massecuites before reheating. It might be considered reasonable to use the elements provided for cooling, also for reheating. However, for cooling there was comparatively little objection to substantial temperature differences between the cooling fluid and the material under treatment. For reheating this was not so, and, unless the heating surface area were very generous, unduly high temperature differences were likely to be encountered. These facts made electrical reheating worthy of consideration.

Mr. Davis inquired as to the reason why numerous electrodes and a number of circuits had been provided when it would appear simpler to group the electrodes as two grids with a single circuit.

Dr. Doss replied that there were two reasons for the scheme adopted. Mainly it was a precaution designed to cope with accidental short circuits. If a piece of foreign matter in the massecuite shorted one circuit that one could be cut out without interruption to the process. It was also convenient to have several circuits for ease of control of the heat input.

In reply to Dr. Douwes Dekker who enquired whether resistance heating was operated on a factory scale, Dr. Doss replied that, as yet it was working only on a small scale in the Experimental Sugar Factory at Kanpur. As soon as a little more information was secured the process would be advanced to the full factory scale.

In the absence of the authors Mr. D.H. Foster presented the follwoing paper.

Paper

THE SOLUBILITY OF SUCROSE IN AQUEOUS SOLUTIONS

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THE SOLUBILITY OF SUCROSE IN WATER

The first serious attempt to determine the solubility of sucrose in water appears to be that of Flourens (1) who published a solubility table from 0 to 100 °C. in 5° intervals. Later Herzfeld (2) communicated the results of solubility determinations which are shown in Table I.

TABLE I

SOLUBILITY OF SUCROSE (HERZFELD)

Temp. °C	% Sucrose in Saturated Solution
5.20	66.17
19.15	66.65
28.80	68.31
49.53	72.23
59.40	74.33
99.45	82.76

To these results a second degree equation was fitted ;

$$C=64.18+0.1348t+0.000531t^2$$

where 'C' is the saturation concentration and 't' is the corresponding temperature °C. This equation has been used to calculate the table of sucrose solubility given in the standard reference books of the industry [e. g., Spencer and Meade (3) ; Honig (4)].

It is rather surprising that this table should have survived for so long. There is the obvious criticism that there is a large gap between 60° and 100°C., and therefore much reliance is placed on the value at 99.45°C. Owing to the possibility of inversion occurring at high temperatures this value is very likely to be in error, giving in fact too low a value. This has been frequently pointed out, e.g., Bieselaar(5). It appears to be not so generally realised that the value at 5.20°C. is also likely to be in error, giving too high a value. Equilibrium was approached in this solution from supersaturated solution and the time of the experiment was 165 min. Calculations carried out using the rate of crystallisation data of Kucharenko (6) have suggested that 165 min. is too short a time for equilibrium to be reached. As an example the time taken for a sucrose solution of supersaturation 1.02 to reach a supersaturation of 1.002 (i.e., as close to the equilibrium value as can be experimentally distinguished), when placed in contact with crystals of surface area 0.05m^2 per 100 g. water present, is 30 days at 0°C. ; 3 days at 20° C. and 9 hr. at 50°C. Some confirmation of the correctness of these long equilibrating times is given by the results of Verhaar (7) who found that equilibrium was not reached in his experiments at 30°C. after 20 hr. It should be mentioned, however, that Savinov (8) has shown that Kucharenko's rates are diffusion limited and so can be increased by intense stirring of the solution; the equilibrating times would then be decreased by a factor of about 6, i.e., 5 days would still be needed to reach equilibrium at 0°C. However, the technique used in solubility determinations is, in most cases, likely to correspond with the rates of Kucharenko.

In more recent years further attempts have been made to determine the solubility of sucrose in water more accurately. The values of Grut (9) are widely quoted ; they are consistently higher than those of Herzfeld, and it appears probable that evaporation was the factor responsible. Values obtained by D'Orazi (10) and Hruby and Kasjanov (11) lie between the values of Grut and those of Herzfeld. What appear to be the most reliable values are those of Taylor(12) who used a new method of determining solubilities. Instead of maintaining the temperature of a solution constant and determining the saturation concentration, she determined the saturation temperature of a sucrose solution of fixed concentration. This was done with a carefully designed "saturascope." The present authors (13) have recently determined the saturation temperature of sucrose solutions by another method, due to Dauncey and Still (14). This method is very suitable for use with sucrose solutions as it enables results to be obtained very quickly before inversion can cause a significant error. It was also usable over a much wider range of temperature than the saturascope method of Taylor. In the range of temperature available to both methods, however, good agreement was found between the two sets of results. The equation found for the solubility curve was :

$$C = 62{\cdot}77 + 0{\cdot}1706t + 0{\cdot}000344t^2$$

A table of values of sucrose solubility calculated from this equation is given below.

TABLE II

SOLUBILITY OF SUCROSE IN WATER

Temperature°C.	g. sucrose per 100 g. solution.	g. sucrose per 100 g. water
20	66.32	196.9
22	66.69	200.2
24	67.06	203.6
26	67.44	207.1
28	67.82	210.8
30	68.20	214.5
32	68.58	218.3
34	68.97	222.3
36	69.36	226.4
38	69.75	230.6
40	70.14	234.9
42	70.54	239.4
44	70.94	244.1
46	71.35	249.0
48	71.75	254.0
50	72.16	259.2
52	72.57	264.6
54	72.99	270.2
56	73.40	275.9
58	73.82	282.0
60	74.24	288.2
62	74.67	294.8
64	75.10	301.6
66	75.53	308.7
68	75.96	316.0
70	76.40	323.7
72	76.84	331.8
74	77.28	340.1
76	77.72	348.8
78	78.17	358.1
80	78.62	367.7

It may be of interest to note here that, as pointed out by Emmerich (15),the extrapolation of the solubility curve to obtain the melting-point of sucrose (by putting a value for C of 100 in the empirical equation) is unable to give an accurate result. At first sight the extrapolation from 80% to 100% concentration appears to be not unreasonable. However, a concentration of 80% sucrose corresponds to a mol. fraction of sucrose of about 0.17. To obtain the melting-point it is necessary to extrapolate to a mol. fraction of 1.00. On this basis it can be appreciated how long an extrapolation is actually involved. Further, the empirical equation of the form $C=\alpha+\beta t+\gamma t^2$, although useful for interpolation purposes, only fits the solubility curve over a part of the temperature range; in order to describe the solubility curve from low temperatures to the melting-point of sucrose, a more complicated equation would be required.

THE INFLUENCE OF OTHER SUBSTANCES ON SUCROSE SOLUBILITY

It is well-known that other substances affect the solubility of sucrose and that the loss of sucrose in molasses is, partly at least, due to this effect. Reducing sugars are known to decrease the solubility of sucrose in water, as pointed out by van der Linden (16) and confirmed by the experiments of Jackson and Silsbee (17). On the other hand, salts generally increase the solubility of sucrose, as shown, for example, by the results of Schukow(18) and of Rao and Gupta(19).

The data which exist on the effect of added susbstances on sucrose solubility are not however extensive and since the method of Dauncey and Still provides a rapid and convenient method of carrying out these determinations, a programme of research using this method is now being carried on in these laboratories. The results described below are on the influence of potassium chloride on sucrose solubility; they serve to illustrate the technique used.

EXPERIMENTAL

A solubility cell was machined from a stainless steel cylinder 6″×2½″. The cylinder was used standing in an upright position on its circular base. Window holes were drilled in the sides of the cell and glass polarimeter-tube disks were used as windows, being held in place by a threaded tube and sealed by a rubber gasket. The general technique used was as described previously(13). The potassium chloride used was A.R. grade which was powdered and then dried over phosphorus pentoxide for some days before use.

A sucrose solution of convenient concentration was prepared by concentration of a dilute solution under vacuum. The saturation temperature of this solution was then determined in the usual way. Dry potassium chloride, which readily dissolved, was then added to the sucrose solution. A new saturation temperature was determined and a solution removed into a weighed flask. More potassium chloride was added and experiments were carried on in this way until several amounts of potassium chloride had been added. The chloride content of each sample was determined by titrating with silver nitrate; control experiments showed no interference by sucrose with the results obtained by this method.

RESULTS

The results obtained are summarised in Table III.

TABLE III

EFFECT OF POTASSIUM CHLORIDE ON SATURATION TEMPERATURES OF SUCROSE SOLUTIONS

% KCl	0	0.38	0.57	0.87	1.86	3.41	5.28	7.24	—
Temp. °C.	28.5	29.1	28.8	28.2	27.1	24.4	20.6	17.8	—
% KCl	0	0.25	0.63	0.99	2.41	4.42	6.42	8.36	—
Temp. °C.	35.6	36.2	36.6	36.4	34.9	32.3	28.5	25.4	—
% KCl	0	0.37	0.85	1.25	2.44	4.99	7.65	10.39	—
Temp. °C.	44.6	45.2	45.9	45.5	44.7	41.5	39.0	35.5	—
% KCl	0	0.38	0.75	1.10	1.61	3.00	5.92	8.28	10.99
Temp. °C.	48.2	48.7	49.4	49.5	49.2	48.2	45.0	42.2	38.3
% KCl	0	0.30	0.66	1.09	2.23	4.04	5.73	7.58	—
Temp. °C.	56.6	57.0	57.2	56.5	55.6	53.6	51.0	49.1	—
% KCl	0	0.30	0.53	0.96	1.90	3.63	5.91	8.57	10.93
Temp. °C.	59.1	59.5	59.6	59.0	57.9	56.1	53.6	50.7	47.6

In order to calculate the saturation concentrations as a function of potassium chloride concentration and temperature, the following smoothing procedure was adopted.

The initial saturation temperature, when no potassium chloride has been added, enables the ratio of sucrose/water to be obtained from the solubility equation previously given. It is assumed that the sucrose/water ratio remains unchanged throughout the experiment, i.e., that no loss of water by evaporation occurs.

Let p be the % potassium chloride in the solution
s be the sucrose / water ratio, g. sucrose per g. water
x be the ratio g. potassium chloride/g. sucrose.

then, $$x = \frac{p(1+s)}{s(100-p)}$$

and values of x can therefore be readily calculated from corresponding values of p and s. Graphs of Δt against x can now be plotted where Δt is the difference between the saturation temperatures of the initial solution and the solution to which potassium chloride has been added. Smooth graphs are obtained, the curves being drawn by eye through the experimental points. From these smoothed curves values of Δt can be read off for regularly ordered values of x. To any value of x and the corresponding saturation temperature we can calculate the sucrose/water ratio for a solution of sucrose in pure water at the same temperature. Thus we can find ΔC, the increase in the sucrose / water ratio caused by the presence of potassium chloride at the corresponding temperature. Finally, by drawing graphs of ΔC against saturation temperatures for fixed values of x, the values at regular temperature intervals can be interpolated. In this way Table IV has been constructed.

TABLE IV

INFLUENCE OF POTASSIUM CHLORIDE ON SUCROSE SOLUBILITY

g. KCl per g. sucrose	Sucrose solubility g. sucrose / 100 g. water						
	25°C.	30°C.	35°C.	40°C.	45°C.	50°C.	55°C.
0	205.4	214.5	224.3	234.9	246.6	259.2	273.0
0.005	206.1	213.5	223.1	233.4	245.0	257.6	271.7
0.010	206.9	214.2	222.8	232.5	243.9	256.4	271.0
0.015	207.7	215.0	223.4	232.9	243.9	256.2	271.7
0.020	208.4	215.7	224.2	233.5	244.4	256.4	272.7
0.030	209.8	217.3	225.6	235.1	245.6	257.8	275.2
0.040	211.2	218.7	227.1	236.5	247.1	259.7	278.0
0.050	212.7	220.3	228.7	238.1	248.6	262.0	281.0
0.060	214.2	221.7	230.2	239.7	250.1	264.4	284.1
0.070	215.6	223.3	231.7	241.2	251.8	267.1	287.3
0.080	217.0	224.8	233.2	242.7	253.4	269.7	290.8
0.090	218.5	226.3	234.7	244.3	255.3	272.5	294.6
0.100	220.0	227.7	236.2	245.9	257.3	275.4	—
0.110	221.4	229.2	237.8	247.4	259.8	278.3	—
0.120	222.9	229.8	239.3	249.0	263.4	281.4	—
0.130	224.4	231.7	240.6	250.5	—	—	—
0.140	225.8	—	241.9	252.1	—	—	—

The results in Table IV show that as the amount of potassium chloride is increased at constant temperature the solubility of sucrose at first decreases slightly and then increases fairly rapidly at higher concentrations of potassium chloride. The minimum is most marked at about 50°C.

Further experiments which will be reported and discussed later are now being carried out on the effect of other salts and sugars on the saturation temperatures of sucrose solutions ; it may even be possible to use this method to examine the solubility relationship of molasses.

ACKNOWLEDGMENTS

This work forms part of a programme of research being carried out under the aegis of the British West Indies Sugar Research Scheme. The authors wish to thank the Director, Professor L. F. Wiggins, for his interest in this work, and Mr. A.F. Thomson for his help in the design and construction of the solubility cell.

REFERENCES

1. Flourens. 1876. *Bulletin de la Societe Industrielle du Nord de la France*, No. 17.
2. Herzfeld. 1892. *Zeit. ver. Rubenz.—Ind.*, 42, 181.
3. Spencer and Meade. *Cane Sugar Handbook*, New York.
4. Honig. 1953. *Principles of Sugar Technology*, Amsterdam.
5. Bieselaar. 1939. *Bull. Assoc. Chim.*, 56, 85.
6. Kucharenko. 1928. *Plant. and Sugar Manufact.*, 80, 464, 484.
7. Verhaar. 1941. *Int. Sug. J.*, 43, 50.
8. Savinov. 1929. *Nauch Zapioki Sakharnoi Prom.*, 7, 416.
9. Grut. 1937. *Zuckerind. Czechoslav.*, 61, 345.
10. D'Orazi. 1938. *Ind. Sacchar. Ital.*, 31, 401.
11. Hruby and Kasjanov. 1940. *Int. Sug. J.*, 42, 21.
12. Taylor. 1947. *J. Chem. Soc.*, 1678.
13. Wise and Nicholson. *J. Chem. Soc.* (in press).
14. Dauncey and Still. 1952. *J. Applied Chem.*, 2, 399.
15. Emmerich. 1953. *La Cristallisation du sucre : Compte-rendu de la VIIme Assemblee de la C.I.T.S., Bruxelles.*
16. van der Linden. 1919. *Arch. Suikerind.*, 27, 591.
17. Jackson and Silsbee. 1924. *Tech. Pap. Bur. Stand.*, 18, 277.
18. Schukow. 1900. *Z. Ver. Zuckerind.*, 50, 313.
19. Rao and Gupta. 1940. *J. Ind. Chem. Soc.* (*Ind. and News Ed.*), 3, 49.

DISCUSSION

Mr. Kelly stressed the importance of having correct data for the saturation temperatures of sugar solutions. He referred to the work of Miss Taylor who had determined a series of solubilities with the aid of a saturascope of special design. The determination of saturation temperature was not easy at any time and the difficulties were particularly marked when dealing with solutions of pure sucrose. Extreme patience was required since temperature changes of the order of one degree per hour had to be adopted.

There was urgent need for information as to the solubility of sucrose at concentrations of solution having saturation temperatures above 100°C. Some determinations had beeen made and these suggested that the melting point of sucrose was in the range 150-160 °C. The melting point had been determined, in India, to be 188°C. by direct methods, and the speaker himself had determined the melting point at 186-188°C. In some of the literature the value 155°C. was quoted. This suggested that there might be, or might have been a metastable form of sucrose. As it was, there existed a discrepancy between the melting point values for sucrose as determined directly and from solubility data.

Mr. Vishnu drew attention to the fact that work carried out at the National Sugar Institute, Kanpur had shown that the saturation temperatures of sugar solutions could be determined from conductivity curves. This method would be restricted to solutions in which inorganic salts were present.

Dr. Doss enlarged on the statement made by Vishnu. In work on massecuites, he said, it had been found from conductivity studies that a period of some seven days was required for phase equilibrium to be established at a particular temperature. With more nearly pure solutions the attainment of equilibrium would doubtless be sooner.

The advantage of the conductivity method was that the saturation temperature could be approached on rising and falling temperature trends. Whilst he admired the efforts of the other investigators he felt that it was essential to approach the critical condition from both sides.

Dr. Doss indicated that it would appear that the inflexion in the conductivity curve at the saturation temperature was due to a change in the visocity characteristics of the solution.

In reply to Mr. Foster who asked about a detail of the equipment Dr. Doss replied that the sample was contained in a tube having a bore of 3 mm. The whole sample container was very small and would come to temperature equilibrium with the containing bath in about 10 minutes.

Dr. Doss pointed out that the accuracy of the conductivity method was limited by the fact that the curves for the conditions above and below the saturation temperature intersected at a small angle. He went on to mention that useful supplementary information could be derived from studies of the conductivity curves for isothermal conditions over the period necessary for equilibrium to be established between the solid and liquid phases.

In the absence of the author Dr. J. L. Clayton presented the following paper.

Paper

INTRODUCTION OF THE TRIPLE SEED SYSTEM TO A SUGAR FACTORY - FOR THE PRODUCTION OF RAW SUGAR FOR REFINING PURPOSES

Luis Lopez Carsolio
Ingenio del Mante. S. G. L., C. Mante. Tams

The manufacture of a good quality raw sugar at the least possible cost is, undoubtedly, a fundemental matter for a refined sugar factory producing its own raw sugar. The possibility of obtaining a raw sugar formed by large, low coloured crystals, that drain well and may be washed with little water. circumstances that may reduce the costs of refining and all the problems brought by low quality raws, made the Ingenio del Mante adopt the system which we have called of "Triple Seed", in the operation of its boiling house.

This system is basically the same one called "double einwurf" mentioned in paragraph 296 of the 2nd edition of Oliver Lyle's "Technology for Sugar Refinery Workers". It was found logical and easy to be applied and thought it might solve the old problem existent of lack of the equipment necessary to effect the double purging of the raw that passes to the refinery, which problem had become acute because of the official requirements for an improvement of the quality of the sugar produced in the country.

The system, in brief, is the following : Unwashed sugar coming from "C" strike or Third, is used, conveniently prepared as seed grain to form "B" strike or Second, and, at its time, the unwashed sugar from "B" strike is used as grain seed to form "A" strike or First. The sugar from this last strike, well washed, is the raw sugar passing to the refinery.

This system has been applied at the Ingenio del Mante (El Mante Sugar Factory) in the following way :

"C" strike is made, following Gillett's method for the preparation of strike footings using extra fine sugar powder as seed grain. This is introduced to the vacuum pan as magma, mingled with a saturated sugar solution.

In our case the quantity of sugar powder introduced is approximately seven kilograms and with these we form a grain strike of 75 to 78 apparent purity, using "A" washes and syrup. This strike gives footings for three "C" massecuites totalling about 3800 cu. ft. The part not used immediately from this grain strike, is passed to a grain container where it remains until needed. "C" strike is followed on each of these footings exclusively with "B" molasses. When finishing this strike it is discharged into an open crystallizer provided with stirring blades and water cooling-heating stationary coils.

Because of its relation to this matter, the form of controlling the centrifugal work for "C" strikes run into the crystallizers is herein mentioned. Former to the present arrangement the only factor taken into consideration for passing "C" strike to the centrifugals, was the time of permanence in the crystallizers. In other words, the crystallizers were rigorously centrifuged in the order they had been filled. Taking into account that curing time is not the only important factor in the exhaustion of a "C" strike in the crystallizer and that instead it is of the maximum importance to centrifuge the strike producing in a given moment, the lowest purity final molasses among all the available strikes, the following way of control has been used.

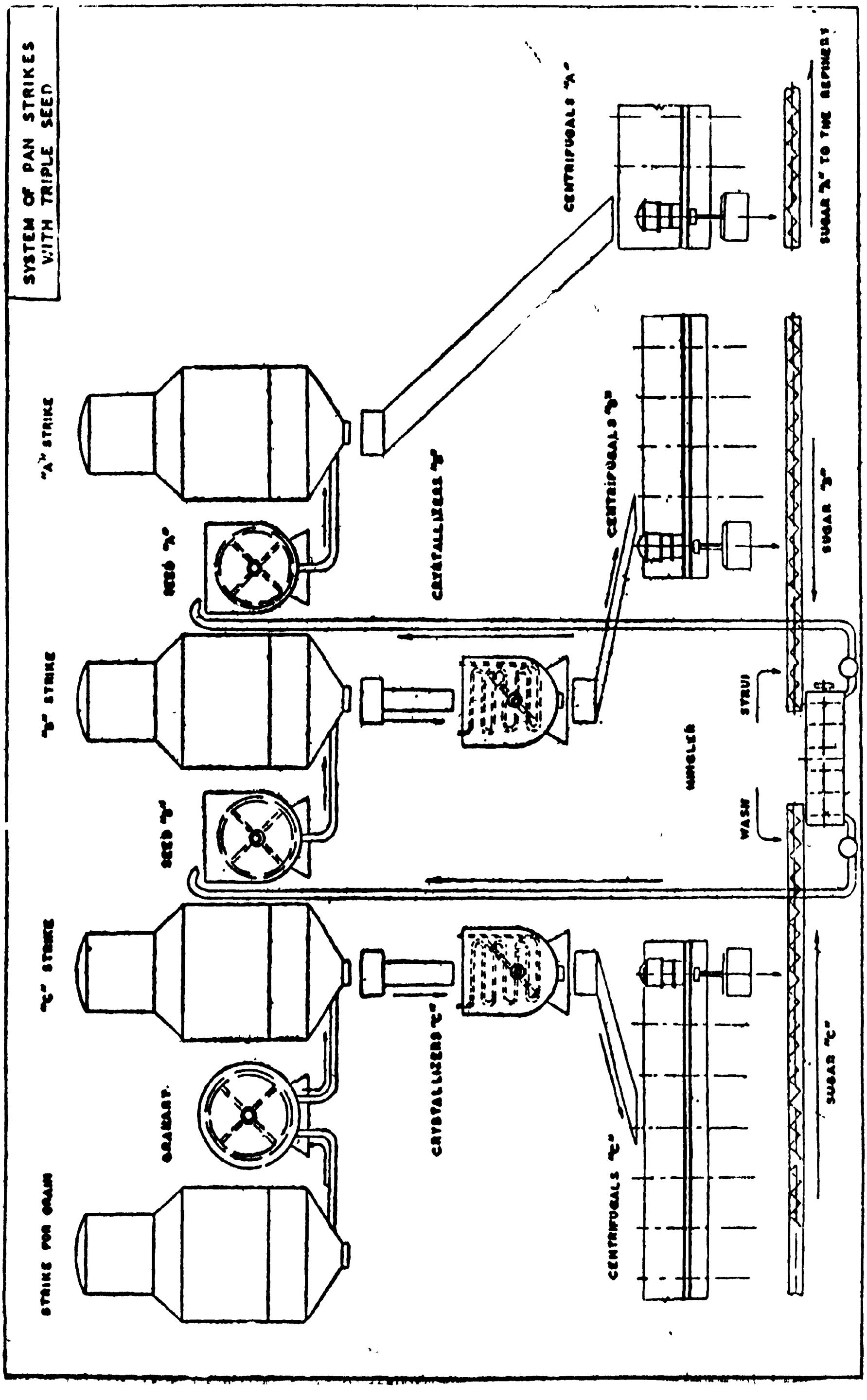
We take from eight to ten samples from a relative number of crystallizers and send them to the laboratory every eight hours. There, by means of a small centrifugal, the molasses of each crystallizer is separated, analyzing by purity. The analysis determines which is the crystallizer whose strike must be centrifuged because of having the lowest purity in the whole lot. A record of these analyses and the exhaustion history of each "C" strike are registered in a note book. Most of the times the strikes with more time in the crystallizers are the ones that logically appear with molasses of lower purities, however, the influence of viscosity, temperature, density, size and number of crystals is big in the exhaustion velocity and only in the way mentioned can these factors be taken into consideration, the arrangement allows the strikes more curing time for the strikes of lower exhaustion velocity in benefit of the factory's efficiency.

Continuing with the Triple Seed System, the unwashed "C" sugar is mingled with "A" washes and the resultant magma is deposited in a storage crystallizer provided with an agitator, from which the footings to make "B" strikes are taken. This, at its time, is made with the mentioned footing and finished with "A" molasses. It is passed from the vacuum pan to the crystallizer where it stays a little time before passing to the centrifugals.

The unwashed "B" sugar is mingled with syrup and the magma is passed to a storage crystallizer also provided with an agitator from where the footings to make "A" strikes are taken. These strikes are almost exclusively made with syrup and occasionally also carry "A" washes. The sugar from this "A" strike, well washed, passes to the refinery and is characterized because of its being formed by large crystals.

The attached drawing shows schematically the use of the mentioned system at the Ingenio del Mante.

The proven results in four consecutive crops show that this arrangement is superior to the one formerly used, consisting in crystallizing syrup and "A"



washes to obtain the footings, both for "C" and "B" strikes. These results may be simply resumed as follows :

1. No recirculation of molasses. This improves the factory efficiency and saves calories.

2. Graining is avoided, all strikes are made on seed grain. Consequently there is a better control in the operation of vacuum pans and an increase in the equipment's capacity.

3. The raw sugar passing to the refinery is well purged and washed, as the crystals are always of a good size. Among other advantages, we achieve mainly savings in active carbon and filter-aid, obtaining a sensible increase in the refinery's filtering capacity and an improvement in the quality of the product.

DISCUSSION

The Chairman commented that the triple seed system was an unusual one as far as the Indian Industry was concerned. As regards the suggestions that "C" strikes be not centrifuged in the order in which they were produced, but rather having regard to which had the lower purity, the Chairman said it would be better to obtain consistent results from each strike for exercising care during the boiling process.

Session II—Wednesday, 1st February, 11-15 A.M.

Dr. H.W. Kerr, *Chairman*

Dr. Takeo Yamane presented the following paper.

Paper

DECOMPOSITION OF INVERT SUGAR IN THE ALKALINE MEDIUM AND ITS EFFECTS UPON CANE SUGAR MANUFACTURE

TAKEO YAMANE

Japan Sugar Refineries' Association, Tokyo

The invert sugar content of cane juices is rather large and milk of lime is the main purification agent in the manufacturing process of raw sugar and plantation white sugar. The decomposition of invert sugar in the alkaline medium, therefore, is an old but ever-new theme for sugar chemists. The researches in this field by organic chemists (1), together with sugar chemists (2), are classified in the three groups ; (i) mutual transformation among sugars, (ii) formation of acids, and (iii) formation of coloured substances and its effect on the sugar manufacture.

The following subjects have been discussed in this paper :

(1) Decomposition of invert sugar in cane juices by the action of milk of lime,

(2) Formation of lactic acid and coloured substance, sugar-humic acid, in invert sugar solutions, and

(3) Properties and effects of sugar-humic acid.

THE DECOMPOSITION OF INVERT SUGAR IN CANE JUICES BY THE ACTION OF MILK OF LIME

In cane sugar factories the glucose ratio decreases from mixed juice to fine syrup owing to the alkali-decomposition of invert sugar; an average mean value of glucose ratio (3) for mixed juices of defecation factories (19 factories) and carbonatation factories (9 factories) is in Taiwan respectively 7.10 and 7.44, while that of fine syrups is 5.84 and 5.94. The decomposition of invert sugar amounts to respectively 17.8% and 21.5%.

The quantity of milk of lime used in cane sugar factories is about 5 ml. (15° Be'.) per 1 litre of mixed juice for defecation and 80ml. for carbonatation.

Effect of temperature.

When 1 litre of mixed juice was added with 20 ml. of milk of lime (CaO 3g.) and heated for 30 minutes at required temperatures under good agitation, the decomposition of invert sugar was found slight at under 45°C. while at over 50°C. it increased remarkably, as shown in Fig. 1. This critical temperature coincides with that (55°C.) for the De Haan process (4).

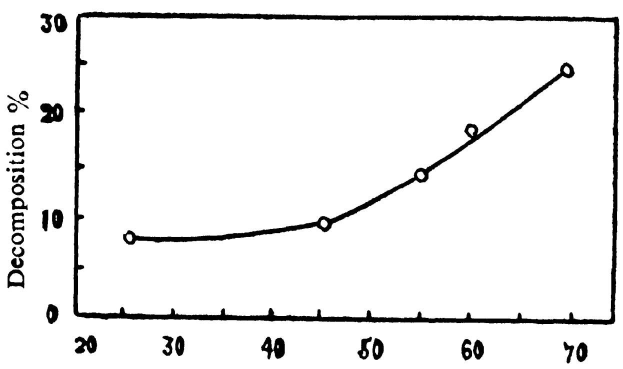


Fig. 1. Relation between temperature and decomposition %.

Effect of quantity of milk of lime used.

When 1 litre of mixed juice was respectively added with 20, 40, 60 and 80 ml. of milk of lime (15° Be'.) and heated for 30 minutes at 55°C., the decomposition of invert sugar naturally increased with the quantity of milk of lime added as shown in Fig. 2.

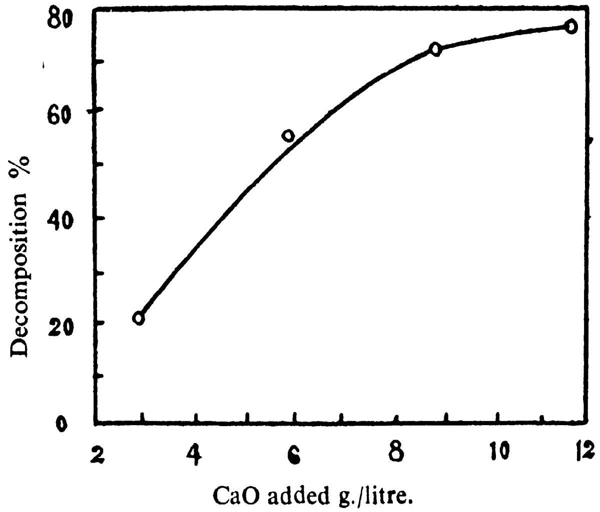


Fig. 2. Relation between quantity of milk of lime used and decomposition %.

ANALYTICAL DATA OF MIXED JUICES USED WERE AS FOLLOWS :

Sample No.	1	2	3	4	5	6	7	8	9	10	11
Bx.	17.2	16.7	16.9	16.3	16.6	17.2	16.7	15.3	16.8	17.9	18.5
Pol	15.4	14.3	14.7	13.9	14.1	14.9	13.9	12.9	14.7	15.9	16.7
Glucose-Ratio	3.32	5.86	5.25	6.13	6.76	6.34	7.08	3.80	4.43	3.96	2.63

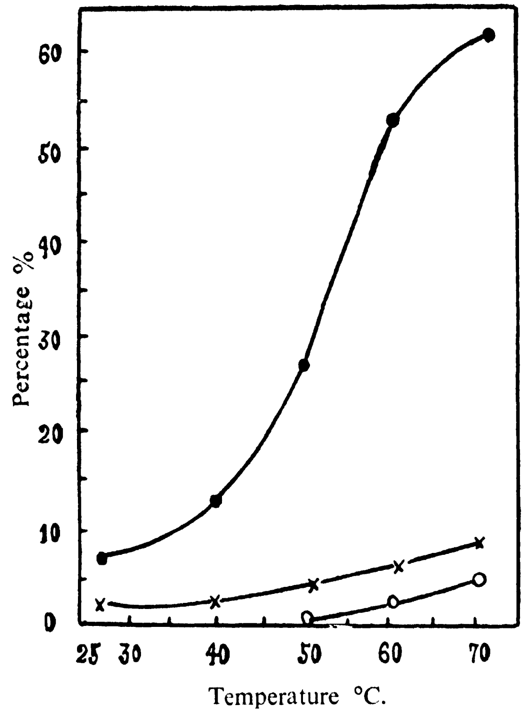
THE FORMATION OF LACTIC ACID AND COLOURED SUBSTANCE IN INVERT SUGAR SOLUTIONS

In the alkaline medium, D-glucose and D-fructose seem to take 1,2 enediol form and in the strong alkaline medium it shifts to 2, 3 enediol and further to 3, 4 enediol form. The last one splits into two molecules of glyceraldehyde and from this, through methylglyoxal, lactic acid is formed. The mechanism of colour fomation is considered in the next section.

As it is difficult to trace the formation of lactic acid and coloured substance in cane juices because of their complex composition, the invert sugar solution was prepared, as described later, and used for the following experiments.

Formation of lactic acid and coloured substance in invert sugar solutions.

6 ml. of milk of lime (CaO 0.9 g.) was added to 100 ml. of 1% invert sugar solution and the solution was heated for 30 minutes at required temperatures under good agitation. The quantity of decomposed invert sugar and lactic acid formed and coloured substance was determined as described later. As shown in Fig. 3 and Table I, the decomposition of invert sugar, the formation of lactic acid and coloured substance increased rapidly with temperature rise. At 60°C. lactic acid formed was 0.055g. in 100 ml. of the invert sugar solution and amounted to about 12% of the decomposed invert sugar, while the colour substance formed was 0.022g. and about 4% of the decomposed sugar.



●—● Decomposition % of invert sugar.
×—× Formed lactic acid % original invert sugar.
o—o Coloured substance % original invert sugar.

Fig. 3. Relation between temperature and decomposition of invert sugar, formation of lactic acid and coloured substance.

TABLE I

FORMATION OF LACTIC ACID AND COLOURED SUBSTANCE

(In 100 ml. of the original invert sugar solution 0.956 g. of invert sugar was contained)

	Per 100 ml. of the original invert sugar solution				Per original invert sugar in the solution			Per decomposed invert sugar
Temp.	Decomposed invert sugar g.	Lactic acid formed g.	Colour value of the solutions after treatment E_{600}(pH 7)	Colour substance formed g.	Decomposed invert sugar %	Lactic acid formed %	Colour substance formed %	Lactic acid formed %
Room temp. (27°C.)	0.0565	0.0160	0	0	5.91	1.67	0	28.32
40	0.1181	0.0183	0	0	12.35	1.91	0	15.45
50	0.2535	0.0318	0.0315	0.0046	26.52	3.32	0.48	12.52
(55)	(0.37)	(0.05)	(0.09)	(0.015)				
60	0.4998	0.0538	0.149	0.0216	52.29	5.62	2.26	10.75
70	0.5860	0.0808	0.319	0.0463	61.30	8.45	4.83	13.61

Lactic acid content in the molasses of carbonatation factories.

Lactic acid formed in the manufacturing process by the action of milk of lime is accumulated in the final molasses, causing increase of soluble lime salt in juices in the course of the process. The lactic acid content of final molasses of three Formosan factories was estimated and found to be about 1% as shown in Table II. In the Puerto Rican molasses 0.05% of lactic acid was found by E.K. Nelson (5).

TABLE II

LACTIC ACID CONTENT IN MOLASSES OF CARBONATATION FACTORIES

	A—Factory molasses	B—Factory molasses	C—Factory molasses
Lactic acid content %	1.24	0.93	0.70
	Analytical data of the molasses used		
Bx.	86.8	95.3	84.1
Pol	25.1	31.4	20.8
Red. sugar	23.1	16.1	20.3

Experimental.

(*a*) Preparation of invert sugar solution.

4.75g. of pure cane sugar was dissolved in about 75 ml. of water and this sloution was mixed with 11 ml. of 6 N H_2SO_4 and after 24 hours the solution was neutralized with milk of lime and filtered. The filtrate was diluted exactly to 500 ml. 100 ml. of this solution contained 1 g. of invert sugar.

(*b*) Determination of lactic acid content.

Lactic acid content was determined according to Shaffer-Friedemann's method (6); lactic acid in the test solution was oxidized to acetaldehyde by boiling with potassium permanganate and H_2SO_4 and acetaldehyde formed was absorbed in sodium bisulfite solution. After excess of Na-bisulfite was exactly oxidized by iodine solution, the combined acetaldehyde was made free from bisulfite by adding Na-bicarbonate solution and by titrating with 0.01 N Iodine solution, the quantity of bisulfite set free in the solution was determined. Lactic acid content was calculated from the titer thereof. As the presence of sugars and their decomposition products caused large estimation error, the greater part of such substances was removed from test solutions by adding the mixture of copper sulphate solution and milk of lime, according to the description of T. E. Friedemann (7).

After 100 ml. of the invert sugar solution was treated as described in (1), it was neutralized with H_2SO_4 and filtered. The filtrate was exactly diluted to 250 ml. 50 ml. of this solution was mixed with 30 ml. of copper sulphate solution (20%) and 30 ml. of milk of lime (20%). After shaking well for 30 minutes the mixture was filtered and the filtrate was diluted to 250 ml. Lactic acid content of 50 ml. of this solution was determined. When the same procedure was traced for the untreated, original invert sugar solution, there was found a minute quantity of substance which consumed 0.01N Iodine solution. This volume of Iodine solution was substracted as the correction value.

(*c*) Determination of colour-substance content.

As the colour value of Ca-salt solution of sugar-humic acid (1 g. in 100 ml.) was $E_{500}=6.89$ (pH 7), as described in the next section, the colour content of the solution was calculated from this value, estimating its E_{500}.

THE PROPERTIES OF COLOURED SUBSTANCE FORMED AND ITS EFFECT ON SUGAR MANUFACTURE

Reddish brown coloured substances are formed by the action of alkali on reducing sugars in hot solutions and because such coloured substances have many effects on the colour of sugar products especially in the case of white sugar manufacture, many researches were made by sugar chemists as cited above. The names like Saccharum Saure, Apoglucine Saure or Melassin Saure (8) were given to such coloured substances. As these substances, however, are not pure compounds but a mixture, it is better to name them "Sugar-humic acid" as a whole.

Preparation of sugar-humic acid.

100 gm. of cane sugar was dissovled in one litre of water and 210 ml. of 6 N HCl was added to this solution and after this solution was set aside for 24 hours at room temperature, the solution was neutralised with NaOH solution. When this invert sugar solution was mixed with milk of lime (25 g. of quick lime in 100 ml. of water) and heated for 1.5 hours at 70°C., lime was dissolved once in this solution but afterwards Ca-salt of sugar-humic acid was settled at the bottom of the flask. After this, precipitate was collected by filtration and washed with 2 litres of lime water, sugar-humic acid was isolated by suspending the washed precipitate in water and blowing CO_2 gas in it. The filtered sugar-humic acid solution thus made was added with basic lead acetate solution and the acid was set free again by decomposing the lead salt quantitatively with H_2SO_4, the excess of the latter being removed by adding Ba-Carbonate solution. After filtration sugar-humic acid solution was concentrated and dried in a vacuum dessicator. 4.5 g. of dry sugar-humic acid was thus obtained.

Chemical properties.

Sugar-humic acid is reddish brown powder ; it has acidic taste with a little bitter and astringent after-taste ; very hygroscopic and soluble in water, methanol and absolute alcohol ; when this acid was extracted with ether, about 2% of its weight was soluble in this solvent and the extracted substance was also an organic acid, soluble in water too.

(*a*) *Colour value and colour reaction* :—The colour of aqueous solution of sugar-humic acid is reddish brown ; its colour value increases with pH-value rise and it is very interesting that colour values of the salt-solutions of bi-valent-metal as Ca, Mg are larger than those of mono-valent-metal as Na, K, NH$_4$, while those of same valent metals are the same as illustrated in Fig. 4. Fig. 4 shows colour values E$_{500}$ (extinction coefficient for 500 $m\mu$) of 0.1% solutions of sugar-humic acid, their pH-values being raised respectively with KOH, aqueous ammonia and milk of lime, milk of magnesia. E$_{500}$ for 1% solutions at pH 7 are shown in Table III.

TABLE III

COLOUR VALUES OF SUGAR-HUMIC ACID SOLUTIONS

(pH 7, 1g. in 100 ml.)

Sample No.	1	2	3	Mean
Salt solutions of mono-valent metals Na, K, NH$_4$	6.35	5.25	4.47	5.36
Of bi-valent metals Ca, Mg.	8.15	7.05	5.46	6.89

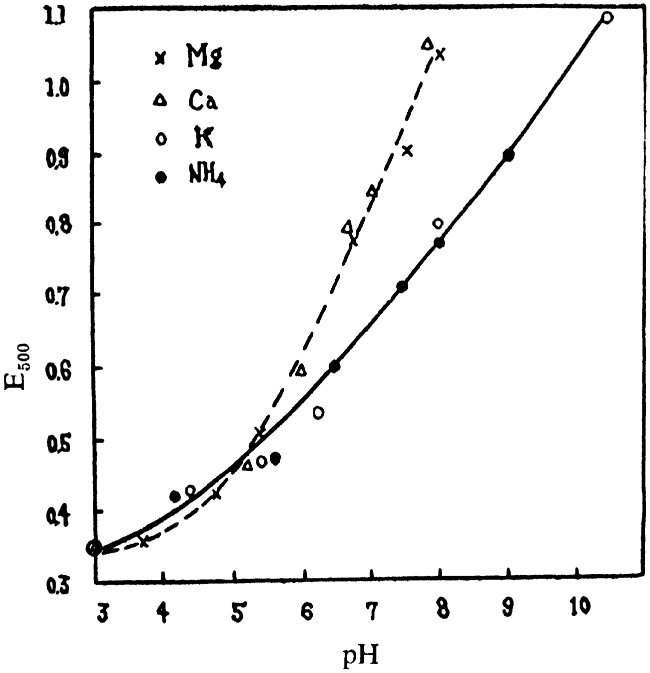


Fig. 4. Relation between colour values of sugar-humic acid solutions and pH.

If a drop of ferric chloride solution is added to sugar-humic acid solution its colour changes to brownish black. When Na-nitro-prussiate solution, NaOH, acetic acid solution is respectively and successively added to the above-said solution, its reddish brown colour is added with greenish blue tone and after standing overnight the blue lake is precipitated. These colourations are the same to the solution of the ether-soluble part of sugar-humic acid. From such colour reactions the ether-soluble part seems to contain "glucic acid", p-hydroxy acrylic acid, which was isolated as crystals in quite a minute quantity by E.K. Nelson and C.A. Brown (9) from the reaction mixture of dextrose and milk of lime.

(*b*) *Chemical composition.* According to the elementary analysis, the molecular formula for sugar-humic acid is $C_{18}H_{22}O_{11}$ (=414) as shown in Table IV.

TABLE IV

ELEMENTARY ANALYSIS OF SUGAR-HUMIC ACID

Sample No.*	1	2	3	4	5**	$C_{18}H_{22}O_{11}$ calc.
C %	52.67	51.05	51.08	52.91	52.49	52.15
H %	4.72	5.23	5.50	5.92	5.95	5.31
Ash %	0.99	1.32	0.78	0.33	0.52	

*All samples were prepared independently as described above.

**Sample No. 5 was the residue, ether-solubles being removed from No. 4.

When 0.385 g. of the acid (Sample No. 5) was dissolved in water and this solution was titrated with 0.1N NaOH by means of potentiometric titration, 0.90 ml. of the latter was required for neutralisation ; the equivalent molecular weight as mono-basic acid was calculated as 429, while the theoretical figure is 414.

Acetyl derivative of sugar-humic acid :

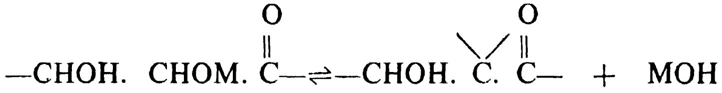
9.6 g. of sugar-humic acid (Sample No. 5, the ether-soluble part being removed) was mixed with 7 g. of anyhdrous Na-acetate, 50 g. of acetic anhydride and after the mixture was heated for 3 hours on the boiling water bath, the reaction mixture was poured out on broken ice; 9 g. of crude product was thus obtained; it was purified two times by recrystallisation from ethanol ; it was brown powder, soluble well in acetone, ethyl acetate and soluble in hot ethanol but insoluble in water ; the result of chemical analysis was as follows :

Elementary analysis : sample 0.0952 g.

found : CO_2 0.1968 g. H_2O 0.0469 g.
C % 56.33 H % 5.47
$C_{26}H_{26}O_{13}$calc. 57.11 4.76
Acetyl-group determination : sample 0.0968 g.
found : acetic acid 0.0423 g. 43.8%
$C_{18}H_{14}O_9(COCH_3)_4$ calc. 44.2

From this result it is able to assume the formula $C_{18}H_{18}O_9$ for the substance deacetylated from $C_{18}H_{14}O_9(COCH_3)_4$; this corresponds to the substance which is two molecules of water less than the original sugar-humic acid $C_{18}H_{22}O_{11}$; as the reagents for acetylation are dehydrating agents, it is probable that dehydration takes place during the acetylation reaction.

Consideration on formation of sugar-humic acid: according to the description of J.U. Nef (10), the reducing sugar in the alkaline solution is as metal salt in the following equilibrium.



$$-\text{CHOH. CHOM.}\overset{\overset{\text{O}}{\|}}{\text{C}}- \rightleftharpoons -\text{CHOH.}\overset{\diagdown\diagup}{\text{C.}}\overset{\overset{\text{O}}{\|}}{\text{C}}- + \text{MOH}$$

and one part becomes "Methylen Polymeren" $(-\text{CHOH.}\overset{\diagdown\diagup}{\text{C.}}\overset{\overset{\text{O}}{\|}}{\text{C}}-)\text{X}$, this is the coloured substance, dehydrated polymer. As mentioned above, the chemical formula for sugar-humic acid is $C_{18}H_{22}O_{11}$; this corresponds to the substance that is formed by removing $7H_2O$ from 3 molecules of hexose, while in the case of acetylation of sugar-humic acid 2 more molecules of water are removed further; thus the huminification seems to proceed by dehydration.

Effect of sugar-humic acid on the sugar manufacturing process.

As evident from the facts so far described, sugar-humic acid is formed in cane juices in the course of defecation or carbonatation process and its quantity formed in the latter case may be estimated from Table I to be at most. 0.022g. in 100 ml. of juices and colour value $E_{500}m\mu = 0.15$, while colour value $E_{500}m\mu$ of carbonatation juice (Bx. 15) is 0.08 at best and that of mixed juices (Bx. 15.2; filtered at 80°C.) is about 0.40—0.47; a serious influence may be effected by sugar-humic acid formation on the colour of purified juices as cited often by many sugar chemists. However the greater part of sugar-humic acid formed seems to be removed by adding milk of lime to high pH-values of juices as seen in Table V.

TABLE V

DECOLOURISATION OF SUGAR-HUMIC ACID SOLUTIONS WITH MILK OF LIME

Original solution Colour value $E_{500}m\mu$	Decolourised solution $E_{500}m\mu$	Decolourisation %
0.748	0.102	85
1.50	0.21	86
1.87	0.27	86
2.24	0.28	87
2.62	0.31	88
2.99	0.32	89
3.36	0.33	90

(pH values of solutions for colour determination were made to pH8).

1.5 ml. of 15° Be'. milk of lime (CaO 0.222 g.) was added to each 100 ml. of solutions containing varied amounts of sugar-humic acid and after 10 minutes' agitation at 60°C., decolourisation was estimated for the filtered solutions.

Almost the same result was obtained in the case of decolourisation by carbonatation using the same quantity of milk of lime.

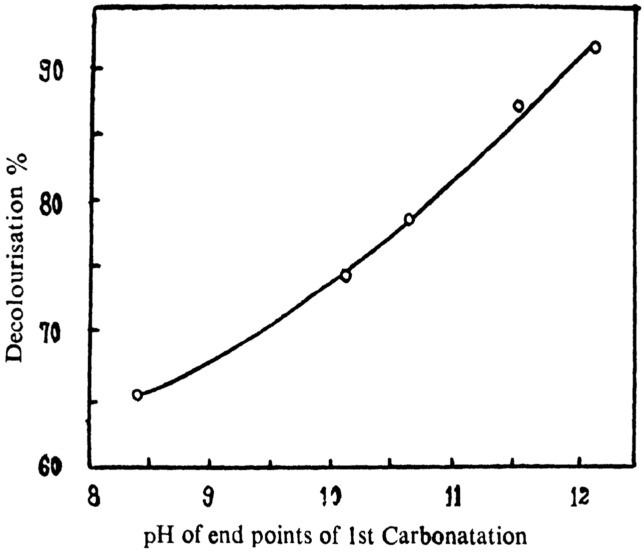


Fig. 5. Relation between removal of sugar-humic acid and pH values of end points of the first carbonatation.

When pH-values become lower sugar-humic acid once removed seems to go again into solution as seen in Fig. 5 ; at pH 9.5 of the end point of the first carbonatation decolourisation is only 70%; it is also estimated from this figure that in the case of defecation juices (pH 7) removal of the formed colour may be about 60% at best.

Despite the fact that as to the colour of carbonatation juices there are optimum pH values for the end point of the first carbonatation between pH 11-12 (11), owing to oversaturation for seeking easier filtration the colour of factory juices is 50-100% higher than that of carbonatation juice made in laboratory, paying careful attention to that optimum pH values as shown in Table VI. This colour increase in factory-carbonatation juice is due to desorbed sugar-humic acid, together with desorbed colouring matters native to cane.

TABLE VI

COLOUR INCREASE IN FACTORY-CARBONATATION JUICES

Colour Value E_{500} $m\mu$

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean	Ratio
A-FACTORY (Nov. 29—Dec. 19, 1935)																
Laboratory juices	0.48	0.42	0.54	0.63	0.52	0.55	0.61	0.49	0.46	0.62	0.54	0.55	0.46	0.47	0.52	1
Factory juices	0.82	0.76	0.88	0.77	0.83	0.92	0.87	0.82	0.90	0.95	0.92	0.89	1.2	0.87	0.88	1.7
A—FACTORY (Jan. 31—Mar. 4, 1936)																
Laboratory juices	0.54	0.45	0.37	0.37	0.34	0.40	0.43	0.36	0.38	0.43	0.50	0.53	0.39	0.40	0.42	1
Factory juices	0.62	0.83	0.55	0.55	0.53	0.64	0.96	0.52	0.65	0.73	0.86	0.67	0.61	0.67	0.67	1.6

$E_{500} m\mu = E_{500} m\mu x 100 / Bx.x(sp.gr.)$

When cane sugar crystals grew in sugar solutions containing sugar-humic acid, the absorbed quantity of the latter by growing sugar crystals was almost in linear relation to the quantity of the latter in mother liquors (11) and when 0.424 g. of sugar-humic acid was added to 1 litre of 60% sugar solution and about 300 g. of sugar was crystallised out therefrom at pH 6, about 0.01 g. of the colour substance was absorbed by 100 g. of sugar crystals, while if the colour substance was huminificated further, the absorbed quantity by sugar crystals became about twice as much (11). As to the effect of pH values of mother liquors, the absorbed quantity of sugar-humic acid by crystals increased remarkably under pH 7 (11).

SUMMARY

Experiments were carried on the decomposition of invert sugar, formation of lactic acid and sugar-humic acid. The chemical properties and composition of the latter were investigated and the effects on sugar manufacture were considered.

1. In cane sugar factories about 20% of invert sugar is decomposed by heating limed juices. The decomposition was remarkable at over 50°C. and with increase of milk of lime used.

2. Lactic acid and sugar-humic acid were formed in invert sugar solutions by heating with milk of lime ; their formation increased with the temperature rise. At 60°C. decomposition of invert sugar and formation of lactic acid and sugar-humic acid were respectively about 2, 1.7, 4.7 times as much in comparison with those at 50°C. Colour increase at over 50°C. was striking.

3. Lactic acid content in molasses of carbonatation factories was determined and found to be 0.70—1.24% of molasses.

4. Chemical properties and composition of sugar-humic acid were as follows :—

Reddish brown powder, very hygroscopic, soluble in water, methanol, absolute alcohol. Colour value of solutions of bi-valent-metal-salts was larger than that of mono-valent-metal-salts whereas that of same valent metal salts was the same. The colour of the solutions changed to brownish black by adding drop of ferric chloride solution. Chemical formula was $C_{18}H_{22}O_{11}$ while acetyl derivative was $C_{18}H_{14}O_9(COCH_3)_4$.

5. Sugar-humic acid is formed by dehydration and polymerisation from hexoses in alkaline medium and its huminification proceeds by further dehydration.

6. Sugar-humic acid solution was decolourised well at high pH values by adding milk of lime, but at lower pH values sugar-humic acid once absorbed by lime particles or Ca-carbonate precipitates again went into solution ; thus the oversaturated carbonatation juices contained much colour.

7. Absorbed quantity of sugar-humic acid by growing crystals increased remarkably when the colour substance was huminificated further and also it increased as pH-values of mother liquors were lowered.

ACKNOWLEDGEMENT

The author wishes to express his hearty thanks to Mr. M. Kitani and Mr. M. Abe for their earnest assistance in these experiments.

REFERENCES

1. Nef, J. U. *Annalen*, 357 (1907) 214 ; 376 (1910) 1 ; 403 (1914) 204.
   Shaffer, P. A. and Friedemann, T. E. 1930. *J. Biol.* Chem., 86 ; 345.
2. Dekker, K. D. 1931. *Archief* v. *Suikerind, Mededeelingen*, 19, 89.
   Spengler, O. and Todt, F. Wirtschaft, *Z.* 1939 and 1941. *Zuckerind*, 589,19.
   Heinemann, B. 1940. *Centralbi. Zuckerind.*, 469, 493, 509.
3. Tseng, Ray. H. 1954. *Taiwan Sugar*, Dec. 21-4.
4. Harloff, W. H. T. and Schmidt, H. 1926. *Handleiding v. Tropische Witsuikerfabricatie* (*Amsterdam*) p. 17.
5. Nelson, E. K. 1929. *J. Am. Chem. Soc.*, 51, 2808-10.
6. Friedemann, T. E. ; Cotonio, M. and Shaffer, P. A. 1927. *J. Biol. Chem.*, 73, 335.
7. Friedemann, T. E. 1928. *J. Biol. Chem.*, 76, 75.
8. Beilsteins Handbuch der Organischen Chemie, 4 Aufl., I, S. 896.
9. Nelson, E. K. and Brown, C. A. 1929. *J. Am. Chem. Soc.*, 51, 830.
10. Nef, J. U. 1914. *Annalen*, 403, 224.
11. Yamane, T. 1954. *Proc. Research Soc. Japan Sug. Refn. Techn.*, 3, 152. 23*rd Proc. Sug. Techn. Assoc. India*, 195.

DISCUSSION

Prof. K. S. G. Doss said that studies on colour development at the National Sugar Institute, Kanpur had shown that it was slow at first and then very rapid. This suggested an autocatalytic reaction.

Mr. C. Davis said that the varying figures for lactic acid in molasses given in Table II suggested that lactic acid might be produced by microbiological action as well as by chemical processes.

Dr. S. Mukherjee then presented the following paper.

Paper

CATION EXCHANGE RESINS FROM SUCROSE—PART I

PREPARATION AND OPERATING CHARACTERISTICS

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National Sugar Institute, Kanpur

Since the pioneering work of Adams and Holmes (1) and Bhatnagar and co-workers (2) on the synthesis of ion-exchange resins, rapid progress has been made in the improvement of these resins for use in a variety of chemical processes. Synthesis of resins showing marked ion-exchange properties from a wide variety of raw materials has clarified the nature of the exchange reaction and has made it possible to define the essential requirements for a good exchange material.

Cation exchange resins are high molecular weight polyacids which are virtually insoluble in aqueous and non-aqueous media. The acid or acids which constitute the exchange groups are usually the sulfonic, carboxylic or phenolic type and are substituents in the resin structure, usually of the phenol-aldehyde type (3). Their exchange properties can be ascribed as being entirely due to the exchange of various cations for the dissociable hydrogen ion. Resins of phenol sulfonic, phenol formaldehyde have been prepared and are commercially available, which contain about 10% of sulphur and a corresponding exchange capacity of 3.1 moles per gram.

Most of the cation-exchangers available in the market, having a sulfonic acid group, are prepared by the condensation of o- and p-phenol-sulfonic acid with formaldehyde (4,5). Holmes (6) in 1937 had shown that insoluble resins suitable for use in the treatment of water by an ion exchange, can be prepared by condensing m-phenylene-diamine with mono—or disaccharide, like sucrose. Work (7) carried out at the National Sugar Institute, Kanpur for a number of years have shown that insoluble resins could be prepared by the condensation of phenol with sucrose or molasses, suitable for making moulding powder for thermosetting plastic and with that experience it was thought practicable to prepare a cation-exchange resin by the condensation of sucrose with phenol sulfonic acid. The present paper deals with the preparation of sulfonic type cation-exchange resins by the condensation of sucrose with varying amounts of phenol-sulfonic acid at different temperatures and determination of optimum conditions for producing a resin of maximum capacity with improved performance.

When a cation-exchange resin is synthesised, one of the requisites of its characterisation is the knowledge of the ionogenic groups present and the variation of the replacable hydrogen with pH. This can be best determined by the titration curves of the resin in the hydrogen form as the titration curves are characteristic of the ionogenic groups present in the resin (8, 9). The titration curves of a synthetic resin in conjunction with known principles of organic synthesis could be a useful tool for elucidation of the structure of the resin. The replacable hydrogen can also be determined by other methods, such as, the determination of ash in the salt form of the resin and the limiting exchange with salt solutions (10). The behaviour of ion-exchange resins in the dynamic system and the estimation of the break through capacity (11) from that, also furnish useful information especially for design purposes.

The study of exchange properties of cation-exchange resins synthesised in the laboratory has shown that resin prepared by the condensation of sucrose with phenol-sulfonic acid in the ratio of 1 : 1 at a temperature of 130°C. (hence forth known as CS 130-1) possesses better physico-chemical properties with a good exchange capacity. The operating characteristics of the resin CS 130-1 were also determined in the sodium hydrogen cycle,

EXPERIMENTAL

Sulfonic acid cation exchangers were prepared by the reaction of sucrose and phenol-sulfonic acid in different proportions and at different temperatures, in which a product usually water was formed along with the polymer.

Preparation of Resin CS 130-1. Sucrose (50 gms.) was added to phenol-sulfonic acid (151.5 ml. of 33.0% i.e., in the ratio 1 : 1) in distilling flask and the mixture was heated on wax bath at 120°C., till most of the water distilled over, and the product further heated for three hours at 130°C. under reduced pressure, till a hard shinning resin was left in the flask. The resin was crushed (20-60 mesh), repeatedly washed with hot distilled water to remove any caramalized material, and fine particles and dried in air.

Regeneration. For the regeneration, the resin was soaked in distilled water and transferred to a glass column (Pyrex) with glass wool at the bottom. A large quantity of 5.0% hydrochloric acid was passed slowly (15-20 ml./mt.). The resin was then washed with distilled water till free of chloride ions ; exhausted with sodium chloride solution (amount and strength equivalent to that of hydrochloric acid) and washed again. The cycle of regeneration and exhaustion was repeated thrice. The regenerated (hydrogen form) resin was finally washed with distilled water, till free of chloride ions. The regenerated resin was taken out, air dried and stored in a glass bottle.

The procedure adopted for the preparation of other resins in laboratory was similar to the above, except with variable amounts of sucrose and phenol-sulfonic acid and at different temperatures. The regeneration of resins were followed as mentioned in the case of CS 130-1.

Moisture. Known amounts of air dried resins were taken in weighing bottles (pre-heated to constant weight) and dried at 105°C.±2°C. in an electrically heated air oven, and the moisture percentage determined. The results were within 16-27%.

Ash (12). Known amounts of air dried resins of known moisture percentage were taken in the crucibles (pre-heated to constant weight), impregnated each with 1.0 ml. of sulphuric acid and heated gently until the carbonization was complete. These were then kept in a muffle furnace maintained at about 700°C. (a dull red heat) until white ash remained. These were again moistened, with 1.0 ml. of sulphuric acid and heated for a short time to a constant weight. The percentage of ash was within 0.15-0.18.

Titration curves. As the resins were in hydrogen form, titration curves could be utilized for the exchange capacity. Titration curve for the resin (CS 130-1) was obtained and found to be similar to those of Mattson (13), Topp and Pepper (loc. cit.). Mukerjee and Sen Gupta (14), and Shah and Bafna (15). The curve was in agreement with the fact that exchange capacity of resins depend on the ionic strength at the same pH.

The sample of resin (CS 130-1, 0.5 gm. oven dried) was added to each ser of bottles (capacity 60 ml.). To each bottle 50 ml. of different concentration sodium hydroxide with a fixed concentration of sodium chloride was add (5 ml. N/20 NaCl). The bottles were allowed to stand for 24 hours at roc temperature with intermittent shaking for equilibrium and the pH of the decant liquid determined in each case with Beckman pH meter. The capacity w calculated from the titration curve at pH 7.

Limiting Exchange Value. 50 ml. of normal barium chloride soluti was added to known amount of air dried resin (CS 130-1) in a stoppered bot and kept for 24 hours at room temperature to attain equilibrium. The liqu was decanted and acidity in a portion was determined by titration with a standa sodium hydroxide solution. The amount of the acid liberated in this case ga the capacity.

Ash from the salt (Barium) form. The barium salt resin (CS 130-1) obtain in limiting exchange value was washed free of barium ions and chloride ions a dried at 105°C. ± 2°C. in an electrically heated air oven and percentage moistu determined as before. Known amount of the barium salt resin (CS 130-1) w then ignited in a crucible (pre-heated to a constant weight) first gently and th strongly. To the white ash a drop of sulphuric acid (A. R.) added and ag heated to a constant weight. From the weight of the ash (Barium sulphate), t capacity was calculated.

Capacity by the dynamic system. In this case an excess of normal sodiu chloride solution was passed through a known amount of air dried re (CS 130-1). The total effluent was titrated for acid with standard sodium hydroxi solution. The total acidity obtained gave the capacity of the resin.

Table I gives the results for the available replaceable hydrogen milli equivalent per gram of oven dry resins (dried at 105°C. ± 2°C.) obtain by the limiting exchange value method.

TABLE I

Sucrose Phenol Sulfonic acid Ratio	Name of the resin	Temp.	Capacity in m.eq./gm. oven dry resin by limit exchange value meth
1 : 1	CS 120-1	120°C	1.54 m. eq./gn
1 : 1	CS 130-1	130°C	1.60 „
1 : 1	CS 140-1	140°C	1.35 „
1 : 1	CS 150-1	150°C	1.20 „
1.5 : 1	CS 120-2	120°C	1.37 „
1.5 : 1	CS 130-2	130°C	1.30 „
1.5 : 1	CS 140-2	140°C	1.27 „

The capacity data obtained using the limiting exchange value method clea bear out that resin CS 130-1 exhibits the highest capacity.

With a view to compare the exchange capacity of resin by different methods a detailed study of the resin CS 130-1 was carried out. The column performance of this resin (CS 130-1) was also studied.

The results obtained of the resin CS 130-1 are given below in Table II.

TABLE II

CAPACITY OF CATION EXCHANGER CS 130-1 BY DIFFERENT METHODS

Method		Capacity in m. eq./gm. (oven dry resin)
(a)	By titration curve in the presence of NaCl at pH 7	1.61 m. eq./gm.
(b)	By estimation of the limiting exchange with $BaCl_2$ solution	1.60 ,,
(c)	By determination of ash (as $BaSO_4$) from the barium salt of the resin	1.57 ,,
(d)	By passing a solution of N NaCl through the column of resin and determining the acidity of the effluent	1.66 ,,

Column performance :—The column exchange characteristics of any ion-exchange resin are by far the most important criterion in their evaluation. Although it is impossible for any evaluation technique to include the performance for all possible ion pairs, the performance of cation exchanger in the hydrogen and sodium cycle affords an excellent insight into the utility and economy of an exchanger. In hydrogen cycle, hydrogen ions are exchanged for sodium ions. Kunin (loc. cit.), Shah (et al) (15), (16), (17) have described in detail the operating characteristics of a number of Amberlite resins and discussed the effects of such variables, as flow rate, bed length, concentration of the influent, level of regeneration, etc.

The operating characteristics of the resins (CS 130-1 and Duolite C-3H) were determined in the sodium hydrogen cycle. The experiments were carried out in glass column (Pyrex) and the operational data were as follows :—

TABLE III

OPERATIONAL DATA FOR CS 130-1 AND DUOLITE C-3H

	Particulars	CS 130-1	Duolite C-3H
1.	Length of glass column (Pyrex)	50 cm.	50 cm.
2.	Diameter of glass column (Pyrex)	1.9 cm.	1.6 cm.
3.	Bed volume of regenerated settled and drained resin	68.66 ml.	52.24 ml.
4.	Weight of the resin (dried at 105°±2°C.	22.0 gms.	19.0 gms.
5.	Regenerant	N HCl	N HCl
6.	Flow rate for adequate regeneration	2-3 ml./mt.	2-3 ml./mt.
7.	Distilled water required for rinsing	2-3 litres	2-3 litres
8.	Influent	0.01 N NaCl solution	0.01N NaCl solution
9.	Rate of effluent	80 ml./mt.	80 ml./mt.

The amounts of regenerant (N HCl) for regeneration were calculated from the bed volume of the resins for getting the desired regeneration level m. eq./ml. It was then washed with distilled water till free of chloride ions. The influent

(0.01N NaCl) was passed through the resin column. Successive portions of 250 ml. each were collected and were titrated against standard sodium hydroxide solution. The concentration of the cycle was plotted as volume effluent versus percentage sodium exchanged at different regeneration levels.

At the end of the cycle, the resin was back washed and regenerated as before.

In Table IV and V are given the data obtained from the sodium hydrogen cycle of the resin CS 130-1 and Duolite C-3H.

TABLE IV

CAPACITY OF THE RESIN CS 130-1

Total capacity of the Resin CS 130-1 at Regeneration level m. eq./ml.									
1.60		1.30		1.0		0.7		0.364	
m eq./gm.	m.eq/ml	m.eq./gm.	m.eq./ml.	m.eq./gm	m.eq/ml.	m.eq/gm.	m.eq./ml.	m.eq./gm.	m./eq/ml
1.31	0.421	1.30	0.419	1.30	0.419	1.27	0.408	0.98	0.316

TABLE V

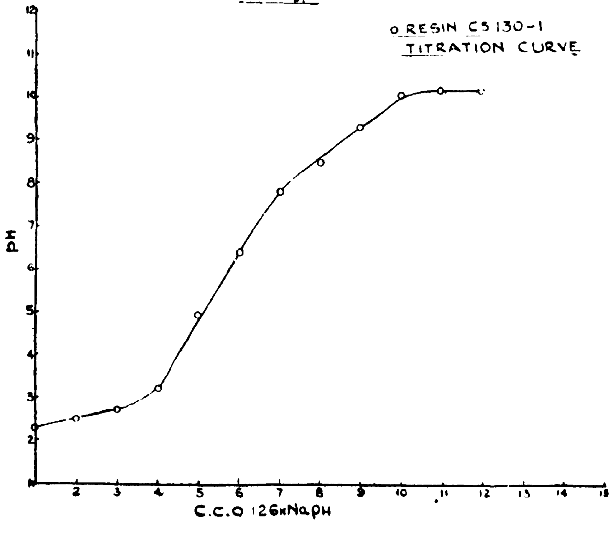
CAPACITY OF THE RESIN DUOLITE C-3H

Total capacity of the Resin Duolite C-3H at Regeneration level (m.eq./ml.)									
1.60		1.30		1.0		0.70		0.40	
m.eq./gm.	m.eq/ml.	m.eq./gm.	m.eq/ml.	m.eq./gm.	m.eq./ml.	m.eq./gm.	m.eq./ml.	m.eq/gm	m.eq/ml
2.33	0.849	2.33	0.847	2.08	0.759	1.82	0.66	1.25	0.449

DISCUSSION

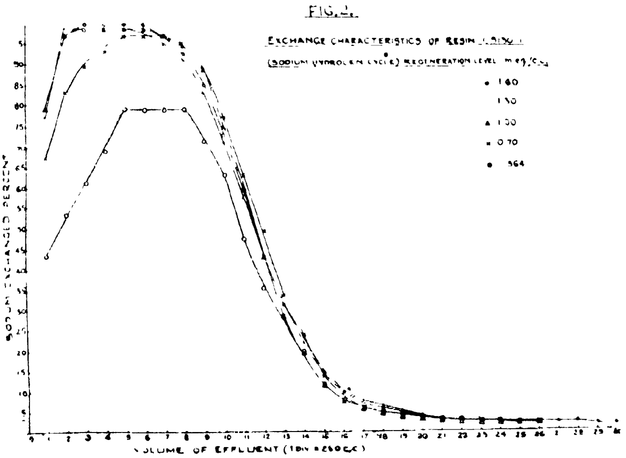
Titration curve. Titration curve of the resin (CS 130-1) (Figure 1) with 5 ml. N/20 NaCl indicate that the active group at low pH are of sulfonic type

FIG 1.

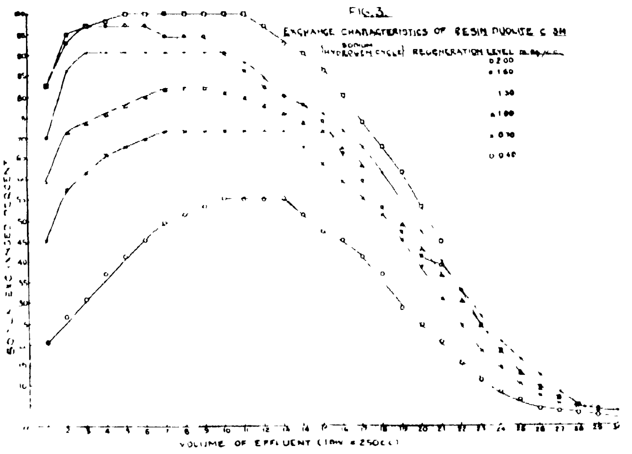


i.e., 2—4 pH and above 10 pH those of hydroxyl type. This view is also supported by the titration curves of Shah (loc. cit.), Kunin and Myres (loc. cit.), Topp and Pepper (loc. cit.).

Sodium hydrogen cycle. The column performance of the resins (CS 130-1 and Duolite C-3H) in sodium and hydrogen cycle is consistent with the equilibrium and rate data. The resin (CS 130-1) exchanged almost 100% of the Na ions at a regeneration level of 1.60 m.eq./ml. of the resin (Figure 2). Similar exchange was obtained at regeneration level 1.30 m.eq./ml. and 1.0 m.eq./ml. Even at a regeneration level 0.70 m.eq./ml., the exchange was 97% of the Na ions. Still lower regeneration level 0.364 m.eq./ml. the percentage of the Na ions exchanged was below the break through point.



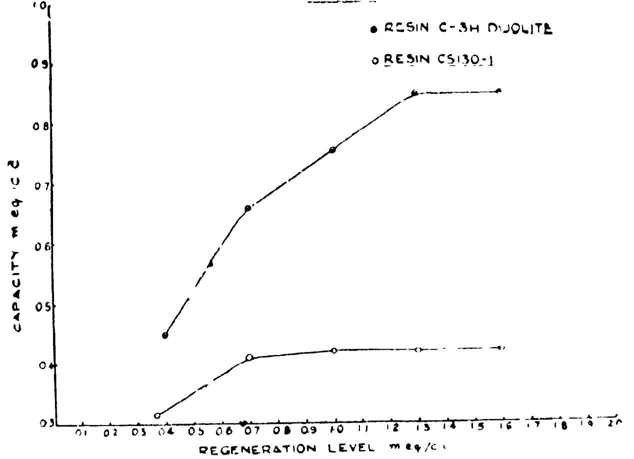
The resin Duolite C-3H exhibits similar exchange characteristics (Fig. 3). 100% of the Na ions exchange was obtained at regeneration level 2.0 m.eq./ml.



At the regeneration levels 1.6 m.eq./ml. 1.3 m.eq./ml. the percentage of Na ions exchanged was 97.

The plot of regeneration level against capacity as shown in (Fig. 4) shows an increase in capacity upto a regeneration level of 1.0 m.eq./ml. of the resin (CS 130-1) after which the increase was negligible. In the resin Duolite C-3H an increase in capacity upto regeneration level of 1.30 m.eq./ml. was obtained, after which the increase was negligible.

FIG 4



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REFERENCES

1. Adams, B.A. and Holmes, E.L. 1935. *J. Soc. Chem. Industry* 54 ; I.T.
2. Bhatnagar, S.S. and Workers. *J. Ind. Chem. Soc.* (1936) 13 ; 679, (1939) 16 ; 241, 261, (1940) 17 ; 361, (1941) 18 ; 447.
3. Myers, R.J. 1941. *Advances in Colloid Science Vol. I. Inter Science Publishers Inc. New York.*
4. Wassenegger, H. and Jaeger, K. 1940. (*I-G Farben Industrie*) *U. S. Patent* 2, 204, 530.
5. Bauman, W. C. 1946. *Industrial and Engineering Chemistry* 47.
6. Holmes, E.L. and United Water Softner Ltd. Sept. 20,1937. British patent 472, 404.
7. Mukherjee, S. and Srivastava, H. C. 1948-54. *Annual Reports of National Sugar Institute, Kanpur* & 1954 *Proceedings of Sugar Technologists Association of India* p. 50.
8. Topp, N. E. and Pepper, K. W. 1949. *J. Chem. Soc.* 3299.
9. Gregor, H. P. and Bregman, J. I. 1948. *J. American Chem. Soc.* 2370.
10. Hymann and O'Donnell. 1949. *J. Coll. Sci.*, 4 ; 395.
11. Kunin, R. and Myers Robert, J. 1950. *Ion Exchange Resins* (*Wiley, New York*), 69-74, 76-87, 90-99.
12. Methods of chemical control for cane sugar factories and gur refineries. Published by Sugar Technologists' Association of India, Kanpur.
13. Mattson, S. 1942. *Ann. Agr. Coll. Sweden*, 10 ; 56-73.
14. Mukherjee and Sen Gupta. 1950. *Science Culture*, 15 ; 1325.
15. Shah, H. A. and Bafna, S. L. 1952. *J. Indian Chem. Soc.* Vol. 29 No. 3 and No. 8.
16. Shah, H. A. and Govindan, K. P. 1955. *J. of Scientific and Industrial Research.* Vol. 14*B*, No. 5, p. 222-229.
17. Shah, H. A., Pai, M. U. and Bafna, S. L. 1952. *J. of Scientific and Industrial Research, V.* 11 *B No.* 4. p. 134-136.

Mr. D. R. Parashar then presented the following paper.

Paper

CHARACTERISTICS OF INDIAN CANE JUICES IN RELATION TO THEIR BEHAVIOUR DURING CLARIFICATION IN THE SULPHITATION SUGAR FACTORIES

D. R. PARASHAR
National Sugar Institute, Kanpur

INTRODUCTION

India is a vast country having highly divergent climatic and soil conditions with multifarious varieties of sugar cane. Apart from wide differences in the climatic, soil and cane varietal conditions, even some disparity is caused in the quality of cane as a result of the mode of cane transportation which differs from factory to factory. As such no particular variety of cane or a cane belt can serve the purpose for a study of the characteristics of Indian cane juices. Moreover as a result of the protection granted to the sugar industry in 1932, a vast expansion in the number of sugar factories occurred mainly in Northern India and a majority of sugar factories adopted the sulphitation process of juice clarification.

To start with when the sugar industry in India was still in its infancy, an attempt was made to follow a pattern of the system of clarification on a study of the characteristics of cane juices in foreign countries. The result was that in view of certain differences in the Indian cane juices, there was no uniformity in the methods of working in the sulphitation plants and a lot of difficulty was experienced in the settling and filtration of juices. Accordingly, a general study of the main characteristics of cane juices was undertaken by the author in relation to the difficulties that were experienced in the settling and filtration of juices in the sulphitation sugar factories. This study was confined to sugar factories located in Northern India and wherever possible, it was extended to some of the sugar factories in other tracts as well. The present publication is a review of these studies and their practical applications since such problems are of particular interest to all the cane countries. This paper is therefore being presented to initiate discussion on this subject.

CHEMICAL COMPOSITION OF RAW JUICE AND THE BEHAVIOUR OF DIFFERENT CONSTITUENTS DURING CLARIFICATION

To study the influence of soil on the chemical composition of raw juice obtained from the mixed commercial varieties of sugar cane and the behaviour of different constituents of cane juice during the process of clarification, a few sugar factories were selected in different tracts of U. P. and the data were collected under their actual operating conditions. The samples of raw juice and their corresponding clarified juice obtained after usual liming and sulphitation were analysed for their ash content and the carbonated ash of these juices was analysed for its different constituents such as, silica, iron and alumina, calcium, magnesium, alkali, sulphate, phosphate and chloride. These are given in Table I. Although a good deal of diversity exists in the percentages of the constituents of ash in the cane juices obtained in different countries, yet a few figures, as reported in some of the recent publications 2, 3, are given in Table IA.

From the figures given in Table I the following conclusions can be drawn.

1. The ash percent raw juice in India is fairly high and varies from 0.4 to 0.7 percent as against the range of 0.2 to 0.6 percent mentioned by Davies (4) leading to the conclusion that our soils are more saline in character.
2. Some of the sugar factories show an increase in ash content from mixed to clarified juice thus indicating that most of the inorganic constituents of the raw juice escape to the clarified juice and rather there is an addition of some of the constituents as a result of defective clarification.
3. The phosphate content in the ash of raw juice varies from 11 to 17 percent which is higher than that observed in other countries and particularly in P. O. J. varieties of cane indicating that these juices are not deficient in phosphates. Their presence in the clear juice is determined by the degree of liming used in clarification. Those factories in which the degree of liming has been properly adjusted show that the phosphates have been precipitated from the raw juice to a fairly large extent. But if the juice is underlimed, the phosphate escapes to the clarified juice possibly in the colloidal state and thus there is no appreciable difference in the phosphate content of raw juice and clarified juice.
4. The percentage of chloride is small i.e., 3—5 percent which is lower than that in other countries and the same practically persists in clear juice.
5. The amount of sulphate in the raw juice is extremely high i.e., 35—38 percent ash as compared with that in the cane juices of other countries indicating that the Indian soils are sufficiently rich in this constituent. The same, however, persists in clarified juice indicating that if any portion of sulphate has been precipitated during clarification the same has been replaced by sulphites or bisulphites during sulphitation.
6. The calcium content in the ash of raw juice is 4 to 5 percent which is slightly lower than that in Cuba or Louisiana but higher than that in Java. But this has increased to 14 to 17 percent in the ash of clarified juice. This increase is due to either high initial acidity of raw juice or to the decomposition of reducing sugars or underliming during clarification. Out of these three factors, the latter two were observed to be more prominent.
7. Total alkalies in the ash of mixed juice is 23-24 percent as against 45-50 percent observed in other countries. The addition of lime and sulphur dioxide to the juice should not cause their precipitation, but merely bring

TABLE I

SHOWING THE ASH PERCENT JUICE AND ITS CONSTITUENTS

	Factory A		Factory B		Factory C		Factory D		Factory E		Factory F	
Ash percent juice	Raw juice	Clarified juice	Raw juice	Clarified juice	Raw juice	Clarified juice	Raw juice	Clarified juice	Raw juice	Clarified juice	Raw juice	Clarified juice
Constituents % ash	0.52	0.54	0.46	0.54	0.41	0.38	0.41	0.42	0.70	0.56	0.59	0.72
Silica (SiO_2)	4.1	—	4.4	6.3	5.3	0.5	4.6	4.5	2.1	—	—	2.1
Iron and alumina (Fe_2O_3, Al_2O_3)	11.4	5.8	7.4	2.1	5.2	3.6	8.14	3.4	10.9	—	—	7.4
Calcium (CaO)	4.0	14.7	5.6	14.3	4.6	17.2	5.2	14.3	3.0	—	—	6.8
Magnesia (MgO)	6.2	7.2	4.1	5.0	1.4	7.7	2.1	4.6	1.2	—	—	2.13
Cholride (Cl)	4.1	3.9	3.7	5.1	5.1	5.6	3.20	3.7	2.8	—	—	2.3
Sulphate (SO_4)	35.0	38.3	36.9	37.0	35.9	39.2	35.0	33.2	35.6	—	—	4.4
Phosphate (P_2O_5)	10.8	8.2	11.7	3.3	17.2	10.1	14.1	7.7	16.2	—	—	14.4
Total alkali	23.8	17.9	24.2	—	24.0	15.4	24.9	24.5	24.4	—	—	16.2

TABLE I (A)

PERCENTAGE ON ASH

Constituents	Cuba		Louisiana		Java (Calculated)		
	1	2	1	2	Highest	Lowest	Average
Silica (SiO_2)	5.56	6.46	3.20	4.00	9.25	8.93	8.99
Iron (Fe_2O_3)	19.00	3.00	0.37	0.33	11.42	2.38	3.02
Alumina (Al_2O_3)	—	—	2.00	2.60	2.76	0.01	0.43
Lime (CaO)	7.62	4.70	5.70	7.90	7.45	2.25	2.40
Magnesia (MgO)	6.55	5.01	6.70	7.50	5.05	3.36	4.04
Potash (K_2O)	25.15	46.28	49.50	43.90	45.07	6.00	36.83
Soda (Na_2O)	5.35	1.36	0.30	0.90	—	—	—
Phos. acid (P_2O_5)	5.44	4.21	13.10	11.40	10.70	3.11	4.39
Sulf. acid (SO_4)	15.02	4.08	17.90	16.20	19.23	6.00	16.70
Carbonic acid (CO_2)	2.68	10.53	—	—	—	—	—
Chlorine (Cl)	5.14	12.90	6.70	6.50	—	—	—

about an exchange of acid radical. The analytical figures, however, indicate that a slight reduction occurs in the amount of alkali salts during clarification for which the only explanation can be that the phenomenon of adsorption comes into action.

8. The iron and alumina constitute 8 to 11 percent on ash and these are appreciably higher than those in the juices of other countries though some of the South African (5) cane varieties show much higher content i.e., about 20 percent. The silica and magnesia vary from 3 to 5 percent and 2 to 5 percent respectively, but whereas magnesia is more or less the same as in Cuba, Java and Louisiana juices, proportion of silica is much higher i.e., 7-10 percent in Java juices. But in the process of clarification, the precipitation of iron and alumina appears to be easy while magnesia usually shows a rise from mixed juice to clarified juice and silica sometimes a fall and sometimes a rise. An increase in the amount of silica and magnesia may be attributed to the inferior quality of lime used in clarification.
9. The organic non-sugars percent total non-sugars in raw juice vary from 80 to 82 but irrespective of the rise or fall in the ash content of clarified juice as compared with that of mixed juices the elimination of organic non-sugars, is a constant feature of clarification. But as observed in these juices this removal of organic non-sugars without reduction in ash content of clarified juice does not appear to exert an appreciable influence on the clarification efficiency. This indicates that the organic non-sugars in solution play a subsidiary role during clarification of raw juice, but a simultaneous removal of both the inorganic as well as organic constituents is necessary for improving the clarification efficiency.

Cane varieties in other tracts of India—The observations stated above relate mainly to the cane juices obtained from the mixed commercial varieties in U.P., where on the whole no serious operational difficulties have been experienced, provided the degree of liming has been properly adjusted as discussed later. The author has had the opportunity of observing the nature of juices in other tracts of India as well. The P. O. J. varieties such as 2878 in Southern India yield juices which are highly deficient in phosphate content and create difficulties in settling unless an additional dose of phosphate is applied. The result is that whereas the clarified juice in sugar factories in Northern India contains calcium salts varying between 600 and 800 milligrams per litre, the juices in sugar factories in South India have been observed to contain 1000 to 1200 milligrams per litre resulting in the formation of heavy scales in the evaporators. The cane juices of the commercial varieties in Bengal have not shown any peculiar characteristics during the manufacturing operations.

THE SETTLING (6) AND FILTRATION CHARACTERISTICS WITH REFERENCE TO pH AND COLLOIDS (ALCOHOL PRECIPITABLE NON-SUGARS) OF RAW JUICE

Another remarkable feature was observed in the newly introduced cane varieties in North Bihar, when Co. 313 variety was introduced for the first time in that region, a serious difficulty was faced on account of high mud volume and filtration at the filter press station with the result that the crushing capacity of some of the sugar factories was reduced by 15 to 20 percent. A study of these juices indicated that the raw juice contained a fairly high percentage of alcohol precipitable non-sugars i.e., nearly 50 percent more than that observed in other cane varieties. It was therefore concluded that this trouble was mainly due to high percentage of these non-sugars. A study was therefore undertaken in respect of the following factors.

1. Influence of the soil and climatic conditions on the alcohol precipitable non-sugars in raw juice.
2. Influence of these non-sugars on the settling and filtration characteristics of juices.
3. Precipitation of these non-sugars by the different methods of clarification.
4. Relationship of the alcohol precipitable non-sugars and pH of raw juice and the effect of artificially lowering the pH of raw juice on the behaviour of juices in respect of their settling and precipitation of alcohol precipitable matters. This aspect attracted attention, because it has been observed that with the advance of the cane crushing season the low purity juices indicate a quicker rate of settling and yield more compact mud than the high purity juices under identical conditions of working. Since the pH of low purity juices usually falls in the range of 4.8 and 5.4 pH and moreover as shown by J.G. Davies (7), S. Duncan etc., some of the alcohol precipitable non-sugars such as proteins are precipitated by heat at a pH within this range, the pH of high purity juices was lowered artificially within this range.

These experiments were conducted in the laboratory and also in sugar factories under actual operating conditions during the period of maximum maturity of cane i.e., middle of January to the end of February. These observations in sugar factories were recorded on juices obtained from Co. 313 variety in North Bihar and from the mixed commercial cane varieties in Western U. P. The colloidal non-sugars were estimated in 5 ml. juice (10 Bx.) by alcohol precipitation method. Since during the period of maximum maturity of cane the pH of raw juice usually increases and falls outside this range, the pH of raw juice was artificially lowered by adding a weak acid i. e., oxalic acid in the proportion of 0.5 to 0.75 lb. per 1000 gallons of raw juice. The required quantity of oxalic acid was dissolved in hot water and added along with the flow of raw juice in the sulphitation tanks and allowed to remain in contact with the juice for nearly 5 to 10 minutes and then limed and sulphited in the usual manner.

The results of examination of the alcohol precipitable non-sugars in raw juice, clarified juice and syrup in sugar factories situated in different tracts along with the volume of milk of lime used in clarification and also the filtration and settling characteristics of juices in relation to the rate of settling and filtration trouble if any are shown in Tables II and III.

TABLE II

SHOWING COLLOIDAL* CONTENT AND FILTRATION CHARACTERISTICS

Factory	Cane Variety	Raw juice			Colloids* in 5 ml. raw juice (10 Bx.)		Clarified juice Colloids		Syrup Colloids*		Milk of lime % raw juice	Filtration trouble	Mill Extraction
		Bx.	Purity	pH	Total	Inorganic (ash)	Total	Ash	Total	Ash	Available lime 75-80%		
A	Co.313	17.2	85.3	5.8	0.0547	0.0112	0.0216	0.0044	0.0496	0.044	1.5% (15°Be′)	No	93.88
B	Co.313	17.0	85.4	5.7	0.0236	0.034**	0.0599	0.005	0.023	0.0017	1.5% (15°Be′)	Yes	92.66
C	Co.313	17.8	86.2	5.7	0.060	0.0112	0.0503	0.0244	0.0552	0.017	1.2% (13°Be′)	Yes	93.55
D	Co.313	17.4	88.4	5.5	0.0547	—					1.5% (15°Be′)	No	94.54
E	Mixed	16.2	80.1	5.2	0.0324	0.0101	0.024	0.0092			1.7% (12°Be′)	No	91.53
F	Mixed	17.1	83.2	5.1-5.2	0.0244		0.0193		0.0142		0.8% (15°Be′)	Yes	90.75
G	Mixed	16.7	83.5	5.4	0.067	0.0123	0.056	0.0092	0.077	0.0094	1.3% (10°Be′)	Yes	92.56

*The term refers to alcohol precipitatable non-sugars.

**Filter press juice in circulation.

TABLE III

SHOWING DEGREE OF LIMING AND SETTLING RATE

Factory	Milk of lime % raw juice	Raw juice			Original vol. of juice ml.	Rate of settling**				Final volume	Mud volume % juice	Colloids*	Clear juice Cal. Salts mgm. per litre
		Bx.	Purity	Colloids*		10 mts.	20 mts.	30 mts.	45 mts.				
A	1.5 (15°Be′)	(a) 17.2	85.9	0.0236	1120	560	460	405	365	320	26.3	0.0499	—
		(b) 16.9	87.9	—	1170	400	370	330	300	260	22.2	0.023	—
B	1.5 (15°Be′)	(a) 17.0	86.5	0.054	1170	530	370	340	300	260	22.2	0.0216	619
		(b) 16.1	85.4	—	1180	450	320	290	260	220	18.64	—	—
C	1.2 (13°Be′)	16.6	86.8	0.060	1200	1050	500	450	390	330	27.5	0.0503	—
D	1.5 (15°Be′)	17.3	85.9	0.0547	1210	580	360	310	280	230	19.0	0.019	598
E	1.7 (12°Be′)	17.0	81.0	0.032	1130	510	370	320	290	250	22.12	0.024	677
F	1.0 (15°Be′)	17.5	86.3	0.0244	1230	550	500	450	400	320	26.02	0.0193	711
	1.4 (15°Be′)	16.5	84.2	—	1140	580	400	350	300	240	21.05	0.015	—
G	1.8 (10°Be′)	16.7	85.6	0.067	1220	650	520	450	890	300	24.6	0.0532	795

*The term refers to alcohol precipitable non-sugars.

**The rate of settling was observed in a graduated glass cylinder.

From these observations the following conclusions could be drawn :—

1. The alcohol precipitable non-sugars in raw juice are independent of the variety of cane, pH and purity of juice. The soil and climatic conditions appear to exert a good deal of influence.
2. The alcohol precipitable non-sugars are mainly of organic nature, the inorganic constituents being about 25% of these non-sugars.
3. The amount of alcohol precipitable non-sugars in clear juices is influenced to a large extent by the degree of liming used in clarification as further shown by the following figures.

Raw Juice alcohol precipitable non-sugars	Degree of liming	Clarified juice alcohol precipitable non-sugars	
		Total	Ash
0.0547	1.5% (15°Be′)	0.0357	0.0181
	1.3% (15°Be′)	0.0455	0.0125
	1.1% (15°Be′)	0.0521	0.0132
0.045	2% (10°Be′)	0.0252	
	1.7% (10°Be′)	0.0270	
	1.3% (10°Be′)	0.0379	

If the degree of liming is insufficient the alcohol precipitable non-sugars will appreciably increase causing filtration trouble.

4. The rate of settling and mud volume do not appear to be so much correlated with the alcohol precipitable non-sugars in raw juice as with that in clarified juice. The ratio of total alcohol precipitable non-sugars in clarified juice to those in raw juice becomes higher with an increase in mud volume. For decreasing this ratio, the compactness of mud is an essential feature for which the degree of liming and brixes of raw juice play an important part.
5. In view of the wide variations in the temperatures of preheated raw juice, the method of addition of milk of lime, the degree of liming, the time of sulphitation etc., there is every possibility of widely varying results being obtained from factory to factory even by the application of the same method of clarification and using raw juice of the similar quality. The fractional liming method, however, gives better results in respect of settling of juices than the usual methods in vogue as shown by the figures in table IV (A).

TABLE IV(A)

Method of sulphitation	Raw Juice Bx.	Pol.	Purity	Colloids (alcohol precipitable non-sugar)	Mud Vol. % Juice	Calcium content mgms. per litre.	Time of Sulphitation	Milk of lime % raw juice
Fractional liming at 50°C.	16.6	14.0	84.4	0.0435	21.5	693	10.5 mts.	1.3 (15°Be'.)
Simultaneous liming at 160°F.	16.6	14.0	84.5	0.0466	23.5	729	9.5 ,,	1.3 ,,
Fractional	16.4	13.7	83.7	0.044	21.9	729	10.5 ,,	1.3 ,,

TABLE IV (B)

Method of Sulphitation	Raw juice Bx.	Pol	Purity	Colloids Total	Ash	Mud volume % raw juice	Clear Juice Calcium salts (10Bx.)	Red. Sugars/ sucrose	Time of sulph.	Milk of lime % raw juice
S1	17.1	14.5	84.6	0.040	0.0106	34.8	479	3.87	14mts.	1.3 (15°Be'.)
S2	16.8	14.3	85.1	0.026	0.012	29.0	560	3.67	10 ,,	1.3 (15°Be'.)
S3	16.8	14.4	85.2	0.036	0.0108	30.6	434	3.87	9 ,,	1·1 (15°Be'.)
S4	16.9	14.3	84.6	0.0442	0.016	27.9	658	3.89	16 ,,	

S1 Fractional liming at 50°C.
S2 Simultaneous method of liming and sulphitation at 160° F.
S3 Fractional liming at 50°C.
S4 Fractional liming and sulphitation at 160°F.

It has however to be observed from the data given in Table IV B that results of a diverse nature may be obtained if the time of sulphitation is too long on account of the unsteady supply of SO_2 gas or the time of contact of lime with the raw juice is prolonged. The influence of high alkalinity combined with high temperature on the amount of alcohol precipitable non-sugars in clarified juice is shown by the following data.

TABLE IV (C)

Method of treatment	Raw Juice Bx.	Pol	Purity	Alcohol precipitable non-sugars	Milk of lime % Juice
	18.9	16.30	84.8	0.0279	1.7 (10°Be'.)
S1				0.0522	
S2				0.0522	
S3				0.0278	

S1 Juice heated to 160°F. added full dose of lime and kept for 5 minutes before sulphitation.
S2 Juice heated to 160°F. added full dose of lime and kept for 10 minutes before sulphitation.
S3 Fractional liming at 160°F.

THE EFFECT OF ARTIFICIALLY LOWERING THE pH OF RAW JUICE

As explained earlier some difficulty is usually experienced in the proper settling of juices if the pH of raw juice is high particularly during the peak period of maturity of cane. A few tests were therefore conducted by artificially lowering the pH of raw juice by adding the superphosphate solution and oxalic acid respectively to the raw juice while adopting the same process of juice clarification. The results are given in Table V.

TABLE V

pH of raw juice	Method of treatment	Clear Bx.	Juice Purity	Final mud volume % juice	Colloids (alcohol precipitable non-sugars)	Milk of lime % raw juice
5.8	S 1	17.2	86.1	22.2	0.0474	1.5 (15°Be′)
5.1	S 2	17.1	86.3	20.30	0.0386	,,
5.4	S 3	17.6	84.6	20.20	0.0458	,,
5.7	S 4	17.3	85.9	19.0	0.0511	,,
5.1	S 5	17.2	85.1	17.30	0.0343	,,
5.4	S 6	17.0	84.7	22.60	0.0563	,,
5.7	S 7	16.8	84.6	23.1	0.0535	,,
5.1	S 8	17.3	85.4	21.4	0.0503	,,

S1—Simultaneous liming and sulphitation at 160°F.
S2—Addition of oxalic acid and further treatment as in S1.
S3—Addition of superphosphate and simultaneous liming and sulphitation at 160°F.
S4—Simultaneous liming and sulphitation at 160°F.
S5—Addition of oxalic acid further treatment as in S4.
S6—As in S3.
S7—As in S4.
S8—As in S5.

It is clear from these observations that depending on the quality of juice the addition of oxalic acid accelerates the rate of settling and at the same time causes better precipitation of alcohol precipitable non-sugars. As mentioned earlier the quicker rate of settling and low mud volume appear to be a characteristic of the low purity juices on account of the presence of larger quantity of organic acids. These acids possibly affect a certain constitutional change in the composition of raw juice with the result that low purity juices are rendered less refractory than the high purity juices unless the extent of deterioration in the low purity juices has proceeded so far that the organic products are dispersed in a highly colloidal state.

As regards the influence of the quantity of oxalic acid that should be added, and the duration of contact of acid with juice that should be maintained, it has been observed that for high purity juices having a pH of 5.7—5.8 a lowering of pH to about 5.1—5.2 is sufficient. But when the purity of raw juice is high, and the pH is low, a further lowering of pH, i.e., to 4.7—4.8 is helpful. As regards the time of contact, the acid must be allowed to remain in contact with the juice for about 5—10 minutes before liming and sulphitation should start. The use of phosphoric acid (super-phosphate) as a substitute for oxalic acid results in an increase of mud volume while in the case of SO_2 gas the required duration of contact cannot be maintained for two reasons i.e., firstly on account of the loss of SO_2 gas in hot juices and secondly owing to operational difficulties.

A study of the purity rise in relation to the alcohol precipitable non-sugars indicates that the amount of these non-sugars in clarified juice exerts its influence on the rise in purity from mixed juice to clarified juice. If the ratio of these non-sugars in clarified juice to that in mixed juice is either equal or more than unity there may be either no rise or fall in purity from mixed juice to clarified juice. For a proper rise in purity this ratio should be as low as possible.

OPTIMUM (8) DEGREE OF LIMING IN SULPHITATION PROCESS OF JUICE CLARIFICATION

In view of the wide variations observed in the degree of liming used in the Indian sugar factories causing large differences in the rate of settling, mud volume, clarity, calcium salts and alcohol precipitable non-sugars in clear juice it was considered necessary to study the optimum degree of liming that should be used in clarification. It was observed that the cane juices responded satisfactorily if the quantity of milk of lime corresponding to a pH of 10.60 was used. For determining this quantity a representative sample of cold raw juice is obtained and divided into four or five parts of 500 ml. each and treated with different proportions of milk of lime. After shaking thoroughly, the limed juice is filtered and its pH determined with the help of a Hellige comparator using Alizarine yellow indicator.

REFERENCES

1. Parashar, D.R., Kripa Shankar and Lall, S. B. 1947. *Proc. 34th Indian Science Congress*, p. 91.
2. Spencer and Meade : Cane Sugar Hand Book p. 22.
3. Pieter Honig : Principles of Sugar Technology p. 587.
4. Davies, J. G. 1936. Recent improvements in simple clarification of raw sugar production.
5. Pieter Honig : Principles of Sugar Technology p. 298.
6. Parashar, D. R. 1942. *Proc. 11th Annual Convention S. T. A., India* p. 99.
7. *I. S. J.* 1936 p. 298.
8. Parashar, D. R. 1940. *Proc. 9th Annual Convention S. T. A., India* p. 157.

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In the absence of the authors the following paper was taken as read.

Paper

SOME ASPECTS OF THE THEORY OF CANE DIFFUSION

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INTRODUCTION

The extraction of sucrose from sugar-cane by a diffusion process rather than by a milling process has from time to time been considered by the industry and lately appears to be receiving more attention. In view of this a discussion of the theory of extraction by diffusion with particular reference to sugar-cane was thought to be of interest and is considered below. The simple equations for counter-current extraction are, of course, well-known, although they are not always worked out in exactly the same way as given here. The result for the non-equilibrium case is quoted in the literature (1) but no derivation appears to have been published.

THEORY OF COUNTER-CURRENT EXTRACTION

The efficient extraction of sucrose by diffusion of cane is based on the principle of counter-current extraction, the simplest form of which is shown diagrammatically in Figure 1.

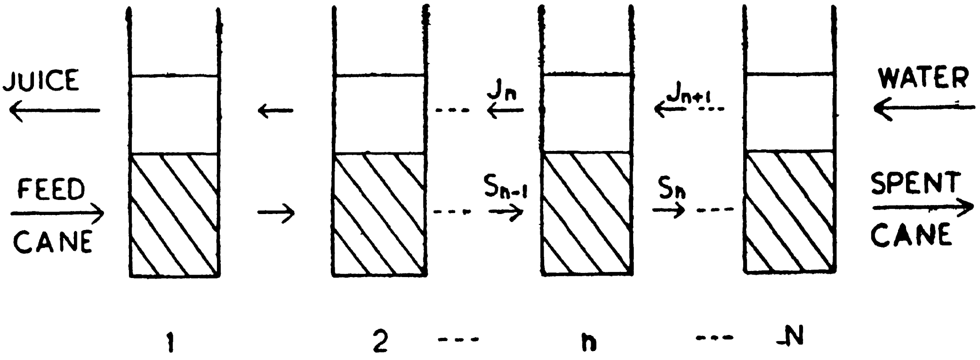

Fig. 1. Counter-current extraction process for cane.

The diffuser is divided into N compartments. Water is fed to the nth compartment and by successive transfers reaches the first compartment where it is removed as juice. Cane is fed into the first compartment and by successive transfers reaches the nth compartment where it is removed as spent cane. The nth compartment therefore contains cane which it has received from the (n—1)th compartment and juice which it has received from the (n+1)th compartment. Let the volume of juice in the nth compartment be V_n and let the cane in the

n^{th} compartment contain a volume v_n of sucrose solution. The respective concentrations of sucrose are J_n and S_n. A material balance on the n^{th} compartment gives.

Total sucrose entering : $V_{n+1} J_{n+1} + v_{n-1} S_{n-1}$

Total sucrose leaving : $V_n J_n + v_n S_n$

We therefore have a series of equations :

$$V_{n+1} J_{n+1} + v_{n-1} S_{n-1} = V_n J_n + v_n S_n \qquad \ldots \quad (1)$$

In any existing factory diffuser we can imagine that the variables V_n, v_n, S_n, J_n are known by experiment and the performance of any one compartment can therefore be measured easily, for example, as the percentage of the sucrose in the batch of cane entering the diffuser which is extracted in the n^{th} compartment, i.e.,

$$\frac{100\,(v_{n-1} S_{n-1} - v_n S_n)}{v_o S_o}$$

where v_o S_o refers to the feed cane. If, however, the performance of a diffuser is to be predicted theoretically certain assumptions have to be made. The first assumption is that the volume of sucrose solution retained in the cane structure is constant throughout the diffuser. Now consider any sucrose solution of concentration S g./ml. and volume v ml. The weight of sucrose present is Sv g. and we can take it as an approximation that in the solution this sucrose will occupy a volume Sv/d where d is the density of solid sucrose. Thus the volume of the water in the solution is v (1—S/d) and the weight of water d_w v (1—S/d) where d_w is the density of water. It must be emphasised that in the above a crude approximation has been made although calculation shows that it is reasonably accurate for dilute sucrose solutions. Using the above in taking a water balance on the n^{th} compartment we obtain :

$$d_w V_{n+1}\left\{1 - \frac{J_{n+1}}{d}\right\} + d_w\ v_{n-1}\left\{1 - \frac{S_{n-1}}{d}\right\}$$

$$= d_w\ V_n\left\{1 - \frac{J_n}{d}\right\} + d_w\ v_n\left\{1 - \frac{S_n}{d}\right\}$$

i.e.,

$$dV_{n+1} - J_{n+1} + dv_{n-1} - S_{n-1}\, v_{n-1}$$

$$= dV_n - J_n V_n + dv_n - S_n v_n \qquad \ldots \quad (2)$$

Equation (2) combined with equation (1) leads to the result that :

$$V_{n+1} + v_{n-1} = V_n + v_n$$

and since we have decided that $v_n = v_{n-1} = v$ throughout the diffuser then $V_{n+1} = V_n = V$, i. e., the volume of the juice is also constant throughout the diffuser.

Initially also we may assume that J_n in equal to S_n in every compartment i.e., that the contact time in the compartments is sufficiently long for diffusion equilibrium to be reached before the cane and juice are moved to other compartments. With these simplifications equation (1) becomes

$$S_{n+1}-(1+\beta)\,S_n+\beta\,S_{n-1}=0 \qquad \ldots \quad (3)$$

where β is v/V. Equation (3) is a linear finite difference equation the solution of which is :

$$S_n=A_1x_1^n+A_2x_2^n \qquad \ldots \quad (4)$$

where A_1 and A_2 are constants and x_1 and x_2 are the roots of the quadratic equation:

$$x^2-(1+\beta)\,x+\beta=0 \qquad (5)$$

Equation (3) is replaced by :

$$S_n=(A_1+nA_2)x_1^n \qquad \ldots \quad (6)$$

in the case when the roots of the quadratic equation (5) are equal. The roots of the quadratic equation (5) are $(1, \beta)$ so that equation (4) becomes :

$$S_n=A_1+A_2\beta^n \qquad \ldots \quad (7)$$

The constants A_1 and A_2 are evaluated by the conditions that the feed water contains no sucrose (if "sweet" water is used the appropriate sucrose concentration is inserted), i.e., $j_{N+1}=0$ and that sucrose concentration in the feed cane is S_0. We therefore have that :

$$S_0=A_1+A_2 \qquad (8)$$

$$0=A_1+A_2\,\beta^{N+1} \qquad (9)$$

Solving equations (8) and (9) simultaneously we obtain A_1 and A_2 giving as the final solution :

$$S_n=\frac{S_0\,(\beta^N-\beta^{N+1})}{(1-\beta^{N+1})} \qquad (10)$$

Equation (10) can be used to find p, the percentage of the sucrose lost in the spent cane for :

$$p=\frac{100S_n}{S_0}=\frac{100\beta^N(1-\beta)}{1-\beta^{N+1}} \qquad (11)$$

Consider now $\lim\limits_{N\to\infty} p$, i.e., the value of the percentage sucrose loss as the number of compartments in the diffuser is increased to very large numbers.

If $\beta<1$, $\lim p=0$ $\qquad$ (12)

i.e., complete extraction is obtained.

If $\beta>1$, $\lim p=\dfrac{100\,(\beta-1)}{\beta}$ $\qquad$ (13)

i.e., complete extraction is not obtained however many compartments the diffuser may have. In the special case where the roots of the quadratic equation (5) are equal, i. e., when β is equal to 1, equation (4) is replaced by :

$$S_n = A_1 + nA_2 \tag{14}$$

giving as the percentage sucrose loss in this case that :

$$p = \frac{100}{N+1} \tag{15}$$

In this case $\lim_{N \to \infty} p = 0$, i. e., it is theoretically possible to obtain complete extraction when $\beta = 1$.

NON-EQUILIBRIUM CASE

In the above it has been assumed that diffusion equilibrium has been reached in each compartment. If this condition does not hold the theory has to be modified as follows.

The sucrose concentrations in the cane and in the juice in the nth compartment change with time as shown diagrammatically in Figure 2.

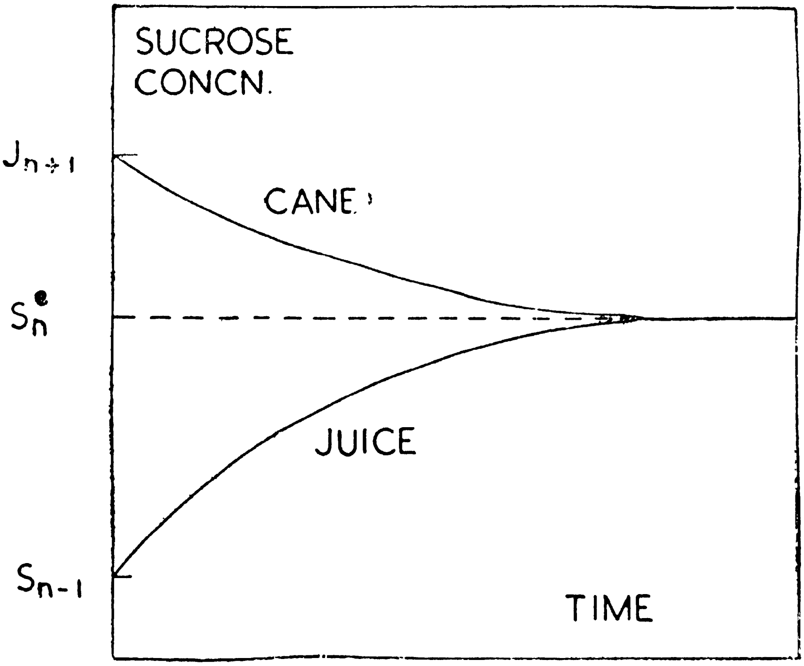

Fig. 2. Graphs of sucrose concentration against time for the cane and juice in the nth compartment.

The sucrose concentration of the juice entering the nth compartment is J_{n+1} and that of the cane is S_{n-1}. During the time in the nth compartment both concentrations approach the final equilibrium value S_n^e. The kinetics of the curves may be represented to a first approximation by first-order behaviour i. e.,

$$\frac{dJ_n}{dt} = k_n \left\{ S_n^e - J_n \right\} \tag{16}$$

In the integrated form this becomes :

$$\ln \frac{S_n^e - J_{n+1}}{S_n^e - J_n} = k_n t \tag{17}$$

It is assumed that $k_n = k$, i. e., all the rate constants are identical. This is the easiest assumption to make although it may not be entirely correct. Equation (17) becomes :

$$\frac{S_n^e - J_{n+1}}{S_n^e - J_n} = \text{const.} \tag{18}$$

It is conveient to write the constant in equation (18) as $1/(1-\alpha)$ where α is a constant for then :

$$J_n = J_{n+1} + \alpha \left\{ S_n^e - J_{n+1} \right\} \tag{19}$$

Equation (19) shows the significance of α. When α is zero then $J_n = J_{n+1}$, i.e., no diffusion of sucrose takes place at all ; when $\alpha = 1$, $J_n = S_n^e$, i.e., complete diffusion equilibrium is established. A material balance for sucrose on the nth compartment gives :

$$VJ_{n+1} + vS_{n-1} = VJ_n + vS_n \tag{20}$$

When complete diffusion equilibrium is established then $J_n = S_n = S_n^e$ and equation (20) then gives for S_n^e :

$$S_n^e = \frac{J_{n+1} + \beta S_{n-1}}{1 + \beta} \tag{21}$$

Where β has the same significance as before. Eliminating S_n^e between equations (21) and (19) we obtain :

$$\beta S_{n-1} = \frac{(1+\beta)}{\alpha} J_n - J_{n+1} \tag{22}$$

Equation (22) now gives the S's in terms of J' s.
Using this in equation (20) we obtain :

$$J_{n+2} - \frac{(1+\beta)}{\alpha} J_{n+1} + \frac{(1+\beta-\alpha)}{\alpha} J_n = 0 \tag{23}$$

which is again a finite linear difference equation. This can be solved in a manner analogous to that for equation (3) giving the solutions :

$$J_n = \frac{\beta S_0 \left(\gamma^{N-1} - \gamma^{N} \right)}{\left(1-\gamma^{N+1} \right)} \tag{24}$$

and

$$p = \frac{100\, \gamma^{N} (1-\gamma)}{\left(1-\gamma^{N+1} \right)} \tag{25}$$

where

$$\gamma = \frac{1+\beta-\alpha}{\alpha} \tag{26}$$

As before, it is assumed that the feed water to the diffuser contains no sucrose. The form of equation (25) is the same as that of equation (11) except that γ replaces β.

If we consider $\lim\limits_{N\to\infty} p$ it follows that the condition for complete extraction is : $\gamma \leqslant 1$

i. e., $(1+\beta) \leqslant 2\alpha$.

From this last condition it can be seen that since by definition $\beta > 0$ complete extraction is only reached when $\alpha > \frac{1}{2}$, i. e., that however much water is used and, howeuer many compartments are added to the diffuser complete extraction is obtained only when, in each compartment, equilibrium is more than half-way reached before transfer takes place. In the case where it is required to calculate the number of compartments required, equation (25) can be rewritten as

$$N = \frac{\log p - \log \left[100 - (100-p)\gamma \right]}{\log \gamma} \tag{27}$$

DISCUSSION

(a) *Estimate of the draft required.*

From the above theory certain general conclusions may be drawn about the possibilities of a diffusion process for cane. The discussion is best carried out by numerical illustration and for this purpose the graphs shown in Figures 3 and 4 have been drawn. The use of these graphs, which represent equations (25) and (26) is made clear from the examples.

One important variable is β and it is the reciprocal of the "draft" term used in beet diffuser calculations. It should be pointed out that in these calculations β is based on the volume of juice contained within the cane cells rather than on the weight of cane itself. β is easily varied operationally and even assuming complete equilibrium within any one compartment, i.e., $\alpha=1$, it has been shown that complete extraction is never obtained however large the number of compartments if $\beta > 1$. Under these conditions the minimum loss of sugar obtainable is given by equation (13). Some calculated values are shown in Table I.

TABLE I

SUGAR LOSS FOR VARIOUS β (>1) WHEN $\alpha=1$

β	$p=\frac{100(\beta-1)}{\beta}$
1.01	0.99
1.05	4.8
1.1	9.1
1.2	16.7
1.3	23.1

It is seen that β must not be very much greater than 1 in order to obtain a reasonable sugar extraction. In practice, however, owing to the fact that the diffuser cannot have an infinitely large number of compartments and also because α will be less than 1, the diffusion battery will always be worked with β values less than 1 and in the following examples such β values only are considered.

(b) *Diffusion of whole cane.*

The first example to be considered will be the extraction of whole cane. The cane may have been cut into small pieces in order to ensure a greater rate of extraction but it is assumed that during this process no juice is extracte, and that no significant number of the sugar-containing plant cells has been disrupted.

Sugar-cane contains about 13% fibre and 87% sugar solution of which about 13% of the weight of the cane is sucrose and 74% water and non-sucrose solids. Assuming a purity of 82% then 100 Kg. of cane contains 13 Kg. fibre, 13 Kg. sucrose, 2.9 Kg. of non-sugar solids and 71.1 Kg. of water. From these values it follows that :

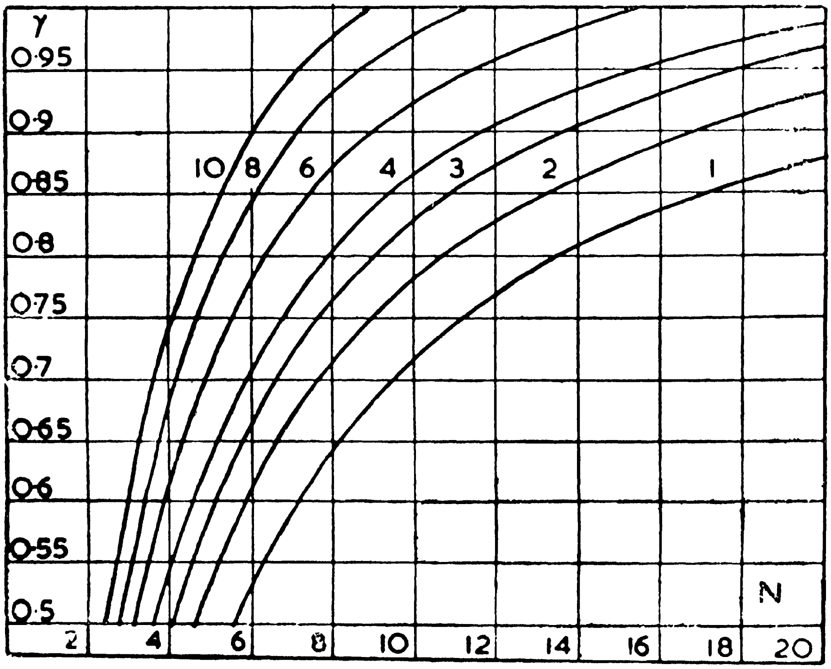

Fig. 3. Graphs of γ against total number of compartments (N) for different values of

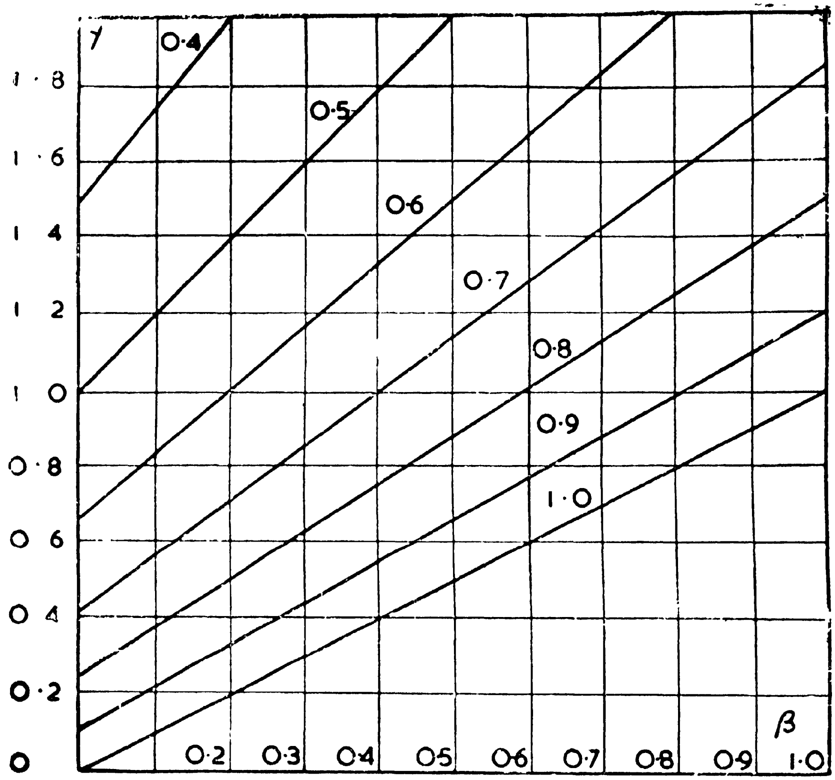

Fig. 4. Graphs of γ against β for various values of α.

$$\text{Sucrose \% juice in cane} = 100 \times \frac{13}{87} = 14.95$$

$$\text{Brix \% juice in cane} = 100 \times \frac{14.95}{82} = 18.25$$

Specific gravity of juice = 1.075

$$\text{Volume of juice in 100 Kg. cane} = \frac{87}{1.075} = 81 \text{ litres}$$

Suppose that complete extraction is reached in every compartment of the diffuser, i.e., $\alpha = 1$, and therefore $\gamma = \beta$. The highest value of γ allowed can be read from Fig. 3. If the diffuser is to contain 12 compartments and a 2% sugar loss is accepted then from Fig. 3 it can be seen that the corresponding value of $\beta = \gamma$ is 0.83. The draft is $\frac{81}{0.83} = 98$ litres of water per 100Kg. cane. From 100 Kg. cane, therefore, 98 litres of juice is obtained containing $13 \times 0.98 = 12.7$ Kg. sucrose and $2.9 \times 0.98 = 2.8$ Kg. non-sugar solids (assuming a rate of diffusion the same as that of sucrose). From specific gravity tables of sucrose solutions it follows that the juice has a Brix of 15.0, a density of 1.061 and therefore the 98 litres weigh 104 Kg.

We therefore obtain about 104 Kg. of juice from 100 Kg. cane, an amount which is very close to that obtained had the cane been milled with 25% imbibition water. So far in the calculations it has been assumed that $\alpha = 1$. The effect of not reaching equilibrium is quite large however. In the case considered above suppose equilibrium is reached to the extent of 90%, i. e., $\alpha=0.9$. Then from Fig. 3 we find as before $\gamma=0.83$ and from Fig. 4 it will be seen that when $\gamma=0.93$ and $\alpha=0.9$, $\beta=0.65$, i.e., in this case $\frac{81}{0.65}=125$ litres of water are required per 100 Kg. cane. The Brix of the diffusion juice will be 11.9 and 130.5 Kg. juice is obtained from 100 Kg. cane.

It is therefore seen that a considerably larger amount of water will have to be evaporated if a cane diffusion process is used. It can however be concluded that a diffusion process for extracting whole cane is theoretically possible. Whether or not such a process is practicable will depend on various other factors such as the quality of the juice obtained, the cost and efficiency of the apparatus required to cut the cane and the retention time of the cane in the diffuser. Little information is at present available by which these factors can be assessed.

It must further be remembered that the spent cane from the diffusion process contains a large amount of a very dilute sugar solution which will have to be removed by milling before the residue can be used for fuel in the same way as bagasse. If the cane is milled the water extracted could be returned to the diffuser as "sweet" water to replace part of the feed water. Whether or not this practice would be desirable would depend on various factors such as the quality of the diffusion juice obtained.

(c) *Extraction of bagasse.*

Another possible process of extracting the sucrose from the cane would be to use the normal milling procedure to disintegrate the cane to bagasse, which is then extracted by a diffusion process. Since milling of the cane will have disrupted many of the plant cells the extraction of the sugar from the bagasse is more accurately a lixiviation rather than a diffusion process. Experiments have shown that the bagasse after a knife and crusher preparation in a commercial mill contained 15-20% undamaged plant cells. The bagasse from a cane which has passed through one set of knives and a crusher may still be considered rather coarse to be used in a diffusion battery and thus could conveniently be further disintegrated in a shredder. Such mechanical treatment would no doubt rupture a further number of cells and if it be assumed that all plant cells have been broken or damaged the process of extracting sugar from the bagasse would be solely one of lixiviation. However, the simple theory outlined above can still be applied.

The simplest layout would be to pass the cane through a set of knives before crushing and shredding. The bagasse is sent to the diffusers and the juice obtained mixed with the crusher juice before processing.

Let us consider a sugar-cane containing 13% fibre and 13% sucrose with a purity of 82. Suppose that the crushing operation removes 55% as juice then from 100 Kg. cane 45 Kg. bagasse, containing 13 Kg. fibre and 32 Kg. juice, is obtained. Bagasse absorbs water like a sponge and carries this immobilised water through the extraction process. Experiments in these laboratories have shown that as a first approximation the water which the fibre in the bagasse absorbs is equal in volume to the juice associated with the same amount of fibre in whole cane. Therefore the 45 Kg. bagasse must be allowed to absorb $\frac{55}{1.075}$ $=51$ litres of water before being sent to the extraction plant.

Since the sugar % of juice in cane is $\frac{13}{87}\times 100=14.95$ the amount of sugar left in the bagasse is 32 x 0.1495 = 4.78 Kg. If a recovery of 98% of the sucrose in cane is aimed at, the spent bagasse contains 13 x 0.02 = 0.26 Kg. and thus the percentage loss in the extraction plant is

$$p=\frac{0.26}{4.78}\times 100=5.4$$

Let the extraction plant comprise 12 compartments. Then from Fig. 3 it is seen that

$$\beta=\gamma=0.94$$

and so $\frac{81}{0.94}=86$ litres of diffuser juice is obtained from 100 Kg. cane.

Processing 100 Kg. cane therefore yields :

55 Kg. crusher juice of Brix 18.25
88 Kg. diffuser juice of Brix 6.25

i.e., a total of 143 Kg. of juice is obtained. Hence more than 40% more water will have to be handled in the clarification and evaporation station compared with the amount obtained had the cane been milled in the normal way using 25% imbibition water.

In order to decrease the amount of juice from the bagasse extraction process the bagasse from the crushing and shredding plant may be allowed to absorb the crusher juice and not water before being sent to the extraction plant. In this case bagasse having the same composition as cane is extracted and the whole purpose of the milling process has been to rupture all plant cells thus exposing the sugar for a straightforward extraction.

Again, assuming a sugar recovery of 98%, i.e., $p=2$ in an extraction plant containing 12 compartments it is seen from Fig. 3 that

$$\beta=\gamma=0.83$$

so that $\frac{81}{0.83}=98$ litres of juice is obtained from 100 Kg. cane. This is the same result as was obtained when considering diffusion of whole cane for $\alpha=1$, the chief difference being that between diffusion and lixiviation, the former being a much slower process than the latter.

GENERAL CONCLUSIONS

It has been shown that a diffusion of whole cane is theoretically possible but there are several factors of practical significance which have to be investigated further. In order that diffusion proper may occur from unbroken plant cells, they have to be killed. This can be accomplished by carrying out the process at elevated temperatures. Indications are however that cane cells are not as easily killed as beet cells. The rate of diffusion is clearly an important factor which, for a given time of transfer, determines α. The fact that more juice is likely to be dealt with than when using the ordinary milling practice is a disadvantage and also the large-scale preparation of the cane may present some mechanical difficulties. Lastly, the spent cane has to be milled in order to obtain a bagasse suitable as fuel in the boiler station.

The process by which the cane is thoroughly disintegrated and the bagasse mixed with the expressed juice before being extracted appears to be more attractive. It has the advantage of being a much faster process compared with diffusion of whole cane with a correspondingly lower retention time and inversion losses. Further more, since the cells have been broken, there is less need to increase the temperature at which extraction takes place although a relatively slight increase in temperature may be advantageous for other reasons.

In this process the spent bagasse would be milled in order to remove water, so making the bagasse suitable for fuel. This expressed water would be used as "sweet" water as part of draft liquid. The process is thus comparable with ordinary milling practice but a large part of the milling train is replaced by the extraction apparatus. The maximum extraction obtainable by lixiviation would depend largely on the efficiency of the disintegrating units in breaking up the cells.

The quality of the sugar juice extracted by a lixiviation process is hardly likely to be lower than that obtained by the normal milling practice; indeed, preliminary experiments in these laboratories have shown that a much clearer juice of a higher purity is obtained by lixiviating at an elevated temperature.

Finally, it should be mentioned that the calculations have been caried out on a batch-wise counter-current extraction. In practice a continuous extraction apparatus would possibly be used. The general conclusions will not be greatly modified however.

ACKNOWLEDGEMENTS

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REFERENCE

1. McGinnis, R. A. 1951. Beet-Sugar Technology, 1st ed., p. 163. New York : Reinhold.

DISCUSSION

Mr. Davis indicated that he was puzzled as to the meaning of the factor β. Mr. Kelly agreed that there was uncertainty as to its exact significance.

Mr. Gundu Rao pointed out that the important questions to be answered in regard to diffusion were how much water would be required to achieve a satisfactory standard of extraction, and how much inversion would proceed during the process.

Mr. Davis agreed with these points particularly in regard to the ratio of water to cane. He also questioned whether the quality of the juice would be impaired. He cited experiments in which juice was extracted from cane which had been heated to near the boiling point of juice. The juice extracted could not be clarified by defecation. He wondered whether any present had found the same.

Mr. Foster emphasised that the mathematical approach to diffusion could provide very little information as to the practical possibilities. Time was a most important factor in the process, since destruction of sucrose would proceed at a significant rate under the working conditions. One of the most important factors influencing the rate of diffusion of sucrose from the cane would be the average size of the cane pieces. Preparation of the cane for diffusion would be of extreme importance and it would be no use depending upon temperature to improve diffusion if the pieces were too large. The same influences operated in the milling of cane.

Mr. Davis wondered whether any delegate could report on the operation of the diffusion process in Egypt. Mr. Henzell said that he knew nothing of the results obtained in Egypt, but he was aware that a diffusion factory was operating in Trinidad in 1928. The process had been discarded long ago. Mr. Gundu Rao reported that there had once been a factory in India using the diffusion process, but there, too, the process had been discarded.

Dr. S. Mukherjee presented the following paper.

Paper

ION EXCHANGE METHOD OF CANE JUICE CLARIFICATION THE EFFECT OF ION EXCHANGERS ON CANE JUICES CLARIFIED BY DIFFERENT TECHNIQUES

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To, few developments in sugar chemistry belongs the designation revolutionary. The commercial realisation of ion-exchange is one of these few—one which has added a new unit process to the domain of chemical industry. The application of ion-exchange materials to the purification of sugar containing solution of all types has been the subject of considerable importance in popular and technical journals and patent literatures during the last few years.

The earliest mention of ion-exchange materials in the sugar industry was by Harm (1) in 1896 when it was suggested that natural zeolites could be used for replacing the melassigenic alkali metal cations for the less melassigenic calcium cations to improve sugar yield. Simultaneously Rumpler (2) had also conducted similar experiments for raw beet juice. Gans (3) improved upon Rumpler's method by using synthetic zeolites instead of naturally occurring zeolites, which increased the speed of the reaction of exchange of calcium for sodium and potassium from the sugar solutions. However these applications were not very successful owing to increased evaporator scale and interest was not revived till the development in 1935 by Adams and Holmes (4) of ion-exchange materials from the sulphonation of organic materials, and also of synthetic anion and cation exchange resins. In 1936, Liebknecht (5) suggested for the first time the demineralisation of sugar solution by passage successively through an acid regenerated cation and an alkali regenerated anion exchanger. Initially the exchange capacity of the new ion-exchange resins was too low to be of practical use with the concentration of non-sugars usually found in sugar containing liquors. However during the last decade ion-exchangers of higher capacity and better physical properties have been developed, with the result that the process has been applied with considerable degree of success to sugar solutions.

Naturally occurring sugar solutions like cane juice, contain a wide variety of constituents so that the reaction occurring during ion-exchange treatment and their equilibria are exceedingly complex. In general, however, the sugars and other non-ionic substances remain unchanged while ionic substances are more or less completely removed (6). In addition, compounds having large molecular weight may be removed by adsorption, a phenomena distinct from ion-exchange. As many of these compounds are dark in colour, ion-exchange results in a high degree of colour removal. The removal of ionic and adsorbed materials results in a substantial increase in the purity and therefore increased sugar recovery. There are various reports of laboratory and pilot plant trials of complete seasons work on raw and clarified beet juices (7-14) but very little has been published on the demineralisation of sugar-cane juice, from which India's entire sugar supply is derived. Riley and Sanborn (13) in 1947 have reported the results of laboratory and pilot-plant investigations on demineralisation of cane juice conducted at Aubudan Sugar Factory, Louisiana State University and at Manati Sugar Factory, Cuba (commercial Pilot Plant trial). Mindler (15) in 1948 has published the report of a pilot plant trial on the demineralisation of Cuban and Louisiana sugarcane juices whilst laboratory studies have been carried out in Trinidad and South Africa (16-17). Shah and co-workers (18) have described first laboratory studies on the ion-exchange treatment of Indian cane juices. Besides there are numerous patents and published data within the last few years on the application of ion-exchange to raw sugar refining, clarification of cane and beet juices, recovery of sugar from molasses etc. (18-22). Ion-exchange experiments normally begin with clarified juices, although some study was done with raw juice also, but the results were less favourable. It has been universally accepted that preliminary defecation is necessary to remove most of the gums and pectins which may clog the resin bed rendering them ineffective for demineralisation.

In direct demineralisation the clarified juice is passed through a highly acidic sulphonic type cation exchange resin as the first element followed by a weakly basic anion exchange resin. It has been observed that if the operating temperature is not kept between 20-30°C., the inverting action of cation resin and of the liberated acids will result in considerable loss of sucrose. In recent years exchange resins have been available which permit demineralisation in the opposite direction i.e., the anion portion is removed first freeing the bases for subsequent removal by a weak cation resin. The first element in this process is a highly basic anion exchange resin which is followed by a weakly acidic or carboxylic type of cation resin. This type of cation resin does not significantly invert sucrose at normal temperatures, nor it is effective in splitting the salts. Fort and Smith (21) describe laboratory studies on reversed cycle demineralisation of cane juice. Use of mixed bed columns have been also suggested to obviate inversion. For effective demineralisation of sugar cane juice multiple columns (alternately cation and anion) in a set of four or six have been recommended. However there are reports that relatively pure solutions of sucrose invert much more rapidly than do solutions containing ash and extraneous orgainc molecules (probably due to somewhat buffering action of these impurities). Thus refining by single pass method is preferred to multiple stage demineralisation (23). To obviate the formation of low pH which brings about inversion during the passage of the juice through cation resin, use in ammonia cycle was suggested but latter workers have shown that ammonium salts are most harmful in sugar boiling resulting in poor quality greyish sugar (24).

The economics of the process of ion-exchange clarification is considered as very sound on the basis of numerous pilot plant experiments in U. S. A. and its advantages are :—

(i) Increased yield of sugar.
(ii) Increased steam efficiency due to less of scaling.
(iii) Low ash content of final sugar.
(iv) Edible syrup instead of molasses.

The disadvantages are :—

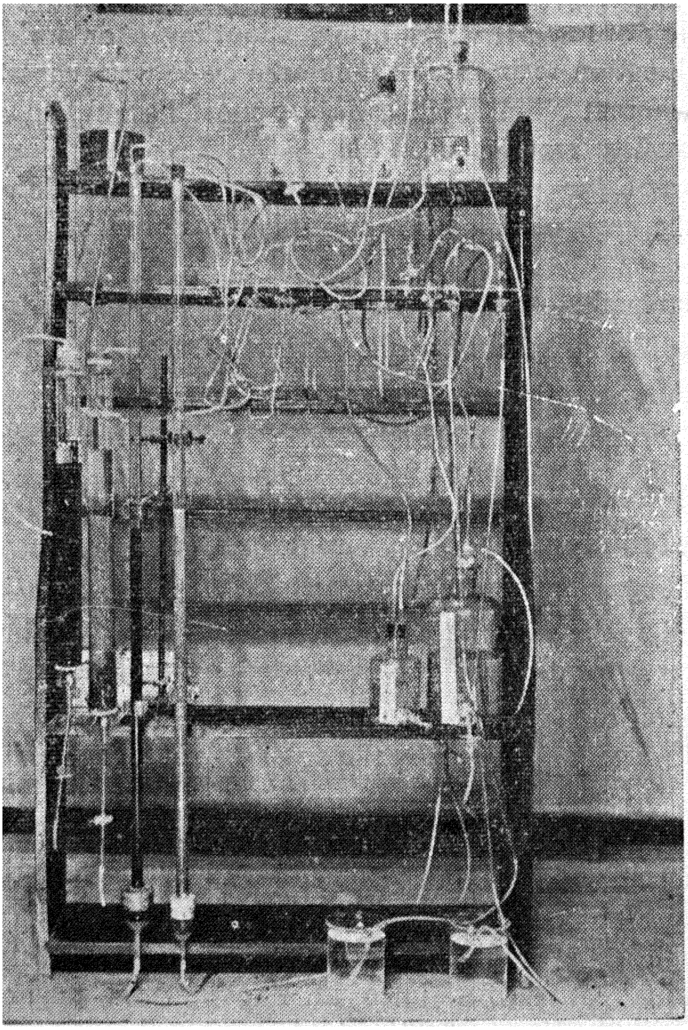
(i) Cooling of juice to 20-30°C.
(ii) Cost of regenerating chemicals.
(iii) Increased fuel consumption owing to about 10% dilution of juice during treatment.
(iv) Clean water requirement for rinsing out the resins after regeneration, and it is considered worth while to study the possiblity of its application in Indian Sugar Industry.

This report represents the results of laboratory trials of direct demineralisation of Indian Cane Juice clarified by various techniques in vogue here these days, the work being undertaken with a view to evaluate their relative suitability to the application of ion-exchange methods. Standard sulphitation and Saha's New Technique (25) clarified juice at Experimental Sugar Factory of National Sugar Institute, Kanpur, Standard sulphitation and Saha's New Technique juices at Godavari Sugar Mills, Kanehgaon, Double carbonation juices at Cawnpore Sugar Works, Marhowrah, Saha's New Technique juices at Bharat Sugar Mills, Sidhwalia, and juice clarified by modified Ghosh's Technique (26) in the laboratory, were subjected to the ion-exchange treatment for this study.

EXPERIMENTAL

on Exchange resins. Sulphonic acid type strongly acidic cation Duolite* C-3 and weakly Anionic Duolite A-7 ion-exchange resins (product of Chemical Process Coy.) were used throughout except in experiment No. 20 where Zeocarb 215 cation and D-Acidite E (Product of Permutit Coy. Ltd.) as anion exchange resins were used.

Resin bed. Tne resin beds were prepared in 60 inch Pyrex glass tube of 25 mm. inner diameter (27 mm. O. D.) with its lower end fitted through a rubber cork to a No. 1 sintered glass buchner type funnel. The beds were about 3 feet (bed volume about 0.0167 cu. ft.,) in depth supported on the sintered glass of the funnel.



Laboratory Ion-Exchange Unit

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* The use of Duolite or Permutit resins does not imply that they are endorsed by this Department.

Laboratory unit. The laboratory ion-exchange unit for single pass direct demineralisation was fitted up as in the photograph (Fig. 1), its operation being evident from the flow diagram (Fig. 2). Pyrex glass 3 way stop cocks fitted in a line in a rectangular perspex sheet fixed at a suitable height on a wooden shelf, were used to control the operations. This sort of arrangement permits control of all the operations of backwashing, regeneration, sweetening off and service run very conveniently from one place. Conductivity cells fixed in cationic and anionic effluents delivery tube before stop cocks No. 11 and 12 greatly facilitate the determination of break through point during the operation. A little suction applied at the collecting vessel is very helpful in adjusting the service run flow rate a any desired value. This is an important step as on the flow rate is dependent the contact time which greatly effects the extent of inversion.

Regeneration. The cation resin was regenerated by 450 ml. of 5% hydrochloric acid solution passed at a rate of 110 ml./minute, followed by rinsing with distilled water (about 4.5 litres) at the same rate till excess of free acid (no turbidity with silver nitrate solution) is removed. From experiment No. 9 onwards the cation resin, before acid regeneration, was leached by 50 ml. of 15% NaOH solution to remove adsorbed protein and nitrogenous bases which decrease the nitrogen and colour adsorbing capacity of the cation exchanger (it is washed almost free of alkali before acid regeneration). The anion exchanger was regenerated by 300 ml. of 15% sodium hydroxide solution passed through the column at the rate of 110 ml./minute and rinsed by distilled water (about 6.5 litres) till the effluent does not give any colour with Phenolphthalein paper. Before regeneration the resins were back-washed at the rate of 100 ml./min. till the resin was fully oriented, the fines and any enclosed air removed. The regeneration of the resin was done after every experiment.

Operation. No effort was made to utilise the full capacity of the resins as the main interest was on evaluating the relative suitability of cane juices clarified by different technique for ion-exchange application. Only 3-4 litres of clarified juice as far as possible properly sampled was taken from the factory and cooled before treatment. The service run flow rate was adjusted between 0.254—0.452 litres/dm.^{3}, by controlling the suction. In trials with Saha's New Technique clarified juice at Sidhwalia (Expt. No. 24, 25 and 26) the flow rates were very low 0.095—0.126 litres/dm.^{3} as suction could not be applied.

First 500-700 ml. was collected in vessel I, as sweetening on, followed by about 2 litres of Deionised juice (D. I. J.) collected in vessel II. After this about 700 ml. of Decationised juice (D.C. J.) and finally about 1.5 litres of 'Sweetening off' was collected.

Analysis. Standard analytical methods (27) were followed for the analysis of clear, decationised and deionised juices (Brix determination by standard Java Brix spindle, true sucrose by Clerget's cold inversion, reducing sugar by Lane and Eynon's, ash by conductivity, lime by soap titration and nitrogen by Kjeldahl's methods) and therefore do not need detailed description. The

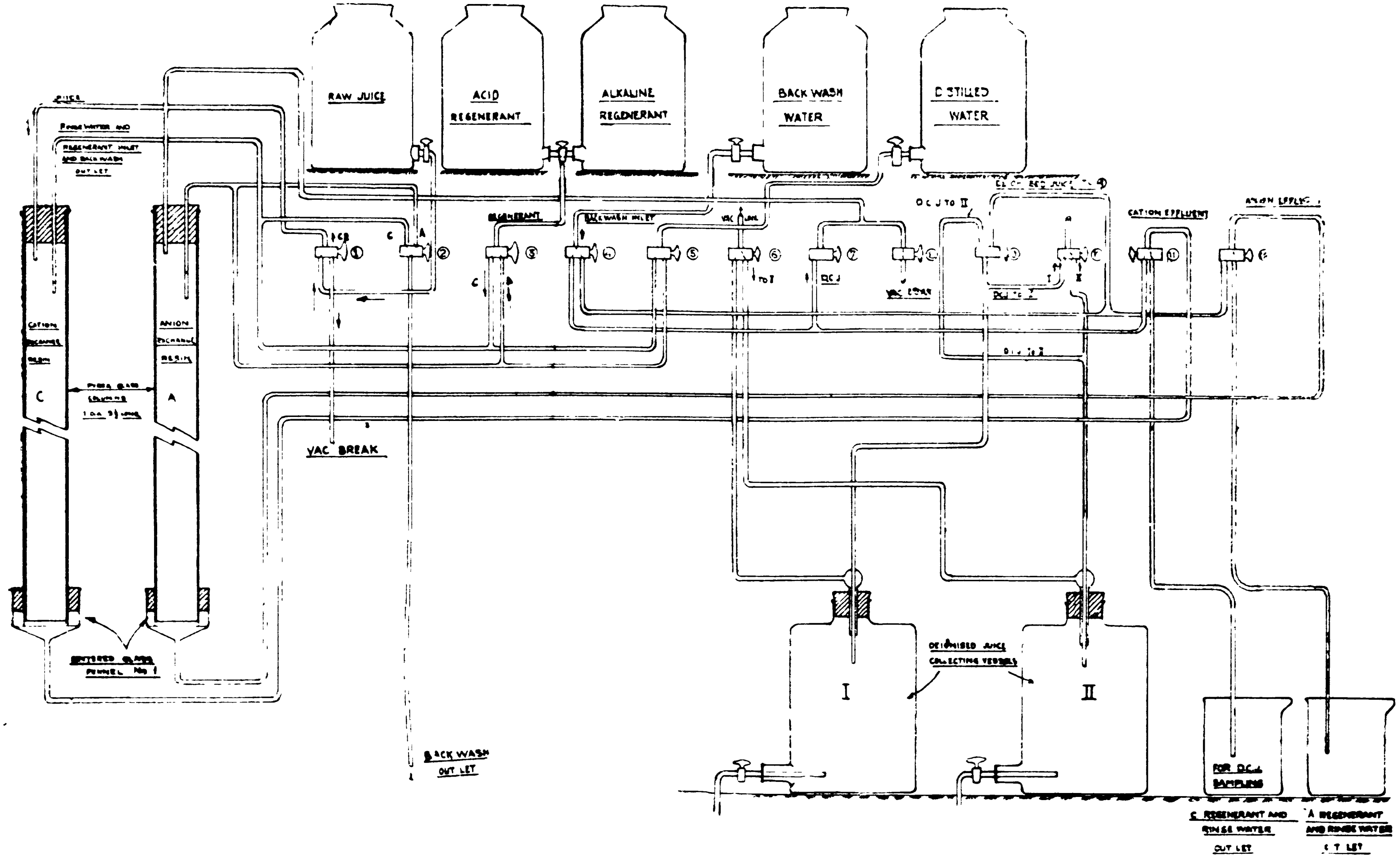

Fig. 2. Laboratory Ion Exchange Unit.

colour of juice was determined by diluting the juice with an equal volume of buffer pH 9 and taking the reading by Klett Summerson photoelectric colorimeter using Klett Filter No. 40 Transmittance 380-430 mμ. The results and the analytical data are given in the Table I.

DISCUSSION OF RESULTS

Experiment No. 2. The operation of the column was not satisfactory so far as colour, lime and organic non-sugar removal were concerned, although purity rise was of the same order as expected, probably because clarified juice used in this experiment was collected from Dorr after formaldehyde had been added to prevent fermentation during periodical shut-down.

Experiment No. 3. The syrup collected on the previous day was diluted to about 16° Brix and used for demineralisation. The purity rise is less as the purity of diluted syrup was high although the final purity of deionised juice is of the same order as in other experiments.

Experiment No. 5. Here again the operation of the resins was unsatisfactory as condensate water, which was used for rinsing the resins after regeneration was found to be alkaline and had probably partly exhausted the resins.

It is evident from the table that by single pass direct demineralisation it is possible to remove 90—96% conductivity ash and most of the nitrogenous bodies without any appreciable inversion at operating temperature between 20°—28°C. and service run flow rate varying from 0.09—0.452 litres/dm^3. The colour removal was very good; in almost all cases water white or very light yellow coloured deionised juice was obtained irrespective of the process of clarification of juice. In some cases the organic non-sugars removal was more than 100 percent,the extra may be accounted for, as the Brix basis used for its calculations does not give an exact idea of true solids. But some of these figures definitely show that organic non-sugars are completely removed contrary to the earlier findings (21) but these need further verification before any conclusions can be drawn from it. Ion-exchange is known (21) to remove a large proportion of all the reducing non-sugars, so if there had been no inversion of sucrose the reducing sugar values should decrease significantly. Consequently if the reducing sugar concentration before and after exchange is the same, there has actually been inversion of sucrose to the extent of removal of non-sugar reducing substances. It can be seen from Experiment 16 and 18 that even though the operating temperature was 25°C. at a service run flow rate of 0.349 and 0.317 litre/dm^3. which is much higher from other experiments, the reducing sugar on 100 sucrose is less in the deionised juice than in the clarified which confirms the above statement.

It is evident from the table that there is no marked difference in demineralising cane juice clarified by New Technique (9), Standard sulphitation or

TABLE I—ANALYTICAL DATA

Exp. No.	Factory	Clarification Process	Variety of Cane		Temperature in °C.	Service run flow rate in litres/ dm³.	Brix			Pol				True Sucrose			
										Percent		Purity		Percent		Purity	
							Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.I.J.
1.	Godavari	New	Co. 419		25	0.263	13.75	13.25	12.35	11.5	11.3	83.5	91.3	11.4	11.1	82.7	90.1
2.	Sugar	Tech-	,,		25	0.211	14.27	14.25	12.95	11.5	11.4	80.2	87.8	10.9	10.8	76.5	83.2
3.	Mills	nique	Adsali.		24.5	0.263	16.64	16.24	15.55	14.7	14.4	88.1	92.5	14.5	14.4	87.2	92.3
4.	Ltd.	Standard	Co. 419		25	0.211	17.06	16.82	15.47	14.2	13.9	83.2	90.2	14.1	14.0	82.9	90.6
5.	Kaneh-	Sulphita-	,,		25	0.451	16.59	16.29	14.92	13.7	13.5	82.8	90.7	13.7	13.4	82.6	90.1
6.	gaon	tion	Adsali.		25	0.254	15.99	15.35	14.53	13.1	12.9	82.1	88.9	—	—	—	—
7.	Experi-	New	Mainly		22	0.263	14.9	14.8	12.63	12.1	12.0	81.0	95.5	12.0	12.0	80.4	94.8
8.	mental	Tech-	Co. 421		22	0.254	15.4	14.0	13.10	11.9	11.6	78.0	88.5	12.1	11.9	78.6	90.8
9.	Sugar	nique			22	0.263	14.87	14.0	11.83	11.9	10.8	80.0	92.7	12.0	10.9	80.5	92.9
10.	Factory		Co. 453		20	0.243	13.72	12.08	10.54	9.3	8.7	68.0	83.0	9.6	8.9	70.0	85.0
11.	National				20	0.263	15.0	13.90	12.47	11.6	10.8	77.0	86.9	11.6	10.9	77.8	87.6
12.	Sugar	Standard	Mainly		21	0.263	17.15	15.80	14.10	14.1	12.9	82.0	91.5	14.1	13.2	82.2	93.4
13.	Insti-	Sulphi-	Co. 421		21	0.254	15.8	14.3	12.6	12.5	11.2	79.0	89.2	12.7	11.5	80.5	91.0
13.	tute	tation	Co. 453		21.5	0.263	16.5	—	14.1	13.3	12.8	80.6	90.8	13.3	13.1	80.8	92.8
14.	Kan-	New Tech-	Mainly		25	0.263	13.8	12.95	11.6	11.1	10.5	80.0	90.7	11.2	10.7	81.3	92.4
15.	pur	nique	Co. 421		25	0.349	15.52	14.22	12.58	12.2	11.4	78.6	91.0	12.4	11.6	79.6	91.8
16.			Co. 453		25	0.263	14.85	13.35	12.29	11.7	10.9	78.6	88.9	11.8	11.1	79.7	90.5
17.		Standard			23	0.317	17.47	—	15.18	13.7	13.0	78.8	85.6	13.8	13.2	79.0	87.2
18.		Sulphita-	Co. 421		24	0.263	16.49	14.88	13.78	13.3	12.9	80.6	93.4	13.5	12.9	81.6	93.5
19.		tion	Co. 453		22	0.263	17.5	15.4	14.2	13.0	11.6	74.0	82.2	13.2	12.1	75.4	85.1
20.	Cawnpore		Co. 453	65%	26.5	0.340	17.64	16.1	14.1	13.7	12.7	78.1	90.3	13.7	12.5	77.4	88.5
21.	Sugar	Double	Co. 513	31%	27.0	0.337	16.91	15.49	14.39	13.7	12.8	81.2	88.9	13.6	12.8	80.3	89.1
22.	Works	Carbo-	Bo. 11														
	Marhowarh	nation	Bo. 21	4%	25	0.317	16.95	15.0	13.58	13.9	11.6	82.1	92.9	13.7	12.4	80.7	91.6
			Bo. 22														
23.			Bo. 23														
24.	Bharat	New	Co. 513	70%	20	0.095	16.07	15.17	13.94	12.7	12.3	78.9	88.2	13.1	12.8	81.7	92.0
	Sugar	Tech-	Co. 453	10-15%													
25.	Mills Ltd.	nique	Bo. 11	10-15%	20	0.115	16.5	14.92	14.46	12.7	12.4	77.1	85.9	13.2	12.7	79.8	88.3
26.	Sidhwalia				20	0.126	16.8	15.8	14.44	13.4	13.0	79.8	89.8	13.7	13.2	81.5	91.8
27.	Laboratory N.S.I.	Modified Ghosh's Technique			25	0.422	15.0	12.19	12.29	12.7	11.6	84.5	94.6	12.6	11.6	84.3	94.2

ClJ.=Clarified Juice. D.C.J. = Decationised Juice. D.I.J.= Deionised Juice.

TABLE I—ANALYTICAL DATA—(*Contd.*)

Exp. No.	Reducing Sugars						Lime (CaO) in Mgs./Litre						Colour Klett (FilterNo. 40)						Nitrogen			
													Buffer: Juice 1 : 1 pH-9									
	Percent		On 100 Bx.		On 100 Sucrose					On 100 Bx.						On 100 Bx.			Percent		On 100 Brix	
	Cl.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.C.J	DI.J.	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.I.J.	Cl.J.	D.I.J.
1.	0.63	0.60	4.6	4.9	5.5	5.4	1140	10	3	8300	79	28	183	53.7	10.7	1330	405	86.6	0.018	0.001	0.130	0.006
2.	0.72	0.72	5.1	5.4	6.6	6.7	381	326	94	2670	2285	726	253	24.15	59.5	1752	1695	470	—	—	—	—
3.	0.57	0.63	3.4	4.1	3.9	4.4	708	4	2	4260	24	11	176	48	15	1057	295	96.5	0.015	0.001	0.091	0.004
4.	0.97	1.02	5.7	6.6	6.9	7.2	609	73	4	3570	43	26	248	257	19	1455	1525	123.6	0.027	0.010	0.157	0.066
5.	0.93	0.92	5.6	6.2	6.8	6.9	599	85	8	3610	521	54	135	171	83	813	1050	552	0.014	0.004	0.084	0.027
6.	1.03	1.03	6.4	7.1	—	—	606	23	13	3790	150	89	228	43.5	18.0	1425	283.2	123.7	0.012	0.006	0.075	0.014
7.	0.66	0.64	4.4	5.1	5.5	5.4	450	20	7	3150	135	55	223	65	25	1495	439	198	0.022	0.001	0.145	0.004
8.	0.90	0.89	5.8	6.8	7.4	7.5	770	75	15	5000	535	114	236	79	23	1530	563	177	0.030	0.000	0.193	0.002
9.	0.70	0.67	4.7	5.7	5.9	6.2	920	17	7	6181	121	54	262	83	16	1760	592	135	0.026	0.001	0.178	0.010
10.	1.19	1.10	8.7	10.4	12.4	12.2	815	38	6	5950	314	57	240	68	9	1750	562	85.4	0.030	0.001	0.215	0.014
11.	1.09	0.99	7.3	8.0	9.4	9.1	1003	515	11	6870	371	88	270	80	28	1800	576	224	0.034	0.005	0.230	0.004
12.	0.65	0.59	3.8	4.2	4.6	4.6	714	35	13	4160	221	92	310	133	77	1810	842	546	0.053	0.013	0.307	0.221
13.	0.93	0.83	5.9	6.6	7.3	7.2	489	24	20	3100	168	158	310	134	58	1950	938	456	0.037	0.021	0.236	0.164
14.	0.83	0.81	5.0	5.7	6.2	6.2	476	—	10	2885	—	71	320	—	92	1935	—	650	—	—	—	—
15.	0.81	0.79	5.9	6.8	7.2	7.3	703	22	7	5100	170	60	248	78	14	1790	618	120	0.019	0.004	0.138	0.033
16.	0.99	0.89	6.4	7.5	8.0	7.7	890	94	25	5740	660	199	284	116	46	1828	813	365	0.005	0.001	0.034	0.011
17.	1.14	1.08	7.7	8.8	9.6	9.7	840	29	17	5660	217	138	248	74	14	1669	552	113	0.026	0.001	0.179	0.011
18.	1.16	1.06	6.7	7.0	8.4	8.2	1080	—	75	6180	—	494	278	—	105	1580	—	690	—	—	—	—
19.	1.07	0.95	6.1	6.9	7.5	7.3	930	49	25	5640	329	181	262	92	65	1590	618	470	—	—	—	—
20.	1.09	1.03	6.2	7.2	8.3	8.5	730	4	3	4180	26	21	345	134	151	1970	872	1006	0.028	0.004	0.159	0.027
21.	1.19	1.13	6.7	8.1	8.7	9.0	1000	4	1	5740	25	7	184	68	15	1043	422	106	0.041	0.007	0.235	0.054
22.	0.83	0.76	4.9	5.2	6.1	5.9	965	6	1	5700	39	7	282	122	29	1668	788	201	0.040	0.015	0.235	0.108
23.	1.09	1.06	6.4	7.8	8.0	8.5	890	12	3	5250	80	22	280	201	35	1652	1332	258	0.045	0.011	0.264	0.084
24.	1.15	1.13	7.2	8.1	8.8	8.8	795	4	2	4940	26	14	222	128	10	1383	84.4	72.0	0.033	0.005	0.204	0.034
25.	1.41	1.40	8.5	9.7	10.7	11.0	790	20	2	4780	135	14	286	166	27	1733	1112	187	0.033	0.004	0.203	0.031
26.	0.83	0.84	4.9	5.8	6.0	6.3	—	—	—	—	—	—	228	118	15	1355	747	103	—	—	—	—
27.	0.39	0.37	2.6	3.0	3.1	3.2	—	—	—	—	—	—	294	79	44	1960	648	358	—	—	—	—

TABLE 1—ANALYTICAL DATA (*Contd.*)

Exp. No.	Conductivity	$10^{-4}\times$					pH			Organic Non-Sugars		Per cent Removal on 100 Brix								
				On 100 Brix								Purity Rise		Lime		Colour				
	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.C.J.	D.I.J.	Cl.J.	D.I.J.	Pol	Suc.	D.C.J.	D.I.J.	D.C.J.	D I.J.	Conductivity Ash	Nitrogen	Organic Non-Sugars
1.	42.8	94.2	1.92	311	712	15.4	6.9	1.5	6.1	8.6	4.7	7.8	7.4	99	99.5	69.4	93.5	95.1	89.5	45
2.	46.7	50.0	13.78	307	316	10.6	5.5	5.1	7.8	14.5	11.9	7.6	6.7	14.4	72.8	3.3	73.2	65.4	—	18
3.	31.0	73.8	1.68	181	454	10.8	5.8	1.5	5.9	6.9	3.4	4.4	5.1	99.2	99.6	72.1	90.8	94.2	96.1	51
4.	44.3	50.2	2.59	259	299	16.7	7.1	5.3	8.1	8.0	2.4	7.0	7.7	87.8	99.3	—	84.5	93.5	58	70
5.	44.1	44.7	2.92	265	274	19.5	6.9	4.2	6.8	8.2	3.3	7.9	7.5	84.2	98.5	—	32.3	92.6	67.8	61
6.	40.7	—	8.19	255	—	56.4	6.7	1.4	8.2	8.1	2.6	6.8	—	96	97.6	80	91.4	77.9	44.8	69
7.	70.2	68.0	2.18	468	460	17.2	6.0	2.2	7.4	8.9	-0.3	14.5	14.4	95.8	98.4	70.6	83.8	97.1	97.1	103
8.	78.0	67.0	3.77	530	457	28.7	6.7	2.2	8.3	8.8	1.7	10.9	11.9	89.4	98	63.2	88.5	94.6	98.9	81
9.	66.2	91.4	2.73	445	652	23.1	7.0	1.7	5.7	8.8	0.9	12.4	12.4	98	99.3	66.2	92.4	94.7	94.2	89
10.	71.3	86.0	4.43	520	712	42.0	7.0	1.8	6.2	14.3	3.6	15.2	15.0	94.8	99	67.9	95	92.6	96.9	75
11.	75.0	78.5	4.20	500	565	33.6	6.8	1.9	5.8	8.3	3.6	9.4	9.8	94.6	98.9	68	87.9	93.3	98	57
12.	84.1	75.2	8.14	459	457	57.7	6.7	2.1	8.6	7.5	1.0	9.4	11.2	94.5	97.8	53.5	70.7	87.2	28	86
13.	88.4	102	3.09	658	720	25.4	6.4	1.8	7.7	6.0	1.8	9.8	10.5	94.7	95	52	76.6	95.5	30.1	70
14.	79.2	—	7.42	478	—	52.5	6.7	—	8.9	7.7	0.2	10.2	12.0	—	97.8	—	66.6	89.0	—	97
15.	78.6	110	6.38	570	856	55.0	7.3	1.6	6.9	5.2	-0.5	10.4	11.1	96.8	98.8	60	87.5	90.4	75.9	109
76.	83.6	78.5	6.38	538	550	50.7	6.4	1.6	5.4	6.4	-0.5	12.4	12.2	88.5	96.6	55.6	80	90.6	66.2	108
17.	79.3	79.8	6.28	534	596	51.2	6.6	1.5	7.4	5.5	-0.5	10.3	10.8	96.2	97.4	66.9	93.3	90.4	92.7	109
18.	62.3	—	3.19	356	—	21.0	6.9	—	8.9	9.5	5.3	6.8	8.2	—	92.2	—	55	94.5	—	44
19.	61.4	75.0	2.13	374	503	15.4	6.3	1.7	7.8	7.3	-0.7	12.8	11.9	94.2	96.6	61.2	70.4	95.8	—	109
20.	58.6	98	7.44	335	636	52.4	7.6	1.6	3.9	14.0	6.4	8.2	9.7	99.3	99.4	—	49	94	83	54
21.	73.5	10.6	2.31	417	657	16.3	4.4	1.5	6.2	10.2	2.9	12.2	10.1	99.4	99.6	59.1	89.9	96	77.1	72
22.	66.5	57.4	2.17	394	372	15.0	6.8	2.0	8.1	9.3	5.3	7.7	8.8	99.3	99.8	52.6	88.2	96.2	54	43
23.	57.4	52.5	2.35	339	350	17.3	7.4	1.9	7.8	8.3	0.3	10.7	10.9	98.5	99.6	19.4	84.2	94.8	66	96
24.	57.5	100	2.10	358	665	15.1	7.1	1.7	6.7	6.4	-0.4	9.3	10.2	99.3	99.7	39	95	92.8	83.5	106
25.	56.0	85.5	2.52	339	573	17.4	6.8	2.2	8.5	7.2	1.6	8.9	8.5	97.2	99.6	35.3	89.4	94.8	84.8	78
26.	62.4	73.5	2.31	372	466	16.0	7.4	1.9	7.8	8.6	2.0	10.1	10.3	—	—	45	92.4	95.6	—	77
27.	56.0	57.0	3.10	370	470	25.2	6.5	2.1	7.5	8.1	2.2	10.1	9.9	—	—	67	82	93.2	—	73

Double carbonation and it is concluded that a process of preclarification with minimum of control and better economics should be adopted if the juice is to be processed by ion-exchange methods. However, it is observed that juices from Bombay-Deccan factories have got much lower ash content than juices from North Indian Sugar factories and therefore the former are much more suited to ion-exchange treatment as the regeneration cost will be much less. The rise in purity of Bombay Deccan juices on ion-exchange treatment are of the order of 7.5 units and according to S.J.M. Formula of Noel Deerr about 6.6% additional sucrose is recoverable from deionised juice while with North Indian juices rise in purity is of the order of 10 units therefore about 9.5% additional sucrose is recoverable. The temperature in North India during cane crushing season is usually about 20°C. which will considerably minimise the cost of refrigeration. Shah (18) in 1954 has indicated that inspite of higher cost of regeneration on account of high ash content, the ion-exchange process has distinct possibility in North India also. However pilot plant trials are considered necessary before we get a clear picture of the economics and suitability of the North and South Indian Juices for demineralisation by ion-exchange.

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REFERENCES

1. Harm, F. German Patent 95, 447 (2nd June, 1896).
2. Rumpler, A. Z. Ver. deut. Zuckerind 53, 798 (1903), Ltd. Chem. Ztg. p. 1078 (1903).
3. Gans, R. Z. Ver deut. Zuckerind 57, 931 (1907); ibid German Patent 174097 (Jan. 12, 1915).
4. Adams, B. and Holmes, E. J. (1935) Soc. Chem. Ind. 54, 1-6 ibid U.S. Patent 2104501 (Jan. 4, 1938).
5. Liebknecht, 0. French Patent 808612 (Nov. 14, 1936); Corresponding U. S. Patent 215318 (April 18, 1939).
6. Payne, J. H. Principles of Sugar Technology, Edited by Pieter Honig page 726 ; Elsevier Publishing Co. New York 1953.
7. Weitz., F.W. *Sugar* 38, (1) 26-31 (1943).

8. **Gutleben, D. and Harvey, F.** 1954. *International Sugar Journal* 47, 11-13.
9. Haagensen, E. 1946. *Sugar* 41 (4), 36-41.
10. Rawlings and Shafor. 1942. *International Sugar J.*, 44, 19.
11. Ellison, H. E. and Porter. 1948. *L.B. Sugar* 43, (3), 30-34.
12. Winters, J.C. 1948. Chemical Industries 754-758 .
13. Riley, F. R. and Sanborn. 1947. *W.E. Sugar* 42, (7), 24.
14. Dickinson, B.N. 1948. Chem. Eng. 55, (7), 114-7.
15. Mindler, A.D. 1948. Ind. Eng. Chem. 40, 1211-5.
16. Fitzwilliam, C.W. and Yearwood, R.D.E. 1947. *International Sugar Journal* 49, 69-73.
17. Du Toit, J.L. 1948. *Proc. South African Sugar Tech. Assoc.*
18. Shah, H.A. *Proc. 7th Ann. Conv. Deccan Sugar Tech. Association* : Shah, H.A. and Bafna, S.L. 1951.ibid. 8, 147 ; Shah, H.A. : Joshi K.A.; Bafna, S.L. and Govindan, K.P. 1952. ibid, 9, 43 ; Shah, H.A. 1954. *Proc. of the Sugar Technologists' Association* 27, 46.
19. Morini, M. 1954. Ind. Sacc. Ital., 47. 353-359 ; 1955. S.I.A. 35.
20. Asami, T. and Co-workers. 1954. *Proc. Res. Soc. Japan Sugar Refin. Technol* : 31-32. 1955. S.I.A., 36.
21. Fort, C.A. and Smith, B.A. 1953. Sugar j. (2), 16, 1955. ibid. *Sugar* 50 (4), 43.
22. Mitchell, E. and Sommerfield, C.A. 1951. *Proc. Queensland Sugar Cane Technol.* 18, III-120.
23. Refinings of sugar Solution, Duolite Data Leaflet No. 28 pp. 6 (April 1953). *Publication of Chemical Process Coy.* Redwood City, California. (U.S.A).
24. Von Lillienskiold M. Zucker. 1953. 6. 483-486, S.I.A. 775.
25. Saha, J.M., Jain, N.S. ; Sexena, K.S. and Nigam, G.M. 1950. *Proc. of the Sugar Technologist Association of India* 19, 156. Saha, J. M. and Jain, N. S., ibid. 20-37 1951. ibid, 23, 168 1954. Indian Patent 43812 (26.9.50) 48795 (15.1.53) and application No. 51164 (1.2.54).
26. Unpublished work (Professor K.S.G. Doss).
27. A Manual for Manufacturing control, 1931. *Bulletin No. 11 of Proof station Java* (English translation *Published by S.T.A. India*)

DISCUSSION

Dr. H.W. Kerr stated that he was very interested to learn that work was still proceeding on means to achieve an ideal desired by all chemists—the removal of non-sugars from juices.

In reply to Dr. Yamane who was interested in the working life of the resins, Mr. Mukherjee said that the use of the resins had not extended beyond the actual test period which was too brief for any information to be secured as to the life of the resins.

When Mr. Davis enquired as to whether any problem had been encountered through the activity of micro-organisms in the resin beds, Mr. Mukherjee replied that this problem had not arisen, but the conditions of operation were such as to render it unlikely that any substantial growth of micro-organisms could establish itself.

Mr. Clayton pointed out that one of the major drawbacks to the use of the ion-exchange process was that the sugar solutions could not be processed at high temperatures. This meant that the solutions must be cooled for treatment and then reheated for further proceesing. Some use could be made of heat interchanges within the process but substantial measures of heating and cooling from outside sources would be required.

Mr. Mukherjee acknowledged this but went on to explain that the problem would be greatly alleviated by the use of a reverse process of demineralisation. With the aid of suitable resins it would be possible to treat the juice first with an anion exchanger and then with a cation exchanger.

It would then be possible to work at as high as 45°C. Dr. Kerr commented that juice clarified by the electrical method might prove ideal for subsequent treatment in the ion-exchange process.

Dr. Doss reverting to the subject of the growth of micro-organisms in resin beds pointed out that the regular cycle of regeneration should effectively suppress any such growth.

Mr. D.R. Parashar then presented the following paper.

Paper

CHARACTERISTICS OF INDIAN CANE-JUICES IN RELATION TO THE PURITY OF FINAL MOLASSES PART II

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INTRODUCTION

The characteristics of Indian cane juices in relation to the settling and filtration of juices in sulphitation sugar factories have been described in Part I. In addition to the different problems that the Indian sugar factories had to face from time to time in connection with the process of juice clarification, the problem of the purity of final molasses has also been one of the notable features of the Indian cane juices A good deal of divergence has been existing in the apparent purities of final molasses from region to region and even in the same region ; the maximum i.e., 35 to 40 being in sugar factories situated in North Bihar and the lowest i.e., 30-35 being in Western U.P. Investigations were therefore taken up by the author to study the causes of these variations in purities. The results of investigations are summarised in this paper.

1. *The effect of inorganic non-sugars on the exhaustibility of final molasses.* The ash analysis of a few samples of graining liquors used for boiling the final massecuites in the sulphitation and carbonation sugar factories situated in U.P. and Bihar is given in Table I.

It would be observed from these figures that although slight discrepancy might arise in the mole-equivalents of cations and anions which according to Honig (2) should be equal in the ash components, yet the analysis of ash indicates that the sulphates, alkali and calcium salts predominate in the graining liquors. In order, therefore, to study the effect of these non-sugars on the exhaustibility of final molasses a few experiments (3) were conducted on a large scale by artificially adding to the graining liquors the following substances which are commonly present in the syrup.

A. Dirt particles (suspended matters).
B. Sodium salts (mixture of sodium chloride and sodium sulphate).
C. Calcium salts (decomposition products of reducing sugars with lime).

The results of these observations are stated below :—

A. Dirt particles exert some adverse influence on the purities of final molasses.
B. The effect of sodium salts is rather peculiar. At high concentration of the

massecuite the exhaustion of mother liquor is not appreciably effected by the presence of these salts. But at a lower concentration of the massecuite, the purity of molasses is higher than that obtained from the untreated syrup boiled to the same concentration indicating that these salts exert an adverse influence on the exhaustion of mother liquor particularly at low brixes of the final massecuite.

C. If a final massecuite is boiled on a footing of syrup containing an appreciable amount of reducing sugar decomposition products, the purity of final molasses is no doubt reduced, but the resulting massecuite is rendered so viscous that its curing becomes difficult without having recourse to either heavy dilution or steaming. Thus these salts exert an indirect influence in increasing the purities of final molasses.

On the whole it appears that the presence of inorganic constituents of syrup does not exert an adverse influence on the exhaustion of mother liquor provided the massecuites are boiled to a proper consistency. Further, if a final massecuite is boiled slowly in the vacuum pan to a fairly high concentration, the mother liquor can be exhausted better inside the pan than during cooling in the crystallisers.

2. *Reducing sugars ash ratio and the purity of final molasses.* In view of the wide variations existing in the apparent purities of final molasses in the Indian Sugar Factories, it was believed that as stated by Geerligs (4) it will be impossible to reduce the purity of final molasses to 30 when the ratio of reducing sugars to ash amounts to 1.5. The reducing sugars ash ratios as observed in Java by Geerligs (5) in the graining liquor, massecuite and molasses are given in Table II. The reducing sugars ash ratios observed in the Indian Sugar Factories have been shown in Table I. The analysis of a few samples of clear juice, unsulphured syrup and final molasses obtained from three sulphitation sugar factories situated in Bihar are given in Table III while the analysis of final massecuites and their corresponding final molasses obtained from a few sugar factories situated in U.P. and Bihar are given in Table IV.

TABLE I

SHOWING THE COMPOSITION OF GRAINING LIQUORS

Factory	Graining liquor	Bx.	Pol	Purity	Alcohol Precipitable non-sugars	Red. sugars	Ash	Red. sugar/ Ash	Analysis of ash							
									SiO$_2$	Fe$_2$O$_3$ Al$_2$O$_3$	CaO	MgO	K$_2$O Na$_2$O	SO$_3$	P$_2$O$_5$	Cl
A	Sulphitation syrup	85.2	69.4	81.4	0.036	3.5	2.6	1.36	3.6	2.8	18.1	7.7	36.8	21.7	2.9	5.4
B	Sulphitation syrup	85.8	77.2	84.1	0.027	2.7	3.4	0.80	9.1	2.0	11.9	5.6	35.8	29.3	3.6	4.2
	A wash and A mol.	85.8	69.4	80.8	0.033	3.0	3.1	0.78	—	—	—	—	—	—	—	—
C	Sulphitation syrup	86.0	68.8	80.1	0.025	2.6	3.3	0.80	5.2	1.5	11.1	2.1	46.4	20.1	4.2	6.0
	-do-	87.6	70.0	79.8	0.028	2.8	3.7	0.75	—	—	—	—	—	—	—	—
D	Carbonation syrup	85.8	77.2	90.0	0.039	1.7	2.8	0.60	6.2	3.9	4.6	—	48.3	25.8	13.6	6.3
	Syrup+A mol.	85.8	71.2	83.0	—	2.9	3.3	0.88	—	—	—	—	—	—	—	—
E	Sulphitation syrup	80.8	66.8	83.1	0.066	2.3	2.1	1.1	3.0	2.4	12.2	4.0	27.2	50.6	0.7	—
	-do-	86.3	70.4	84.2	0.06	3.0	2.7	1.09	—	—	—	—	—	—	—	—
	-do-	82.1	69.4	84.5	—	3.4	2.6	1.29	—	—	—	—	—	—	—	—
F	Carbonation syrup	86.7	66.2	76.5	0.061	3.5	5.2	0.67	—	—	—	—	—	—	—	—
G	Sulphitation syrup	77.0	63.8	82.8	0.051	3.1	2.2	1.30	3.1	1.4	11.7	4.4	27.5	50.9	0.7	—
	A wash and B heavy mol.	81.6	55.0	67.4	0.098	6.9	5.4	1.29	—	—	—	—	—	—	—	—
H	Sulphitation syrup	88.0	71.8	81.6	0.044	3.5	3.0	1.16	—	—	—	—	—	—	—	—

TABLE II

	Brix	Dry solid	Pol	App. Purity	Red. Sugars	Ash	Red. Sugars/ Ash
Graining liq.	82.06	81.35	75.42	91.90	3.65	1.0	3.65
Massecuite	97.4	94.1	57.6	59.2	13.9	5.28	2.63
Mother liq.	93.7	84.7	30.6	32.7	24.4	9.55	2.54
Molasses (cooled)	89.5	83.2	24	26.8	27.0	510.0	2.68
Massecuite	95.9	91.4	56.3	58.7	15.6	7.02	2.22
Mother liq.	91.4	85.3	30.6	33.4	22.4	9.43	2.37
Molasses (cooled)	86.2	80.04	23.8	27.5	23.8	9.65	2.47
Molasses	87.38	83.61	—	29.75	27.06	7.61	3.55
,,	85.36	80.82	—	31.51	29.41	6.32	4.65
,,	87.26	82.85	—	29.96	25.64	7.96	3.22
,,	81.84	77.60	—	28.15	25.0	7.45	3.86

TABLE III

	Brix	Purity	Reducing Sugar/ Ash	Ash % solids
Factory A				
Clear Juice	17.8	82.0	1.2	4.0
Unsulphured syrup	57.7	83.0	1.2	3.8
Final Molasses	96.0	31.6	1.4	14.0
Factory B				
Clear Juice	15.6	82.5	1.2	3.7
Unsulphured syrup	63.1	82.4	1.3	3.5
Final Molasses	98.0	32.1	1.4	15.0
Factory C				
Clear Juice	16.1	83.8	0.7	4.3
Unsulphured syrup	50.4	83.7	0.7	4.4
Final Molasses	99.3	37.4	0.734	16.2

It will be observed from these figures that the reducing sugars in the Indian cane juices are much lower than those in Java. It could not, therefore, be expected that the Indian cane juices should be exhausted so easily as the Java juices if boiled under similar conditions.

A. *Concentration of final massecuite in relation to the reducing sugars ash ratios.* A reference to the figures given in Table IV would lead to the following conclusions.

1. Juices having identical reducing sugars ash ratios do not exhaust to the same extent even though these are boiled under similar operating conditions. The reducing sugars appear to exert a greater influence on the exhaustibility of final molasses than the ash. In other words for the same reducing sugars ash ratio, the juice containing a higher reducing sugar content will yield final molasses of a lower purity.

TABLE IV

		Final Massecuite				Final Molasses								
		Brix	Pol	Purity	Refractive Index	Brix	Pol	Sucrose	Gravity Purity	Gravity Purity	Reducing Sugars	Ash	Red. Sugar/ Ash	Refractive Index
'A'	Sulphitation.	99.8	58.4	58.5	1.508	99.0	29.4	33.4	29.7	33.7	27.6	11.4	2.4	1.508
'B'	,,	100.3	58.6	58.4	1.510	98.0	30.4	33·3	31.0	34.0	17.1	11.9	1.43	1.508
'C'	,,	103.6	62.4	59.6	1.516	99.3	29.0	33.0	29.2	33.0	20.1	12.5	1.6	—
'D'	,,	102.7	59.4	57.8	1.512	96.4	31.2	33.3	32.4	34.5	17.1	13.0	1.31	1.506
'E'	(a)	101.4	59.6	58.8	1.511	98.6	33.0	35.4	33.5	35.9	13.7	12.6	1.1	1.508
	(b)	101.2	59.4	58.6	1.511	98.7	33.6	35.8	34.0	36.2	13.2	12.6	1.0	1.507
'G'	(a)	104.0	61.6	58.9	1.515	98.4	34·0	36.1	34.6	36.6	11.5	14.0	0.8	1.507
	(b)	101.0	59.0	58.4	1.510	96.1	34.2	36.1	35.6	37.5	11.2	12.7	0.9	1.505
	(c)	103.5	60.4	58.3	1.514	98.4	35.6	37.6	36.1	38.2	9.9	13.8	0.7	1.506
	(d)	101.0	60.4	59.8	1.510	98.7	36.6	38.3	37.1	38.9	11.2	14.8	0.8	1.507
	(e)	101.5	59.6	58.7	1.510	96.5	37.4	39.1	38.7	40.5	10.4	13.0	0.8	1.506
	(f)	104.1	61.4	58.9	1.516	96.0	31.9	34.4	34.5	35.8	13.5	11.4	1.2	1.506
'H'	Carbonation													
	(a)	103.3	60.6	58.7	1.516	98.6	34.0	36.1	34.5	36.6	13.5	15.4	0.9	1.507
	(b)	102.7	61.9	60.3	1.514	95.9	36.0	38.2	37.5	39.8	13.0	16.0	0.8	—
'I'	Carbonation.												Diluted with final molasses	
	(a)	104.3	56.6	54.2	1.518	99.30	32.56	—	32.8	—	12.8	16.0	0.8	1.509
	(b)	104.60	58.1	56.60	1.518	100.8	33.0	—	32.7	—	—	—	—	—
'J'	Sulphitation	103.1	57.40	55.65	1.516	100.6	28.2	—	28.2	—	20.1	13.8	1.4	1.511

2. The lower is the reducing sugars ash ratio the higher is the concentration required for exhausting the mother liquor in final massecuites. If the reducing sugars ash ratio is sufficiently high i.e., above 2.0, the final massecuite can yield the final molasses below 30 purity even if the brix of final massecuite is below 100.

3. If the reducing sugars ash ratio is below 2.0, but higher than 1.5, it can still be possible to exhaust the final molasses below 30 purity by boiling the C massecuite to higher brix than 100.0

4. If the reducing sugars ash ratio is above unity but below 1.50, it becomes necessary not only to boil the massecuite to a brix higher than 100, but at the same time to boil it to a purity below 58.0 for obtaining final molasses of near about 30 purity.

5. If the reducing sugars ash ratio is below unity, the purities of final molasses are usually above 30.0 and it becomes necessary to boil the massecuite to a brix of 103—104 for checking the shooting up tendency of the purity of final molasses. At lower brixes of the massecuite, there is generally a corresponding increase in the purity of final molasses if the purity of final massecuite is above 58.0 as further shown by the following figures.

	Massecuite				*Final Molasses*		
Bx.	Pol	Purity	Refractive Index	Bx.	Pol	Purity	Reducing Sugars/Ash
103.5	60.9	58.8	1.514	98.5	35.6	36.1	0.72
101.6	60.2	59.2	1.510	96.8	37.5	38.8	0.82
101.5	59.6	58.7	1.510	95.5	37.0	38.7	0.80

It is, however, preferable to express concentration of mother liquor in terms of refractive index rather than apparent solids. According to the refractive indices of mother liquors, the final massecuite can be classified as follows :—

(a) Stiff
(b) Semi stiff
(c) Soft

If the refractive index of mother liquor remains below 1 509, the massecuite is soft in nature. This type of massecuite is easy to cure, but difficult to exhaust unless the reducing sugars ash ratio is sufficiently high i.e., above 2.0. The massecuite having refractive index between 1.509 and 1.512 is semi stiff and this massecuite can be exhausted suitably if the reducing sugars ash ratio is between 1.4 and 2.0 But if the glucose ash ratio is below 1.40 as is usually the case with Indian cane juices, the massecuite is required to be boiled stiff i.e., the refractive index should exceed 1.512, the maximum being attained at 1.516 or 1.517, the degree of stiffness depending on the reducing sugars ash ratio. Such massecuites are, however, required to be diluted for proper curing.

Further as stated above, the purity of final massecuite also exerts a good deal of influence on the exhaustion of final molasses. If the reducing sugars ash ratio is below unity, the purity of final molasses shoots up considerably particularly if the purity of final massecuite exceeds 60. The purity of final massecuites will, however, depend on the initial purity of syrup and on the purity drop that can be obtained in the high grade massecuites such as A and B. The higher is the reducing sugars ash ratio, the greater is the purity drop which becomes more conspicuous in the B massecuite even if the A massecuite has been boiled to a high purity and its purity drop is low. But if the reducing sugars ash ratio is fairly low i.e., either unity or below unity, the purity of final massecuite remains usually between 58 and 60 and consequently it becomes difficult to exhaust the final molasses below 32.0 purity, the ultimate purity depending on the reducing sugar content in juice, the refractive index and purity of the final massecuite.

B. *The effect of artificial increase in reducing sugars ash ratio in the graining liquor on the exhaustion of final molasses.* Considering the low reducing sugars ash ratio in the Indian cane juices and its reaction on the boiling of final massecuite as well as on the purity of final molasses particularly when the reducing sugars ash ratio is below unity, a few experiments were conducted on a large scale to study the effect of artificial increase in the reducing sugars ash ratio in the graining liquor used for boiling the final massecuite on the exhaustion of mother liquor. While doing so there were two objects in view, i.e., firstly to reduce the purity of graining liquor in order to obtain final massecuite below 60 purity. In most of the sulphitation sugar factories it is done by mixing syrup with some low purity molasses and this mixture adversely effects the colour of sugar crystals. The second object was to study if the artificial addition of invert sugars to the graining liquor exerted a favourable effect on the exhaustion of mother liquor. The invert sugar liquor was prepared by making syrup (50-55 Bx.) from sugar lumps (rori) and inverting it with hydrochloric acid. To start with the invert sugar liquor was prepared in the laboratory by taking one litre of sugar syrup and heating it to 80°C. and treating with 2 ml. of hydrochloric acid (1. 19 sp. gravity). This temperature of 80°C. was maintained for 1/2 hour in one sample and 3/4 hour in the other sample. The invert reading when 26 grams of invert liquor was diluted to 100 ml. and observed in 200 mm. tube was found to be-14 in each case. The invert sugar liquor was neutralised with 40 percent caustic soda solution.

For determining the approximate proportion of invert sugar liquor and syrup required for the purpose of graining, two samples of sulphured syrup 500 ml. each were taken and 20 ml. and 50 ml. of invert sugar liquor were added respectively. It was observed that by adding 20 ml. of the invert sugar liquor to 500 ml. of sulphured syrup, the purity of syrup was reduced from 84.0 to 78.2 while by adding 50 ml., the purity was reduced to 74.1. Since the latter purity was too low it was decided that the proportion of 20 ml. of invert liquor to 500 ml. of syrup should be fixed. For large scale experiments calculations were made as shown below :—

Pan capacity 20 tons (actual strike level 18 tons).
Purity of C massecuite required 58-59.
Purity of B heavy molasses 53.0.
Purity of syrup and invert sugar liquor footing 78.0.
Volume of footing required for double C strike 300 cu.ft.

Corresponding volume of syrup 500 cu.ft.
Invert sugar liquor 20 cu.ft.
Acid 1000 ml.
Soda caustic solution (40 %) 3000 ml.
Quantity of sugar required 0.30 ton (about 8 maunds).

The calculated quantity of sugar is dissolved in a tank of drum and inverted by adding the calculated volume of acid. In actual experiments the time of inversion was increased and the polariscope reading obtained was-4 in extreme cases.

These tests were conducted in three sugar factories and the purities of syrup and those of the mixture of syrup and invert sugar liquor along with their reducing sugars ash ratios are given below.

Factory A (carbonation) using 0.11 ton (3 maunds) of sugar for a C strike of nearly 22 tons capacity.

	Bx.	Pol	Purity	Reducing Sugars	Ash	Reducing sugars/Ash
Syrup	59.0	52.8	89.5	—	—	—
Syrup and invert sugar liquor footing	82.4	69.5	84.5	3.1	2.3	1.3

Factory B using about 0.08 ton (maunds) of sugar for a pan of 22 tons strike capacity.

Syrup footing	79.3	67.0	84.4	2.9	2.8	1.0
Syrup and Invert sugar footing	85.0	69.8	82.1	4.4	3.1	1.4

Factory C (sulphitation) using 0.30 ton (8 maunds) of sugar for a double C strike of 18 tons capacity each.

LARGE SCALE TESTS

Test I

Invert sugar liquor	42.0	14.7	35.0	—	—	—
Syrup footing	71.5	59.5	83.1	2.7	2.9	0.9
Syrup and invert sugar liquor footing	76.3	59.8	78.3	5.6	2.2	2.5

Test II

Syrup footing	77.2	65.1	84.3	2.7	2.8	1.0
Syrup and invert liquor	79.7	61.9	77.7	7.4	2.2	3.3

The observations in connection with the C massecuites boiled on different graining media i.e., syrup, mixture of syrup and A molasses, and mixture of syrup and invert sugar liquor alongwith the purities of the corresponding final molasses are given in Table V.

It will be observed from these figures that as a result of the artificial increase in reducing sugar content of syrup, there is a fall in the purity of final molasses by 2 to 3 units as compared with the purity of final molasses obtained from the final massecuite boiled on footing of syrup or a mixture of syrup and A heavy molasses. This reduction in purity may be due to a reduction in the purity of final massecuite as well as due to an increase in the reducing sugars which exert a favourable influence on the mother liquor in exhausting it either at the very initial stages of boiling or gradually as the boiling proceeds. Since ultimately the samples of final molasses obtained from the massecuites boiled with and without the addition of invert sugar liquor do not show an appreciable difference in the reducing sugar content or in the reducing sugars ash ratios, no suitable explanation can be given for this reduction in the purities of final molasses. It is, however, clear that the larger is the increase in the reducing sugars ash ratio in the graining liquor, the better is the exhaustion of final molasses. But the quantity of reducing sugars cannot be increased to such an extent that the purity of graining liquor becomes too low and as a result of the formation of soft grain, the exhaustion of mother liquor is retarded.

It might be argued that the invert sugar liquor itself has effected reduction in the purity of final molasses. Taking the example of factory C, the quantity of sugar used i.e., 0.3 ton (8 maunds) should give about 0.315 ton (8.5 maunds) of invert sugars in case there is complete inversion of sugar. Assuming that 36 tons of C massecuite contain about 22 tons of final molasses, and 0.315 ton (8.5 maunds) of invert sugars mixes direct with the final molasses the percentage of invert sugars on molasses will be about 1.4. If on analysis a typical sample of final molasses shows the results-Brix 95.6, Pol 34.4 and Purity 36.0, the addition of 1.4% invert sugar will reduce the purity of this molasses by about 0.25 unit only. On the other hand if the purity of final molasses is reduced by 2 to 3 units, it indicates that the addition of invert sugar induces the separation of sugar or accelarate the exhaustion of mother liquor.

Further the quantity of sugar used in the extreme case of factory C is 0.3 ton (8 maunds) and the quantity of C massecuite boiled is 36 tons which should contain about 21.6 tons of sugar (pol % massecuite 59-60). If the purity of final molasses is reduced even by 2 units the additional sugar that can be recovered will be about 0.65 ton (17.5 maunds). In other words, there is a net gain of about 0.35 ton (9.5 maunds) of sugar. If, therefore, the total quantity of C massecuite boiled in 24 hours in a 1000 tons sugar factory is approximately 90 tons, the gain of sugar per day will be about 0.9 ton (24 maunds), This can be verified in the following manner as well by assuming the following figures.

Mixed Juice

Bx.	Pol	Purity	Mixed Juice % cane	Sugar in mixed juice % cane
15.0	12.4	83.0	88	11.0

If the purity of final molasses is reduced by 2 units the additional sugar recoverable percent sugar in mixed juice will be about 0.9 or 0.099 percent cane and 0.99 ton per 1000 tons of cane as against 0.9 ton calculated above.

THE PROCESS OF JUICE CLARIFICATION IN RELATION TO REDUCING SUGARS ASH RATIO

Considering that the reducing sugars ash ratio in general and the reducing sugars in particular play an important part so far as the exhaustibility of final molasses is concerned, a few experiments were conducted to determine the method of juice clarification which ensures the minimum destruction of reducing sugars and at the same time effects the maximum removal of ash in sulphitation factories. These observations were confined only to the following three methods of juice clarification, because the simultaneous method of liming and sulphitation at high temperature is being commonly used in the Indian Sugar Factories.

(a) Simultaneous method of liming and sulphitation at 70°C.
(b) Hot preliming method at 70°C.
(c) Cold preliming method (Raw Juice heated to 70°C. after preliming in the cold).

These observations have shown that the method of simultaneous liming and sulphitation at 70°C. as well as the cold preliming method cause an increase in the ash content in clear juice as compared with that in the raw juice. But in the hot preliming method there is a decrease in the ash content. The simultaneous method of liming and sulphitation causes the maximum destruction of reducing sugars while in the hot preliming method and cold preliming method it is relatively less. The results are shown in Table VI.

From these figures it is clear that on the whole the reducing sugars ash ratio in the clear juice remains higher by adopting the hot preliming method than in the other two methods. In the hot preliming method the raw juice is heated to 70°C. and a part of milk of lime is added so as to render the juice neutral. The balance of milk of lime is added gradually in the juice sulphitation tanks simultaneously with SO_2 gas.

TABLE V

Factory	Bx.	C. Massecuite		Graining Liquor			Final Molasses					
		Pol Gravity Purity	Ref. Index		Bx.	Pol Gravity Purity	Gravity Purity	Reducing Sugars	Ash	Reducing Sugars Ash Ratio	Ref. Index	Curing Temperature
A. Carbonation	103.72	59.7	1.516	Syrup and A Heavy	102.7	37.8						Hot at 70°C.
					101.2	35.7						55°C.
					99.7	35.0	38.8	13.0	15.8	0.82	1.507	45°C.
	104.05	60.0	1.517	Syrup Bx. 82.9 Purity 87.0	102.4	37.3						Hot
					101.0	35.4						55°C.
					100.0	34.3	38.3	13.6	16.3	0.83	1.507	45°C.
	104.25	57.0	1.517	Syrup and Invert Sugar Liquor	102.2	34.7						Hot
					101.8	32.4						55°C.
					100.1	32.0	59.9	13.9	15.4	0.9	1.509	45°C.
	104.93	58.9	1.517	—do—	102.8	35.8						Hot
					101.6	33.9						55°C.
					99.8	32.9	36.8	14.1	16.1	0.9		45°C.
B. Carbonation	103.0	57.0	1.517	Syrup & A Heavy Bx. 81.2 Pol 67.5 Pty. 83.1 R. Sugar 3.34 Ash 3.07 R.S./Ash. 1.09	101.6	35.3						Hot
					77.9	33.8		13.3	12.5	1.06		Final
	101.90	59.4	1.513	Syrup	100.0	37.4						Hot
					101.0	35.7						55°C.
					97.3	34.1		13.1	12.6	1.04		Final
	101.60	60.5	1.513	Syrup & Invert Sugar Liquor.	100.6	36.9						Hot
					97.2	32.8		14.0	12.7	1.10		Final
	101.90	60.3	1.513	—do—	100.7	35.8						Hot
					97.2	33.0						Final
	102.03	58.4	1.513	—do—	101.3	34.6						Hot
					97.0	31.0		14.1	12.3	1.14		Final

TABLE V (*Contd.*)

Factory	Bx.	C. Massecuite		Graining Liquor	Final Molasses							Curing temperature
		Pol Gravity Purity	Ref. Index		Bx.	Pol Gravity Purity	Gravity Purity	Reducing Sugars	Ash	Reducing Sugar Ash Ratio	Ref. Index	
C. Sulphitation	103.54	59.5	1.515	Syrup & A Heavy Purity 78-79	101.8	38.1						Hot
					96.6	36.0	38.5	11.5	12.5	0.92		Final 50°C.
	102.15	60.6	1.513	—do—	101.2	38.9						Hot
					97.4	36.8	38.8	11.6	12.1	0.96		Final
	101.46	60.0	1.510	—do—	98.7	38.4						Hot
					98.5	36.4	38.7	11.3	12.0	0.94		Final
	101.70	61.1	1.511	Syrup Purity 83-84	100.7	39.1						Hot
					96.6	37.3	39.8	11.7	12.0	0.97		Final
	102.83	61.4	1.512	—do—	100.7	39.9						Hot
					96.8	37.7	40.0	11.2	11.9	0.94		Final
	Test I.											
	103.20	60.3	1.516	Syrup & Invert Sugar Liquor	102.3	36.9						Hot
					98.2	34.5	36.9	12.1	11.7	1.02		Final
	101.65	59.8	1.513	—do—	101.0	36.8						
					96.7	34.9	37.3					
	Test II.											
	101.85	60.5	1.512-13	—do—	99.3	36.0						Hot
					97.6	33.9	36.6	12.6	11.8	1.07		Final
	101.28	60.8	1.512	—do—	100.1	35.9						Hot
					96.8	33.9	36.4	12.7	12.0	1.06		Final

TABLE VI

DEGREE OF LIMING 1.2% RAW JUICE (12° Be'.)

	Simultaneous method of liming and sulphitation at 70°C.				Hot preliming method				Cold preliming method			
	Mixed	Juice	Clear	Juice	Raw	Juice	Clear	Juice	Raw	Juice	Clear	Juice
Brix	15.7	15.7	15.9	16.3	14.9	14.5	15.5	15.5	15.2	15.1	15.4	15.4
Pol	13.1	13.0	13.4	13.6	12.3	12.1	12.0	12.9	12.7	12.5	12.9	12.9
Purity	83.6	83.0	84.1	83.4	82.4	83.5	82.9	83.6	83.3	82.9	83.7	83.5
Red. Sugar	0.4	0.67	0.4	0.46	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.4
Ash	0.5	0.5	0.7	0.7	0.5	0.6	0.49	0.6	0.5	0.5	0.7	0.60
R.S./Ash	0.9	0.9	0.6	0.6	1.0	0.85	0.9	0.8	0.9	0.8	0.7	0.7
R.S./Pol	3.5	4.4	3.1	3.4	4.0	4.1	3.6	3.6	3.8	3.5	3.6	3.6
Ash % Solid	3.2	3.3	4.4	4.6	3.4	4.1	3.2	3.9	3.5	3.4	4.3	3.9
Ash % Non-Sugar	19.4	19.7	26.8	27.7	19.1	24.2	14.1	17.2	21.0	19.8	26.2	23.5
Alcohol precipitable Non-Sugars percent Juice	0.8	0.1	0.8	1.0	0.8	0.8	0.8	0.7	0.9	0.8	0.7	0.7
Alcohol precipitable non-sugar percent Solids	5.0	6.8	5.2	6.3	5.6	5.3	5.0	4.6	8.9	5.5	- 4.7	4.7

REFERENCES

1. Parashar, D.R. and Kripa Shankar. 1941. *proc. 10th Annual Convention S.T.A. India* p. 163.
2. Pieter Honig Principles of Sugar Technology p. 307.
3. Parashar, D.R. and Nigam, G.M. 1941. *10th Annual Convention S.T.A.* p. 215.
4. Prinsen Geerligs—Cane Sugar and its Manufacture p. 334.
5. Prinsen Geerligs—Cane Sugar and its Manufacture.
6. Parashar, D.R. 1954. *Proc. 23rd Annual Convention S.T.A. India* p. 293.
7. Parashar, D.R. 1954. *Proc. 23rd Annual Convention S.T.A. India* p. 307.

DISCUSSION

Mr. S.N. Gundu Rao suggested that the lower apparent purity obtained, when reducing sugars were added to the 'c' massecuite could be due to a dilution effect rather than the salting out of sucrose.

Mr. Parashar said that the amount of reducing sugar added would not be sufficient to dilute the molasses to the lower purities which were observed.

Mr. P.C. Ganguli said that in his experience of factory trials in which reducing sugars were added to massecuites, no lowering of molasses purity was obtained. He said it was important to use gravity purity rather than apparent purity.

Mr. Parashar replied that the artificial addition of reducing sugars was of greatest value when the reducing sugars : ash ratio was less than unity. With high ratios, the addition of reducing sugars might not prove helpful.

In the absence of the author the following paper was taken as read.

Paper

THE SULPHOBENTONIZATION PROCESS OF SUGAR-CANE JUICES

O. S. Mallea

INTRODUCTION

In the manufacture of direct consumption white sugar from cane, it is necessary to carry out optimum clarification of the juice. This stage is perhaps the most important of the entire process of manufacture.

It is well known that the composition of sugar-cane juice is very complex, since a number of impurities of an organic and mineral character in varying degree accompany sugar in dissolution—which is its principal constituent. The problem consists of eliminating the greater part of these impurities with the object of avoiding their later influence during the entire course of production.

In spite of the great variation in the relative proportions of the principal constituents of sugar-cane juice, according to whatever may be the variety, state of maturity, composition of the soil, conditions of climate and the state of the raw material used, its composition can be defined within the following approximate limits :—

Saccharose	10.0—15.0 %
Reducing Sugars	0.5— 1.5 %
Mineral Substances	0.3— 1.0 %
Non-sugar Organic Material	0.5— 1.5 %

These different substances are found in distinct sub-divisions. Thus, whereas the saccharose, reducing sugars and salts co-exist in molecular solution, the proteins, gums, tannins and some pigments appear in colloidal form. On the other hand appreciable quantities of non-sugar substances exist in a state of gross suspension, as for example : fine particles of bagasse, sand or clay, waxes and chlorophyll, the quantity of which oscillates from between 0.3 to 2.5 grs. per litre of mixed juice.

It has always been very difficult for the sugar industry of our country to execute a perfect clarification of juices ; even some years back when juices of high purity were used and the different clarifying products were at so low a price that they could be utilized in abundance. At present this problem has become notably more acute, since there predominately exists an elaboration of poor quality juices which are generally very refractory towards clarification owing to a number of factors such as : bad cutting, damage by frost, delays occasioned by faulty rationalization of transport, sugar-cane borer, red-rot and new refractory varieties of cane. Therefore it is necessary to perform a more intense purification of the juice, due, in no small degree, to the fact that such difficulties of clarification are themselves due to the increase of certain colloidal impurities of very difficult elimination in it, principally gums, protein-derivatives and pectins.

If one considers also the high prices that the principal clarifying products have reached: i.e., sulphur (an element universally in critical shortage) and phosphoric acid, which obliges the strictest economic employment of them, it is obvious that such factors have created a serious technical and economic problem for the Argentine sugar industry, which at the moment has to process more difficult raw material with more expensive, scarce and sometimes indifferent clarifying products, and in heavy doses as well against juices of such a refractory nature so orginating sugar of inferior quality.

The new process consists of a simple variation of the system at present used for purifying sugar-cane juices by sulphitation, incorporating for the first time in this country a special substance commonly called Bentonite, thus producing very important technical and economic advantages which signify not only an improvement in the quality of the sugar produced, but also, what is more important still, the recuperation of an appreciable quantity of sugar which is otherwise discarded as molasses.

In our country since 1951, well known Argentine technologists have been successfully carrying out intensive scientific studies and industrial tests on the use of bentonite for the clarification of sugar-cane juices, so restricting the use of sulphur to economic proportions merely to act as a bleaching agent, thus eliminating as well the application of all other imported and costly clarifiers (13).

In Puerto Rico, in 1948, the technologist F.J. Ramirez Silva (2) carried out an important study on the use of bentonite on an industrial scale, applying it as a complement to lime in the elaboration of crude sugar for refineries.

In India, the technologists R.S. Dubey and S.S. Mavi (8) of the Shri Ram Industrial Institute of New Delhi, stated in 1953 that the use of bentonite with sulphur in clarification for the production of direct consumption white sugar from cane is the usual practice of sugar factories in that country. Thus it is evident that bentonite is employed as a clarifier and that sulphur is reserved for use only in bleaching.

In Australia, an official government report of 1951, signed by J.H. Nicklin (6), states that excellent results were achieved in various factories by the application of American bentonite "KWK Volclay" both in the clarification of sugar-cane juices and in the purification of refinery syrups.

In Cuba, the eminent sugar technologist C.E. Beauchamp (3), in 1948, carried out a complete analysis and industrial experiment of the process of the clarification of sugar-cane juices destined for the production of crude sugar by means of lime and bentonite "KWK Volclay", arriving at the conclusion that an optimum process for the purification of juices had been evolved, and though unfortunately he gives no figures of the results produced, he quotes the innumerable advantages thus achieved.

From the above it can be seen that the majority of the sugar producing countries of the world have adopted or are in the course of adopting this process either by combining bentonite with lime to obtain crude sugar, or combining it with sulphur in the production of direct consumption white sugar. It speaks for itself that in Puerto Rico even in 1949 more than a million tons of crude sugar were produced by this method, while in our country, during the last three crops more than 150,000 tons of direct consumption white sugar have been produced by the employment of sulphur with colloidal bentonite.

These facts are of enormous interest for our sugar industry, and reveal, at the same time, the unquestionable efficacy of the new process of the clarification of cane sugar juices by the employment of bentonite in combination with sulphur to obtain direct consumption white sugar, the industrial numerical interpretation and evidence of which are the object of this treatise.

CHARACTERISTICS OF COLLOIDAL BENTONITE UTILIZED

The colloidal bentonite apt for the clarification of sugar cane juice is a typical clay of the saturated sodium montmorillonitic series. To this effect and for comparative purposes the data given in this work correspond to the results obtained by the industrial application of colloidal bentonite, known on the Argentine market by the name of Clarigel, of which the principal characteristics are (11) :—

Humidity	8—12 %
Colloidal Montmorillonitic Clay	80—85 % (dry)

Inert impure substances	8—15 %	(dry)
Total cationic exchange capacity	80—85 m.e. %	,,
Sodium adsorbed (Na+K)	76—80 m.e. %	,,
Swelling capacity in 48 hours	10—12 %	
pH (in aqueous suspension 3 to 5 %)	9.2—9.5	

The chemical composition of colloidal montmorillonitic clay separated from its impurities is as follows :—

Chemical components		gr. % (dry)
Silicon	SiO_2	65.24
Aluminium	Al_2O_3	19.60
Ferric oxide	Fe_2O_3	4.75
Ferrous oxide	FeO	0.40
Magnesium	MgO	0.80
Calcium	CaO	0.61
Potash	K_2O	0.10
Sodium	Na_2O	2.95
Combined water	H_2O	5.40
	Total	99.85

REACTIONS BETWEEN COLLOIDAL BENTONITE AND CANE SUGAR JUICE

On mixing a hydrated dispersion of colloidal sodium bentonite with cane sugar juice a series of colloidal reactions and a physicochemical formation are produced that can be summed up as follows :—

1. *Mutual Colloidal Precipitation* : The predominant negative charge of colloidal bentonite attracts all the colloids of the positive charge orginating a mutual colloidal precipitation by simple electrical neutralization. It is obvious then, that the unifying precipitant activity of bentonite is subjected to the magnitude of its electrical charge reflected in the analytic value of its total capacity of cationic exchange.

2. *Cationic Exchange* : The cations iron, aluminium, calcium and magnesium of the juice displace the sodium cation adsorbed in the montmorillonitic micelle—a physicochemical reaction in accordance with the general laws of the process of cationic exchange—originating a coagulation of negative bentonitic sol. The quantity precipitated by the various elements quoted depends inclusively on the available quantity of sodium adsorbed and the electrocinetic potential of the colloidal micelle, whose maximum stabilization value is reached in an alkaline medium of pH 9 to 10.

3. *Adsorption of Polar Substances* : Diverse non-ionic impurities of cane sugar juice are dipoles, owing to the lack of symmetry in the electronic distribution within their individual molecules. Therefore, since the montmorillonitic mineral structure is also polar, on being placed in contact with liquids, solutions, or suspensions containing other polar substances it originates an adsorption of these on producing mutual attractions of contrary charges between the positive and

negative centres of the mineral with the respective antagonistic negatives and positives of the polar substance present (10).

It is then, in the combination of these three reactions that the clarifying power of colloidal sodium bentonite resides. On being added to cane sugar juice it precipitates numerous substances, such as gums, pectins, proteins etc., originating a heavy coagulation, which, on the other hand, draws with it other inert impurities suspended in the medium, leaving the juice completely diaphanous, crystalline and brilliant.

INDUSTRIAL RESULTS OF THE SULPHOLIME BENTONITE PROCESS

This method was applied for the first time in our country during the 1952 crop by six factories (13), its use spreading afterwards to others, though many of them actually apply it only in periods when encountering extreme difficulty in the clarification of juices. Nevertheless, on the basis of the results obtained, it should not be considered as an emergency process, but more as a method deserving constant application, considering its very important technical and economic improvements for the sugar industry especially when juice of an inferior purity is processed.

Crude Juice : Undoubtedly even within the method of clarification by using sulphur the precipitation of phosphates of various mineral and organic constitutents of cane sugar juice comprises the most important factor in the transformation of its purity, elevating it to a value of from 0,22 to 0,82 points. The remaining mineral components exercise a very weak effect, manifesting a possible reduction or increase in purity, depending on whether the increase of lime is greater or less than the reduction of magnesium, iron, aluminium or silicon of the juice.

With regard to the nonsugar organic components, the proteins are the most important factor in the growth of purity, adding their effect to that originated by phosphatic precipitation. Considering that compounds, such as phosphoric anhydride and proteins oscillate in their content according to the variety of the cane, type of soil and conditions of growth, it is evident that each juice has a specific capacity for a definite increase in purity subject to the content in such eliminable substances whose variation originates a growth up to an interval of from 0.5 to 2.7 points in real purity, according to various industrial records carried out on behalf of the sulpholiming method (1).

Nevertheless, the elevation of purity must be complemented by the data of clarity or turbidity of the clarified juice so that a definite judgement be formed on the efficiency of the clarifying process. It is already well known that if, indeed, the method of sulphitation and liming improves the clarity of the juice, its results are very deficient with some types of juices of high content in certain colloidal impurities, such as protein derivatives, gums and silicon, which originate the classic turbidity or opalescence of the clarified juices. It must be emphasised that this muddiness is due only to the proportion of such substances, and is independent of the content in P_2O_5 of the juices, as has been proved in the experiments of C.A. Fort (1).

With respect to the pH in which the clarification is performed, there generally exists a tendency towards its displacement towards the acid zone, closely approaching pH6. If, indeed, it cannot be doubted that a low pH increases the precipitation of proteinaceous substances, it avoids the decomposition of reducing sugars and the excess of lime, proportioning a whiter sugar. It is also certain that it hydrolizes a certain quantity of saccharose and causes an incomplete precipitation of phosphates, sulphides, silicates and sesquioxides, which seriously increase scaling. On the other hand, a high pH stimulates an efficient elimination of these latter impurities, but it redissolves proteinaceous substances and, if it rises above pH7, it decomposes reducing sugars elevating the consumption of lime and affecting the colour of the juice. Therefore to displace this pH from the neutral point is a serious risk unless the composition of the juices with regard to their removable impurities is known.

Colloidal bentonite, on the contrary, exercises its precipitation within an ample zone between pH 5 and 9 ; and it has been proved that all possible excess coagulates completely and is eliminated from the juice with only a minimum concentration of 40 mgrs. of soluble calcium per litre, a condition amply exceeded in cane sugar juices.

On the basis of numerous analyses and much industrial control in various periods of the crop we have been able to ascertain the quantitative discriminatory effect that colloidal bentonite in combination with sulphur exercises over an average crude juice produced in the Province of Tucuman. These results can be observed in Table I, from the figures of which it can be seen that bentonite realises a greater purification equivalent to a minimnm of 695 grs. of organic and inorganic impurities per ton of cane sugar.

This conclusion confirms the result of a 700 grs. increase in the elimination of miscellaneous impurities obtained by the eminent technologist L.R. Bliss (7) "La Corona" factory - Tucuman. Later proofs, according to Table II have demonstrated that this value can ascend as high as one kilo and more for juices of inferior purity (12).

TABLE I

THE ADDITIONAL PURIFYING EFFECT OF BENTONITE IN THE SULPHITATION METHOD OF THE SUGARCANE JUICES

Eliminable substances	MIXED JUICE		ELIMINATION		VARIATION %	
Organic non-sugar	Gr./Kg.	Gr./T.C.	S-Ca	S-Ca-B	S-Ca	S-Ca-B
Proteins (Albumins)	1·50	1,130	−1,000	−1,100	−88.0	−97.0
Protein derivatives	0.30	230	−20	−192	− 9.0	−85.0
Gums (Pento-hexosans)	0.70	530	−135	−415	−25.0	−80.0
Pectins	0.05	38	−6	−34	−15.0	−90.0
Tannins and Pigments	0.02	15	−6	−6	−40.0	−40.0
Total	2.57	1,943	−1,167	−1,747		
Inorganic non-sugar						
Silicon SiO_2	0.35	265	−160	−210	−60.0	−80.0
Phosphorus P_2O_5	0.15	115	−103	−103	−90.0	−90.0
Sulphur SO_3	1.20	910	+ 50	+ 50	+ 5.5	+ 5.5
Calcium CaO	0.39	295	+220	+200	+75·0	+68.0
Magnesium MgO	0.31	235	− 24	− 59	−10.0	−25.0
Iron+Alum Fe_2O_3	0.10	75	− 60	− 70	−80.0	−93.0
Total	2.50	1,395	− 77	−192		
Total substances	5.07	3,838	−1,244	−1,939	−32.5	−50.5
Additional elimination	—	—	—	695	—	—

TABLE II

COMPARATIVE RESULTS OF THE PURIFICATION OF SUGARCANE JUICES OBTAINED BY "LA CORONA" SUGAR FACTORY DURING THE 1953 CROP BY THE METHOD PROPOSED FOR THE ELABORATION OF DIRECT WHITE SUGAR

Characteristics	I	II	III	IV
Duration of test (days)	18	15	6	10
Ground cane (tons)	27,315	26,181	11,508	16,448
Sulphur (gr./ton cane)	286	130	330	100
Hydrated Lime (gr./ton c.)	1,230	900	1,280	800
Clarigel (gr./ton cane)	0	290	0	240
Purity of mixed juice	70.70	72.42	75.76	73.86
Purity of clarified juice	70.54	73.23	76.53	74.49
Variation of Purity	−0.16	+0.81	+0.77	+0.63
Incrustations (gr./ton j.)	14.2	9.1	9.9	4.1
Cachaza (Kg./ton cane)	24.1	27.7	20.0	21.0
Dry material in mud (Kg.)	6.40	7.62	4.96	5.85
Additional elimination (gr./t.c.)	—	1,220	—	890

Comparative Table III shows typical average results according to our systematic control of the gum content+proteins and derivatives and turbidity, for a crude juice of purity 80.

TABLE III

COMPARATIVE PROPORTIONS OF TURBIDITY, GUMS AND PROTIENS (INCLUDING ALBUMINOSES AND PEPTONES) APPLYING THE SULPHOLIME AND ADDITIONAL BENTONITE METHODS

Products	Gums * gr./Kg.	Proteins ** gr./Kg.	Turbidity *** —log t
Crude Juice ...	0.70	1.80	2.90
Sulpholime Juice ...	0.52	0.45	0.80
Sulpholime Bentonized Juice ...	0.15	0.09	0.35

* Precipitation of gums in alcohol, later hydrolysis and subsequent determination of reducing sugars by the Bertrand Method.

** Precipitation of proteins (including albuminoses and peptones) with phofotungstic acid in a sulphuric medium, and later determination of N with micro-Kjeldahl, using factor 6.25.

*** Measuring the percentage of light transmission through a sample and then comparing it with the same when totally crystalline, according to Balch, expressing the results in - log t per wave of longitude of 560 mμ.

In the calculation for the details of Table I, it is considered that of the total content of true juice protein only 88% coagulates in heating by the method of sulphitation and liming to pH 7, according to recent assertions made by P. Honig (9).

With regard to the gums, Table IV deals with typical and periodical determinations of control throughout the 1955 crop at the Marapa factory in the Province of Tucuman. These figures show that the SO_2, even when applied at between 0.4 and 1.39 per litre of juice does not eliminate more than 25% of the original gum content, while bentonite raises this extraction to an average of 80%, though acting in complete absence of any preliminary sulphitation.

TABLE IV

TYPICAL AND PERIODICAL DETERMINATION OF GUMS IN JUICES FROM THE "MARAPA" SUGAR FACTORY DURING THE 1955 CROP *

Date	Mixed Juice			Sulphur-lime		Proposed Method		Total
	Brix	Purity	Gums gr. %	SO_2 gr. %	Gums gr. %	Bentonite gr. %	Gums gr. %	Elimination %
14—6—55	14.73	78.68	0.090	0.7	0.070	0.4	0.020	77.8
30—6—55	14.69	80.45	0.070	0.6	0.052	0.4	0.015	78.5
25—7—55	14.85	81.89	0.050	0.5	0.036	0.4	0.011	78.0
14—8—55	13.65	73.62	0.215	0.7	0.160	0.7	0.040	81 5
29—8—55	12.74	62.08	0.360	0.4	0.270	0.7	0.070	81.0
9—9—55	12.80	59.84	0.530	0.9	0.400	1.0	0.110	79.3
14—9—55	13.29	59.93	0.655	1.3	0.488	1.0	0.147	77.4
27—9—55	13.52	50.59	0.700	0.0	——	1.0	0.125	82.0

* Determination carried out by the sugar-technologist Sr. Carlos D. Politti, appointed for special analyses, whose efficient colaboration is especially appreciated.

Table V presents a total balance of the elimination of gums from cane sugar juice in the Marapa factory during the 1955 crop by both the sulphitation method **and** treatment with additional bentonite as suggested.

TABLE V

TOTAL BALANCE OF GUMS ELIMINATION OF SUGARCANE JUICES AT THE "MARAPA" FACTORY DURING THE 1955 CROP

Time	Gums	Kg. juice or molasses	gr./Kg.	Gums Kg.	Kg./T.C.
	Incorporated in juice	73,610,687	0.70	51,525	0.530
June	Eliminated by SO_2	id	0.18	13,250	0.135
July	Eliminated by bentonite	id	0.37	27,045	0.280
	Total eliminated	—	—	40,295	0.415
	Residue in molasses	3,744,226	3.00	11,230	0.115
	Incorporated in juice	35,563,388	2.15	76,460	1.560
	Eliminated by SO_2	id	0.55	19,560	0.400
Aug.	Eliminated by bentonite	id	1.20	42,700	0.870
	Total eliminated	—	—	62,260	1.270
	Residue in molasses	2,348,004	6.10	14,200	0.290
	Incorporated in juice	30,359,386	5.95	180,640	4.100
	Eliminated by SO_2	id	1.45	44,020	1.000
Sept.	Eliminated by bentonite	id	3.25	99,750	2.250
	Total eliminated	—	—	143,770	3.250
	Residue in molasses	2,903,143	12.70	36,870	0.850

These figures reveal that on a total of 308,625 kilos of gums that entered in the mixed juice during the milling of 190,406 tons of cane sugar elaborated during the 1955 crop, the sulphur eliminated a quantity of 76,830 kilos, while the bentonite precipitated an additional 169, 495 kilos of gums. These facts unquestionably indicate that if bentonite had not been used at all during the crop, that enormous quantity of gums would have continued to produce very serious trouble throughout the entire process of elaboration, and above all in coctions and exhaustion of massecuites 3. Let it suffice to indicate that the gum content in molasses that oscillated between 0.30 and 0.50% for normal juices and from 1 to 1.5%, in those affected by frost and decomposition if bentonite had not been used would have reached proportionately and respectively a percentage of between 1 and 4.4 so causing difficult problems in production.

Bentonite does not affect the colour of sulpholimed juices, according to numerous tests of—log t before and after its application to the juice.

QUALITY OF BENTONITE USED AS CLARIFIER

The various types of commercialized bentonite vary greatly in composition and properties, and those products that comply perfectly with the exigencies of the sugar industry are very limited.

From recorded industrial results and the interpretation of colloidal reaction of bentonite it can be accurately observed that its quantitative purifying effect is directly proportional to its content in active substance (colloidal clay) to the electronegative potential of the substance that defines its montmorillonitic character (cationic exchange capacity) and to the state of alkaline saturation of the former that limits its coagulating capacity. All this united to other physical characters, such as density, granulometric gradient in moisture etc., and the content of certain impurities such as volcanic ash (a typical toxic of clarification) soluble salts, oxide of iron etc., determine the exact value of the bentonite that can be efficiently used in the purification of cane sugar juices.

The importance cannot be over emphasised of executing a good initial preparation of the hydrated dispersion of bentonite, since on the contrary, a perfect coagulation cannot be achieved and the time necessary for it to deposit the impurities precipitated must be increased.

Finally, it is absolutely necessary in the sugar industry to avoid the use of bentonites with an appreciable content of volcanic ashes, which are an exceedingly prejudicial impurity in clarification, since they generally settle in independent form and with such slowness that from the practical point of view it can be said that they become suspended, communicating a cloudiness to the juices that is no longer due to their intrinsic impurities, but which has paradoxically been added by the clarifying agent. All this signifies a very serious risk since such mineral substances can each affect the quality of the sugar produced.

INFLUENCE OF BENTONITE ON BY-PRODUCTS

Cachaza—The greater the purification of the juice, the greater will be the increase in the quantity of mud, so that if we take an increase in extraction of from 700 grs. to 1 kilo of dry material per ton of sugar-cane and add some 250 grs. of dry bentonite utilizing it as a coagulator in the proposed way, we shall have an increase of from 3 to 4 kilos of mud (Humidity content 69%) per ton of sugar cane, which signifies an increase of from 10 to 11.5% in weight, adopting an average content of mud of 3% of the sugar-cane. The increase of volume does not exceed 10 to 15%, except that the clarification is going forward so defectively that on initiating the bentonite treatment this is obliged to precipitate a great quantity of impurities which cause an exceptional increase of volume, so much so that in these cases a level of 35% can be reached.

On the other hand, supposing a mud is obtained of superior filtrability properties on the coagulation of the colloids the inconvenience of the greater quantity of sediments is compensated, often producing lower levels of mud in the decanters 24 hours after the application of this method.

If the physical aspect of bentonized mud is not exceptionally sticky and decomposed it is at least a thick mass, having increased appreciably in density.

Scaling—On the reduction of the quantity of metals (iron, aluminium, calcium and magnesium) in the juice due to the effect of the cationic exchange of bentonite, as on the precipitation of a greater quantity of silicon, an appreciable reduction in the quantity of scaling on the surfaces of the heaters is observed. The scaling may be reduced to between 35 and 50%, according to the value of the quantities used in Table II. The chemical composition, at least of that deposited in the juice heaters, does not indicate any significant difference with respect to that obtained without bentonite.

Molasses—Proteinaceous and derived substances, gums and pectins not eliminated from the juice into the mud, pass indefectibly throughout the entire process of elaboration, occasioning generally very serious trouble, and end up by being eliminated in the form of molasses.

For the following reasons it is obvious that the better the purification of the juice the greater will be the recuperation of sugar :—

a— The elimination of a minimum of 700 additional grs. of impurities per ton of cane sugar prevents these very impurities from forming molasses and frees them for the crystallization of 500 grs. of sugar, supposing an average real purity of 42 for the molasses.

b— The exclusion of these impurities, principally gums and pectins, means less viscosity of syrups, allowing a greater exhaustion of molasses of at least 2 points, according to tests in various factories in our country and abroad.

By suphitation methods with normal juices, molasses reveal a content in gums from 1 to 2 %, whereas by using bentonite we have invariably proved contents oscillating between 0.3 to 0.5%.

The limpidity of the syrup and the lessing of viscosity of the massecuites originated by the application of bentonite tend towards a better crystallization proportioning a sugar of high quality, better appearance and of optimum keeping qualities.

In short, the above industrial records irrefutably confirm all hither to theoretically foreseen concerning the purifying effect of colloidal bentonite, offering us a most convincing solution to the present problems of our sugar industry in connection with the purification of sugar-cane juices, the difficulties of elaboration and the quality of the final product.

ECONOMIC BENEFITS OF THE SULPHOLIME BENTONITE PROCESS

As a consequence of the amazing purifying effect of bentonite, it is evident that it is possible to reduce the consumption of sulphur, thus restricting its epmloyment to that of only a bleaching agent for cane sugar juices. Thus we can finally sum up the following economic benefits of the above "Sulpholime Bentonite" process :—

1—Economy of from 30 to 50% in the use of sulphur, from 20 to 25% on that of lime, and the elimination of other chemical products, such as phosphoric acid, habitually used in the clarification of cane sugar. 25 to 30% economy in the use of caustic soda employed in the cleansing of the containers used for evaporation of juices.

Table VI is a comparative table of the costs of production of chemical products of the simple sulphitation process and those incurred by the suggested addition of bentonite.

TABLE VI

COMPARISON OF THE COST OF CHEMICAL PRODUCTS IN BOTH CLARIFYING PROCESSES OF CANE-SUGAR

Products	PRESENT PROCESS*		SUGGESTED PROCESS	
	gr./Ton-cane	Cost (Arg.Ps.)	gr./Ton-cane	Cost. (Arg. Ps.)
Sulphur	300	0.99	150	0.50
Lime	1.200	0.42	900	0.31
Phosphoric acid	25	0.23	—	—
Caustic Soda	50	0.13	35	0.09
Bentonite	—	—	250	0.29
	Total Arg. Pesos—1.77			Arg. Pesos—1.10

*Present import prices are taken at the recent official rate of 18 Argentine pesos per U.S. Dollar+additional costs of transport etc., into the interior of the country, giving the final figures: Sulphur m$n 3.30/kg.; Phosphoric acid (85%) m$n 9.10/Kg.; Caustic soda m$n 2.60/Kg. We have taken lime at m$n 0.35/Kg.

2— Increased recuperation of sugar as a consequence of :—

(a) Retention of 500 grs. of saccharose per ton of cane, corresponding to the elimination of 700 grs. of juice impurities.

(b) Additional retention of 0.017 per kilo of saccharose entry to mixed juice owing to the reduced viscosity of the massecuites 3, once the gums have been eliminated.

As a result of an approximate calculation of the quantity of sugar recuperated during the function of this last concept we have :—

Real average purity of mixed juice	77.0
Real average purity of molasses (present process)	42.0
Real average purity of molasses (suggested process)	40.0

$$R_1=\frac{100\ (77.0-42.0)}{77.0\ (100-42.0)}=0.7837 \quad R_2=\frac{100\ (77.0-40.0)}{77.0\ (100-40.0)}=0.8008$$

Additional retention = 0.017 per kilo of saccharose in juice.

Calculating the total of the economic benefits resulting from this new process for a factory that has a milling of 450,000 tons of sugar-cane per crop (10.5 saccharose % cane and 90% of extraction) we have :—

1— Economy of clarifying products :—

450,000 tons × m$n 0.67/ton m$n 302,000

2— Recuperation of sugar for purification of juices :—

225,000 kilos of sugar × m$n 3.—/Kg. m$n 675,000

3— Recuperation of sugar through exhaustion of molasses :—

450,000 × 0.105 × 0.90 × 0.017 = 725 tons sugar

725,000 kilos of sugar × m$n 3.—/Kg. m$n 2,175,000

Total m$n 3,152,000

4— Reduction of alcohol 95° on sugar in molasses :—

950,000 kilos sugar × 0.64 × m$n 1.50/litre m$n 912,000

Net economy of method proposed m$n 2,240,000

These figures ratify the above treatise and confirm the importance of the new method suggested for the efficacious clarification of cane sugar juices in the elaboration of white sugar.

SUMMARY

The effect of bentonite in combination with the sulphitation process for clarifying cane juices has been studied in Argentina.

A special type of colloidal sodium bentonite was added in water suspension to the sulphited juices after liming and the industrial results obtained by this method, applied in several factories for producing direct consumption white sugar, are given.

The clarification operations, more specifically the sebimentation and brilliancy of the clarified juices, are improving. The removal of organic colloid non-sugars, like gums and derived proteins (Albuminoses and Peptones), was surprisingly high, giving a considerable decrease of the molasses viscosity and a remarkable increase in sugar yield.

In view of the negligible decolourization of juices by bentonite, the bentonite combination with the dleaching effect of sulphur dioxide to produce a direct white sugar of excellent quality is necessary.

A lot of quantitative data are given to help a better knowledge of the mechanism of the clarification of cane juices by colloidal bentonite.

Since the nature of Argentine cane juices is particularly refractory, this new method may have a good deal of technical and economical success, and it should be adopted in future for general use in clarification.

REFERENCES

1. Fort, C.A. 1939. Changes in the Composition of Cane Juice Produced by Clarification. *Fact About Sugar*, v. 34, No. 9.
2. Ramirez Silva, F.J. 1948. Colloidal Bentonite as a Clarifying Agent. *Sugar Journal*, October.
3. Beauchamp, C.E. 1948. El Proceso Silva de Clarificacion de Guarapo. *Mem. Con. An. Asoc. Tec. Azuc.* Cuba. Noviembre.
4. Ramirez Silva, F.J. 1950. La Clarificacion con Bentonita Coloidal KWK Volclay en Puerto Rico. *Mund. Azuc.* To. 38, No. 2.
5. Mallea, O.S. 1951. Fracciones Coloidales de Bentonitas Argentinas para Clarificacion de Jugos Refractarios. *Bol. Est. Exp. Agr. Tucuman* No. 67. Noviembre.
6. Nicklin, J.H. 1951. Clarification with Bentonite KWK Volclay. *Report Bureau Sugar Exp. Stat.* Queensland v. 5, pp. 48.
7. Bliss, L.A. 1952. Experiencias con la Bentonita "Clarigel" en el Ingenio La Corona. *Bol. Est. Exp. Agr.* Tucuman, No. 68.
8. Dubey, R.S. and Mavi, S.S. 1953. Use of Indian Minerals in Cane Juice Clarification. *Indian Sugar*, pp. 107—114.
9. Honig, P. 1953. Principles of Sugar Technology. Elsevier Pub. Co., New York.
10. Grim, R.E. 1953. Clay Mineralogy. Chapter 10 : Organic Reactions of Montmorillonite. Mc-Graw Hill Book Co., New York.
11. Mallea, O.S. 1954. Bentonita Coloidal Sodica. Estudio de su Composicion Quimica y de su Estructura Ionica. Industria y Quimica, *Asoc. Quim. Argent.*, v. XVI, No. 1.
12. Federici, A. 1954. Accion de la Bentonita en los Jugos de Canna. *Industria y Quimica, Asoc. Quim. Argent.* v. XVI, No. 1.
13. Mallea, O.S. and Varas, D. 1954. Colloidal Bentonite in White Sugar Manufacture. *Sugar*, v. 49, No. 1. January.

CHEMICAL ANALYSIS AND FACTORY REPORTING SECTION

CHEMICAL ANALYSIS AND FACTORY REPORTING

Session—Saturday, 28th January, 9-15 A. M.

Dr. J. L. Clayton, *Chairman*

In the absence of the author Mr. D. H. Foster presented the following paper. This was discussed together with the next paper.

Paper

A HIGH SPEED DISINTEGRATOR FOR USE IN THE ANALYSIS OF POL % BAGASSE

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INTRODUCTION

The use of high speed blenders for the determination of the sugar content of beet cosettes has recently been developed as a routine procedure in the tare laboratories of the beet sugar industry. Such machines as the Waring blender, the Atomix and the Magimix, all primarily designed for household use, have been utilized. Genotelle (1) reports that beet can be macerated within 3 minutes in a high speed blender of this type and recommends for the analysis of the sugar content of beet that the sample be macerated with water and clarifying agent prior to filtration and polarisation. Moore and Hallbeck (2) studied the use of the high speed blender for this purpose in detail and compared the results obtained with those derived from the more usual Sachs-le-Dochte procedure of analysis. The comparison showed that there was no significant difference between the results obtained by the two methods.

In 1951, Schmidt, Wiggins and Yearwood (3) investigated the use of the high speed blender for the analysis of pol % bagasse, and in the course of this work showed that it was necessary to macerate the bagasse with water for 15-20 minutes, in order to release sugar from the bagasse, at least to the extent accomplished by the normal digestion method of pol % bagasse analysis. However, despite the fact that the time necessary for efficient maceration is much longer than that which obtains for beet, the use of the blender enables the analysis of pol % bagasse to be completed within 30 minutes whereas, with the ordinary digestion method, at least 1½ hours are necessary. A comparison was made between the results of two sets of twelve determinations of pol % bagasse using the established factory method and the high speed blender technique. Statistical analysis of these showed that there was no significant difference between the results obtained by the two methods. One disadvantage of the method lies, however, in the fact that the size of the ' Atomix ' or 'Magimix' blenders limits the size of bagasse samples to 40g., whereas in the digestion method it is a simple matter and indeed usual to use 100 g. samples. A more serious difficulty is that these blenders are not sufficiently robust to operate satisfactorily for 20 minute periods or to carry out the many analyses that are required by the control laboratories of a modern sugar factory.

In the laboratory evaluation of paper pulp, a pulp disintegrator is used. This consists of a robust stirring shaft, running through two sets of bearings, to which is attached a triple bladed cutting knife. For paper testing work a brass knife is used but for more rigorous duty this may be replaced by a stainless steel knife. The stirring shaft is driven by a $\frac{1}{3}$ H.P. standard electric motor (1750 r.p.m.) through a simple belt and pulley system so as to rotate at about 3000 r.p.m., the cutting knife being run in a cylindrical vessel of suitable size in which the material to be disintegrated is placed. Baffles are fixed around the inner surface of the vessel so as to keep the contents moving downwards. Splashing occurs and a lid must be fixed so as to avoid loss of material. The machine used for paper pulp evaluation is expensive because it is made to precise specifications so as to provide standardized disintegration of pulp but it is the author's opinion that a machine similar to this but of simpler design could be made and would be useful for conducting the analysis of pol % bagasse and to test this some experiments have been carried out with the apparatus supplied to us for paper work by the Pulp Evaluation Committee to the Technical Section of the Paper Makers' Association of Great Britain and Ireland.

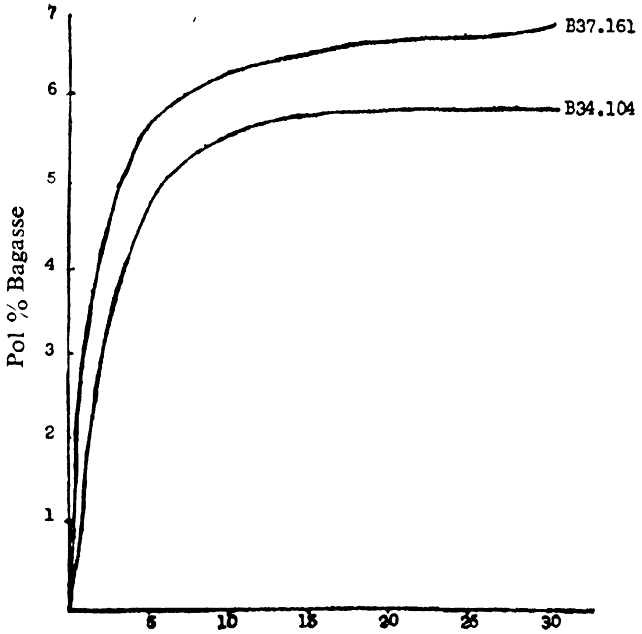
EXPERIMENTAL

The Rate of Extraction of Sucrose from Bagasse by Disintegration. Fresh bagasse (100 gm.) was weighed out and placed in the brass vessel of the disintegrator. Water (1000 ml.) containing 0.25 gm. of sodium carbonate was added and the knife set in motion. At the end of 5 minutes the revolving knife was stopped, the temperature taken and 50 ml. of the solution withdrawn and replaced by 50 ml. of water. The machine was then restarted and a similar procedure followed. Each sample was clarified in the usual way and the polariscope reading taken in a 400 mm. tube. The pol % bagasse was then calculated for each time interval. Table I shows the results for bagasse obtained from a laboratory mill using B.41227, B.37161, B.34104, B.37172 and B.4098 cane. Allowance is made, in the calculation of pol % bagasse at each time interval, for the sugars withdrawn during the experiment.

TABLE I

Time mins.	Pol % Bagasse B.41227	B.37161	B.34104	B.37172	B.4098
5	4.04	5.69	4.80	5.25	8.25
10	4.26	6.12	5.57	5.52	8.91
15	4.41	6.51	5.82	5.77	9.13
20	4.47	6.68	5.83	5.82	9.36
25	4.57	6.78	5.86	5.83	9.31
30	4.66	6.89	5.93	5.93	9.49

In all the experiments the disintegration produced only a slight rise in temperature over the half-hour run, the final temperature being between 35°C. and 38°C. The graphical representation (Fig.1) of two sets of these figures demonstrates that 30 minutes' disintegration time is sufficient to extract the sucrose adequately from bagasse.



Time in Minutes

Fig. 1.

A Comparison between Determination of Pol % Bagasse by the Disintegrator Method and by the Digestion Method.

A large sample of cane (B. 37161) was milled in a laboratory three roller mill and the bagasse preserved at −5°C. in the cold room. Two series of twelve determinations of pol % bagasse, using both the ordinary factory control method and the disintegrator method, were carried out.

Digestion Method. Bagasse (100 gm.) was weighed into the conventional digester, and water (1000 ml.) and 5% sodium carbonate (5 ml.) added. The mixture was heated at 100°C. for 1 hour. Thereafter the tared digester was allowed to cool and weighed. The liquid was expressed from the product, clarified and polarized in a 400 mm. tube and the pol % bagasse calculated.

Disintegrator Method. Bagasse (100 gm.) was placed in the brass vessel of the disintegrator, together with water (1000 ml.) and disintegrated for 30 minutes, the cutting knife being rotated at 3000 r.p.m. Only slight rise in temperature occurred during the disintegration. A loose fitting lid was placed over the vessel to avoid loss by splashing. Thereafter the mixture was filtered, the filtrate clarified and polarized in a 400 mm. tube and the pol % bagasse calculated. The results are shown in Table II.

TABLE II

ANALYSIS OF POL % BAGASSE BY DISINTEGRATOR AND DIGESTION METHODS

	Pol % Bagasse		
Runs	Digestion Method A	Disintegrator Method B	Difference B—A
1	5.18	5.15	—0.03
2	5.23	5.26	+0.03
3	5.33	5.22	—0.11
4	5.37	5.46	+0.09
5	5.45	5.47	+0.02
6	5.50	5.53	+0.03
7	5.73	5.42	—0.31
8	5.49	5.38	—0.11
9	5.23	5.10	—0.13
10	4.92	4.96	+0.04
11	5.21	5.31	+0.10
12	5.30	5.35	+0.05
Total	63.94	63.61	—0.33
Average	5.33	5.30	—0.03

DISCUSSION

The figures given in Table II show quite conclusively that the results of the analysis of pol % bagasse by means of the disintegration method do not differ substantially from those obtained by the normal factory control laboratory procedure. Graphical representation (Figure 2) of these figures brings out still more forcibly how closely comparable they are. Statistical treatment of the figures given in the right-hand column of Table II shows that the mean difference in readings does not differ significantly from zero.

Thus, there can be little doubt that the disintegrator method is adequate for the determination of pol % bagasse. Its advantages are several. It is extremely simple to carry out. It is more rapid than the digestion method. The whole analysis of pol % bagasse can be carried out within 40 minutes, whereas the digestion method can hardly be completed in less than 1½ hours. It is very likely that the speed with which the cutting knife rotates could be easily increased and that this would result in an even more rapid extraction of the sucrose in the bagasse. Furthermore, an advantage of the equipment now described is that it permits the use of 100 gm. samples of bagasse. The technique employing the Atomix blender described by Schmidt, Wiggins and Yearwood was subjected to criticism on the grounds that only 40 gm. bagasse samples could be used. The method may well be more accurate than the normal hot digestion method since it is known that treatment of bagasse with hot water will extract xylan therefrom and that this will tend to hydrolyse to xylose, which, if present, will give an erroneously high pol value. By the new method the extraction of sucrose from the bagasse is carried out at temperatures only slightly above room temperature.

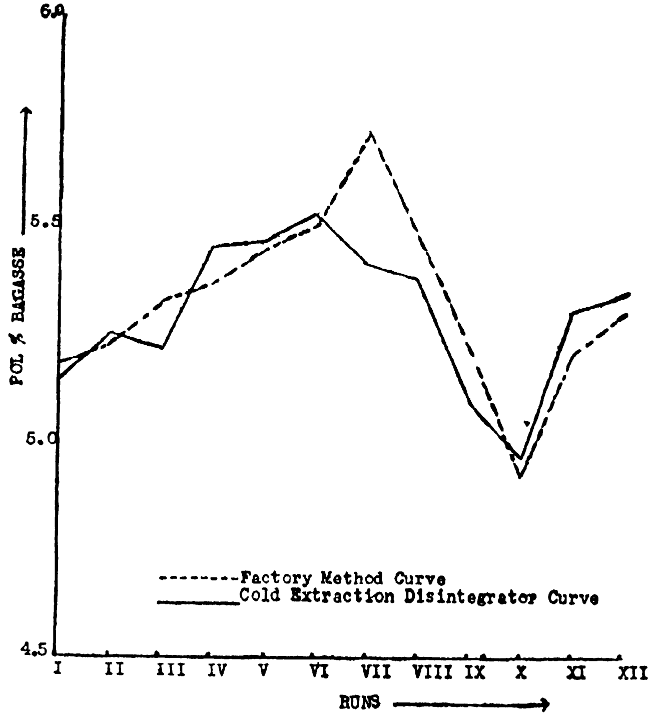


Fig. 2.

ACKNOWLEDGEMENT

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REFERENCES

1. Genotelle, J. 1949 and 1950. *Fabr. Sucre*, 90, No. 10, 20 ; *Int. Sugar* J., 51, 159.
2. Moore, S. and Hallbeck, R. E. 1950. *Sugar* 45, No. 10, 36.

3. Schmidt, N. O.; Wiggins, L. F. and Yearwood, R. D. E. 1951. *Proc. B. W. I. Sugar Tech. Meeting*, p. 171.
4. Second Report of the Pulp Evaluation Committee to the Technical Section of the Paper Makers' Association of Great Britain and Ireland, published by that Association at St. Winifred's, Welcomes Road, Kenley, Surrey, England.

The author presented the following paper.

Paper

ANALYTICAL METHODS USED IN ASSESSING MILL TANDEM PERFORMANCE

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The subject of cane and bagasse analysis is one which has received continuous attention through the years in many parts of the world. No attempt will be made here to review the different methods which have been used and which are in use at present. In Queensland, pol in cane is determined by means of an empirical formula from the concentration of pol in the first expressed juice. The formula used is as follows :—

$$\text{Pol in cane} = \text{pol of 1st expressed juice} \times \frac{100-(F+5)}{100}$$

where F = fibre in cane.

Payment for cane is made on the basis of Commercial Cane Sugar content (C. C. S.) and this is equal to pol in cane minus half the non-fibre impurities in the cane. The formula may be written :—

$$\text{C. C. S.} = \frac{3P}{2}\left\{1-\frac{F+5}{100}\right\} - \frac{B}{2}\left\{1-\frac{F+3}{100}\right\}$$

where P = pol percent first expressed juice,
B = brix percent first expressed juice,
F = fibre percent cane.

This method of payment is only mentioned in passing and the main point to be observed is the method of calculating pol in cane for factory control, as well as for payment purposes. In some years the pol in cane estimated by this empirical formula may average close to the true value, but for assessment of mill performance over a short period, the necessity for a reliable direct method will be appreciated.

Pol in bagasse has, in the past, been determined by a hot water extraction treatment and fibre in bagasse is estimated indirectly. Fibre in cane is estimated by a method involving dry comminution of the cane followed by washing with cold and hot water (1).

During the past three years at the Sugar Research Institute, considerable attention has been given to methods of assessing the value of different maceration techniques and different mill settings. These investigations require the greatest possible analytical accuracy consistent with reasonable speed. In 1951, a paper by Schmidt, Wiggins and Yearwood (2) suggested the use of high speed blenders for the analysis of final bagasse. The equipment then used was considered inadequate in that only small samples could be treated and because it was not sufficiently robust. The report of this work inspired some investigations in Australia, as a result of which a machine was built which could be used for the direct estimation of pol and fibre in cane and bagasse. The purpose of this paper is to describe these methods of analysis and also some other analytical determinations which are useful in studying mill tandem performance.

Bliss (3) has also described the use of a small disintegrator for bagasse analysis and compared the results with those obtained by means of a Norris digestor.

THE DISINTEGRATOR

The essential part of this machine is a tapered shaft carrying three 5″. x 3″ x 1/16″ spring steel blades sharpend at their leading edges. The shaft is spun at about 6,000 r.p.m. in a can 13 in. high by 11 in. diameter. The blades are set ½ in. apart on the end of shaft which almost touches the bottom of the can.

For pol determination, the following quantities are used :—

2,000 g. cane	with	8,000 g. water
1,200 g. first mill bagasse	,,	9,000 g. water
1,000 g. second mill bagasse	,,	10,000 g. water
1,000 g. third mill bagasse	,,	10,000 g. water
850 g. final bagasse	,,	10,000 g. water

The duration of the disintegration treatment is 40 minutes for all samples, with the exception of bagasse from fourth or later mills in which case a period of only 30 minutes is required. In the case of cane, the ratio of fibre to water is limited by the bulk of the cane, while in the case of final bagasse, the limit is about 4 percent fibre in the mixture. At a higher fibre concentration the machine will not perform smoothly.

Pol in the extract is determined after clarification with dry lead. Fibre in the disintegrated cane is determined by placing 1000 g. of slurry in a fine cotton bag, washing in running water for one hour with occasional squeezing, and drying at 105°C. If desired fibre in bagasse may also be determined in this way, so that a complete anylsis of bagasse may be obtained without the necessity of drying a large sample. However, the slurry cannot be accurately sampled if the fibre content is greater than 2.5 gm. per 100 ml.

ANALYSIS OF BAGASSE

Comparison of pol in bagasse determinations by the disintegrator and by a digestor similar to that of Khainovsky, have shown no significant difference in the case of final bagasse but with bagasse from early mills of a tandem, considerable differences have been experienced, the higher value being given by the disintegrator.

One may wonder why close attention is paid to the analysis of first mill bagasse and bagasse from intermediate units of a mill tandem. The reason is that in Australia, the number of units in a tandem is generally small and a high performance must always be maintained. This is assisted by the use of pressure feeders and heavy maceration. Routine analysis of first mill bagasse is made at all factories and in many cases, bagasse from all mills is analysed.

ANALYSIS OF CANE

A typical series of analyses of cane made by means of the disintegrator are given in Table I and are compared with the determination of pol and fibre in cane by the standard Queensland methods (1). The standard Queensland fibre determination was made on a sample of cane sticks collected at the rate of about one per two tons of cane during the passage of about 50 tons of cane. The sticks were then sub-sampled, fibrated on a bank of circular saw blades and washed in cold and then boiling water. The cane for disintegrator analysis was collected from the material fed to the first mill at the rate of about two pounds per two tons of knifed or shredded cane during the passage of the same cane parcel. First expressed juice was collected at the same time to estimate pol in cane by the Queensland method.

It may be seen from Table I that there is good agreement between the two fibre methods. n the case of the disintegrator analysis it is considered that the sample collected as cane entered the mill would be more representative than the stick sample. At the same time the sub-sampling technique is much simpler and the washing treatment is shorter.

In the comparison of pol determinations given in Table I, there is only a small mean difference between the two methods, but in other series of comparisons made at other times, the differences have been greater. This suggests that the " 5 " factor in the formula for pol in cane :

$$\text{Pol in cane} = \text{pol 1st expressed juice x } \frac{100-(F+5)}{100}$$

it too small and this is in agreement with the conclusions which have been made from juice scale analysis in Queensland from time to time (4).

The direct determination of pol in cane has not been a method common to the sugar industry in the past. Attention is drawn to it here as a useful method for the following purposes :—

1. The analysis of cane in tests of milling train performance.

2. As a reference method to check assessment of pol in cane from juice analysis.

TABLE I
ANALYSIS OF CANE WITH AID OF DISINTEGRATOR

Cane Sample No.	Pol in cane from first expressed juice* (A)	Disintegrator Analysis of feed to first mill Pol in Cane (B)	Brix in Cane (C)	Fibre in Cane (D)	Fibre in Cane by Standard Method (E)	Moisture in Cane (Spencer oven) (F)	Brix+Fibre+ Moisture Summation (C+D+F)
1	—	14.0	16.6	13.9	13.7	69.3	99.8
2	—	16.2	17.95	12.5	12.6	69.2	99.65
3	15.8	15.7	17.7	12.9	12.65	68.9	99.5
4	16.2	16.2	18.2	12.1	11.9	71.8	102.1
5	15.6	15.5	17.3	12.5	11.7	70.5	100.3
6	16.5	16.3	18.2	12.3	—	70.6	101.1
7	15.7	15.45	17.6	12.9	11.5	69.8	100.3
8	15.95	15.6	17.8	12.9	13.7	69.3	100.0
9	15.9	16.7	18.0	12.2	12.1	70.2	100.4
10	15.7	15.4	17.4	11.7	12.7	70.8	99.9
11	15.7	15.6	17.85	11.9	12.0	71.0	100.75
12	16.1	16.2	18.15	12.2	12.0	69.9	99.75
13	16.4	16.1	18.1	12.1	—	70.0	100.2
14	16.25	16.8	17.8	12.55	—	69.8	100.2
15	16.25	16.0	18.0	12.3	—	69.5	99.8
16	16.8	16.5	18.45	12.9	—	69.3	100.7
17	16.6	16.2	18.45	12.5	—	69.6	100.6
18	—	—	18.6	12.35	—	68.9	99.85

Pol : Mean Difference (A)—(B)+0.08

Fibre : Mean Difference (D)—(E)+0.10

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*Pol in Cane = Pol in 1st expressed juice x $\frac{100-(F+5)}{100}$

3. As a method for determining the deterioration of juice between cane entering the mill and juice scales.

POL IN OPEN CELLS

The determination of pol in open cells of bagasse is of considerable interest in the evaluation of different maceration and imbibition procedures. Khainovsky (5) proposed a method in which vacuum is alternately applied to and released from a bagasse-water mixture. This procedure was considered by Khainovsky to wash sugar from broken cells by expansion and contraction of entrapped air. In addition the violent circulation on release of the vacuum was considered sufficient to extract the sugar from broken cells which contained no air. Khainovsky claimed that after 10 evacuations, no increase in polarization was registered even on allowing the bagasse to stand and again applying vacuum treatment.

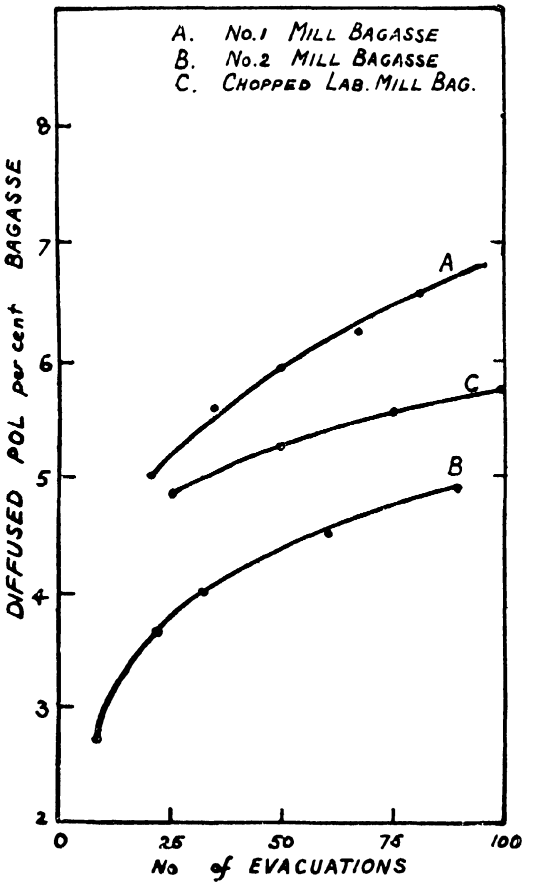


Fig. 1. Determination of Pol in open cells by Khainovsky's Method

It has not been possible to substantiate this claim in tests at this Institute. Repeated tests have shown that pol extraction increases up to 100 applications of vacuum, as shown in Fig. 1, or even 200 applications, and no end point was reached. Further extraction takes place on standing or shaking of the bagasse-water mixture.

The bagasse samples on which the tests were made were at no time in contact with hot maceration liquors which could damage cells. Fig. 2 also shows that a greater extraction of pol in open cells may be obtained by diffusion for one hour on a shaking machine than by 100 evacuations in the Khainovsky technique. In neither case is an end point obtained excepting after many hours diffusion. Then the extraction figure is rendered doubtful by deterioration, which was considerable in some tests. It is important to control the temperature at which the extraction is made since the rate of diffusion increases with increasing temperature. Of course the temperature at which the cells are killed must not be exceeded.

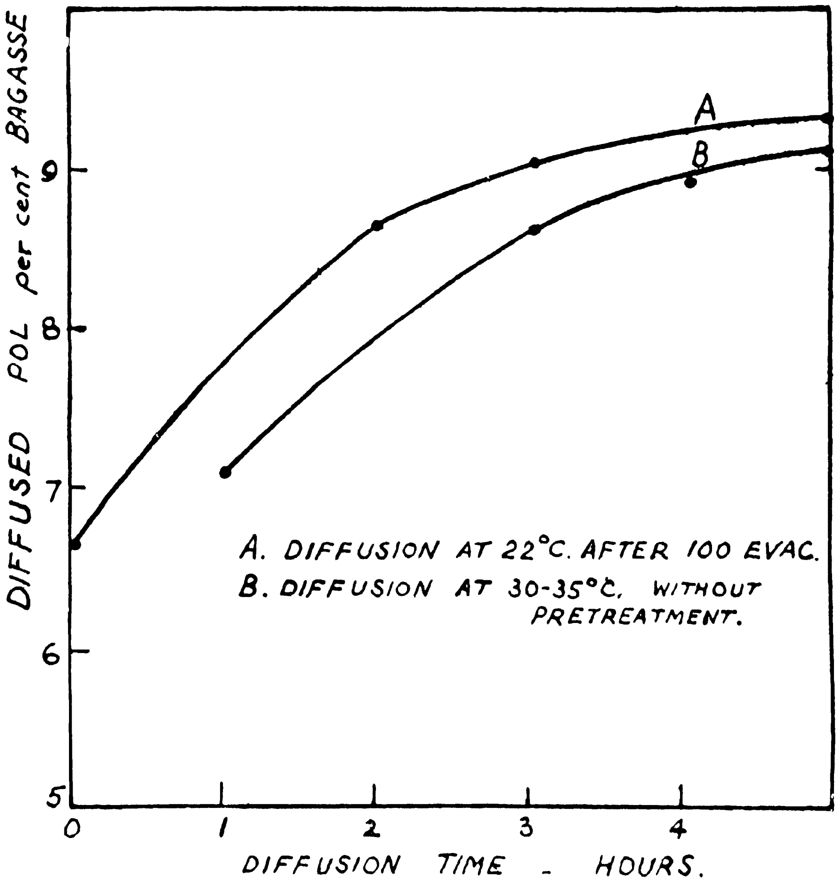


Fig. 2. Diffusion of Pol from first Mill Bagasse on a Shaking Machine.

One suggested explanation of the gradual increase in extraction with time was the possibility of a slow diffusion of sugar from intact cells. It was shown, however, that this explanation is unlikely by studying the rate of diffusion of sugar from 1/16" slices of cane internodes. These pieces contained a high percentage of intact cells, yet very little sugar passed into solution after two hours at 35°C. on the shaking machine.

It is the author's opinion that vigorous shaking of bagasse in water for one hour would give an empirical value of use in maceration and imbibition investigations, but this could not be used as an absolute value for the total " free " sugar.

OTHER PROPERTIES OF CANE AND BAGASSE

In addition to the estimation of total and " free " sugar in bagasse and prepared cane, there are a number of other properties of these materials which require consideration for a proper evaluation of a crushing unit. Three of these properties are :—

(1) The density of cane fibre.

(2) The quantity of juice in cells other than the pith sugar storage cells, that is, in the fibro-vascular bundles. We call this fibro-vascular water and it is comparatively sugar-free.

(3) The quantity of adsorbed or " hygroscopic " water held in the cane fibre under different conditions of temperature and humidity.

There follows a resume of the methods used to obtain information on these properties for application in crushing investigations.

DENSITY OF FIBRE

The density of cane fibre is mentioned here because a number of different values have been given in the past and it is important to have a correct value for comparing fibre volume with mill roll escribed volume. We have obtained a value of 1.53 by placing sugar-free disintegrated fibre in a 500 ml. pycnometer, boiling out the air and determining density in the usual way. More recently Pidduck (6) has given the value.

Fibre Density = $1.512 + 1.61 \times 10^{-6}$ Pa.

where Pa = pressure (p.s.i.) in the axial direction for cane fibre under pressure in a cylindrical press.

FIBRO-VASCULAR WATER

From time to time we have made experiments to study the quantity of juice arising from various types of cells in cane. The extent to which this juice is expressed during the milling process is uncertain, but it seems likely that it is only slowly expressed by reason of the thick cell walls enclosing it.

Microscopic examination of a cross-section of a fibro-vascular bundle presents a picture similar to that shown in Fig. 3 [after Artschwager (7)]. The main features are the large *Xylem* vessels, which carry the soil solution from the roots to the leaves ; the sieve tubes of the *Phloem* which conduct the sugars from the leaves to other parts of the plant ; and the tissues surrounding these elements, which consist of thick-walled true fibres, very short compared with the vessels and sieve tubes. These do not allow the same free passage of liquid. The main function of the thick-walled fibre cells of the bundle is to give the plant strength and rigidity. They do not act as storage cells for the sugary juice ; this function is performed by the mass of thin-walled " pith " cells lying between the bundles, and constituting the bulk of the stalk.

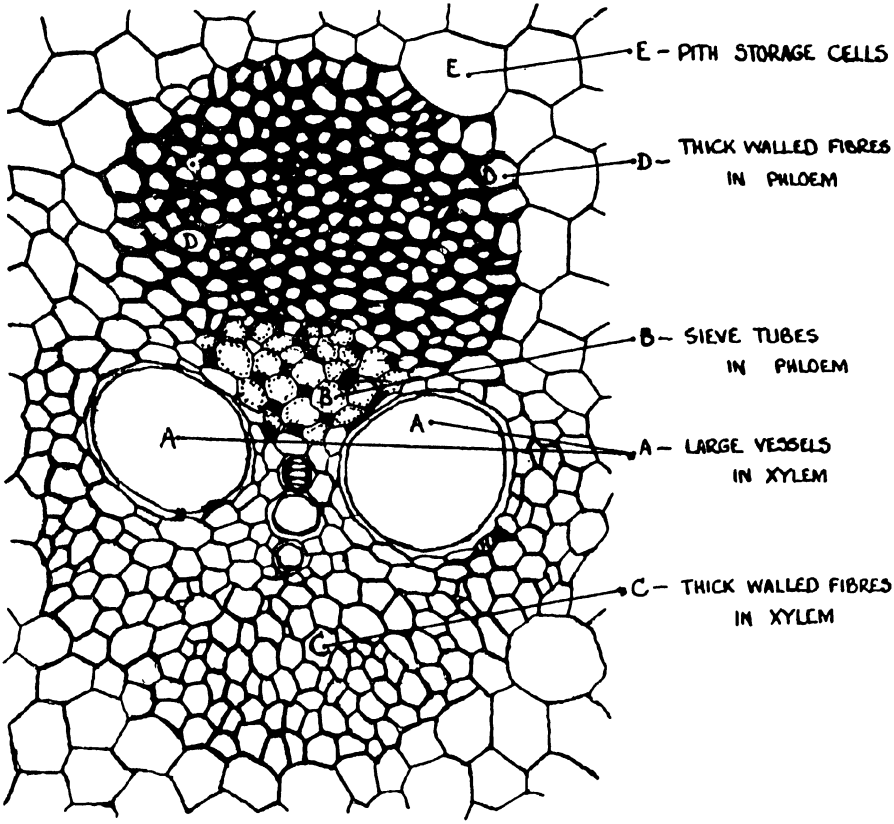


FIG. 3. CROSS SECTION THROUGH FIBROVASCULAR BUNDLE

By examining cross-sections cut from stalks of Q. 50, an estimate has been made of the area occupied by the bundles, and of the individual elements within the bundle. The sections were cut from internodes only, and the nodal tissues with their complex structure were not considered.

The estimates were—

	Proportion of Cross Seticon
Fibro-vascular bundles	5.3%
Vessels only	0.8%

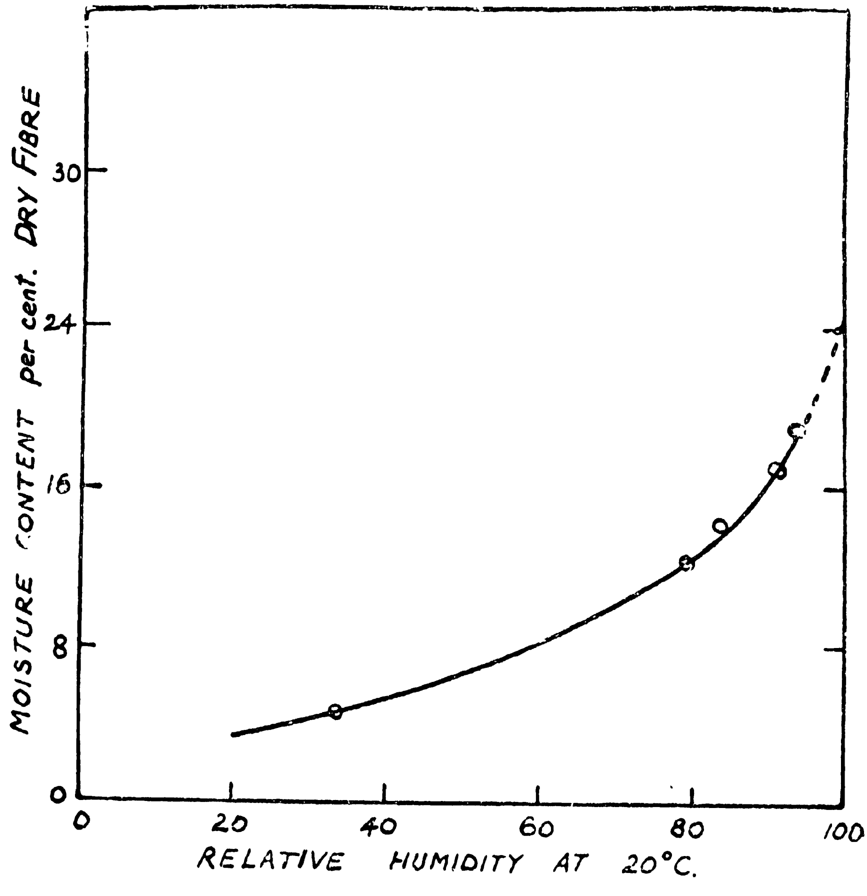
In estimating the quantity of liquid which these elements could hold, some deduction must be made for the volume occupied by the walls of the vessels and cells.

A number of direct estimations have also been made of the quantity of juice which may be obtained from fibro-vascular bundles by displacement with various solutions. In general, values of 0.8 to 1.3 percent were obtained suggesting that the displaced juice was mainly from the large xylem vessels. The brix of this juice was about 0.8. Probably all the juice in fibro-vascular bundles of the internodes would not exceed 3 percent of the weight of the cane. This is apparent from a consideration of the total volume of the fibro-vascular bundles and of the volume occupied by the cell walls which are very thick in the case of the true fibres.

Further research on this subject should help to explain the reason for the decreased concentration of the last expressed juice obtained from dry crushing. This may be due to fibro-vascular water, a variation of concentration of sugar juices in pith cells or a combination of both.

HYGROSCOPIC WATER

When examining the results of various maceration and imbibition procedures, the concentration of the residual juice in bagasse should be considered, and it



is desirable to have a knowledge of the amount of hygroscopic water in cane fibre at 100 percent relative humidity. A graph of moisture content against relative humidity for Q. 50 cane fibre is shown in Fig. 4 upto 92 percent relative humidity. By extrapolation it appears that cane fibre at 20°C. and 100 percent relative humidity would contain about 25 percent hygroscopic water based on the dry weight of the fibre. According to Stamm [8] the effect of temperature on the absorbed moisture in spruce wood at 100 percent relative humidity is to decrease it from 30.7 percent at 25°C. to 25 percent at 80°C. Spruce wood gives a similar curve to that shown in Fig. 4, and since cane fibre is a material of similar chemical composition, a similar effect could be expected.

The presence of hygroscopic water in cane fibre cannot be doubted since it can be readily shown that dry sugar-free cane fibre will adsorb water from sucrose solutions. Hygroscopic water together with fibro-vascular water at least partly explain the necessity of using an empirical factor to calculate pol in cane from pol of first expressed juice.

REFERENCES

1. Bureau of Sugar Experiment Stations. 1954. "*Laboratory Manual for Queensland Sugar Mills*," 3rd Ed., 2, 102.
2. Schmidt, N.O., Wiggins, L.F. and Yearwood, R.D.E. 1951. Imperial College of Tropical Agriculture, Trinidad. *Paper No* .17/51. 1951.
3. Bliss, L.R. 1948. *Proc. XXII Annual Conf. Asso. de Tecnicos Azucareros de Cuba*, 237.
4. Davies, L.E. 1954. *Proc. Q.S.S.C.T., 21st Conf.* 41.
5. Khainovsky, V. 1929. *Proc., I.S.S.C.T., 3rd Cong.* 457.
6. Pidduck, J. 1955. *Proc., Q.S.S.C.T., 22nd Conf.*, 147.
7. Artschwager, E. 1925. *Jour. Agric. Res. 30*, 197-221.
8. Stamm, A.J. 1952. " *Wood Chemistry* " *2nd Ed.*, Vol. 2. *Rheinhold Pub. Corp.*

DISCUSSION

Mr. S. N. Lal asked what effect very high speeds like 12000 r.p.m. would have on the results.

Mr. Foster replied that it was mainly a matter of time required to make the test. Peripheral speed of blade tips was the main factor.

Mr. R. Lagesse observed that Wiggins found a higher pol by digester method, while Foster found the reverse.

Mr. Foster thought this could be explained by the fact that Wiggins worked with final bagasse only, but the differences were very small.

Dr. H. W. Kerr said that the principle of high speed disintegration in liquid was not new and had been used since about 1940 for various types of food analysis. Machine speeds up to 25000 r.p.m. were used, for routine sugar mill laboratory work. The machine must however be robust and cheap. The machine described in Mr. Foster's paper costs only obout £ 60 Australian currency.

Dr. K.S.G. Doss referred to the hygroscopic water in cane fibre and said that dry sugar-free cane fibre will absorb water from sucrose solutions. Extensive work with cane fibre and gum arabic shows that water is first taken up on the surface and later it penetrates as bound water. The fibre cells have a tendency to absorb the water while keeping the molecules of sugar at arm's length. He described work on rates of diffusion which indicated that cell walls are permeable to sugar, but the rate of diffusion decreases rapidly with distance through cane chips. He thought osmotic pressure may be one of the most uniform factors.

Mr. Foster agreed that cane fibre holds water in several different categories. Diffusion of sugar through live cell walls is so slow that, with the every limited time available in the milling operation, cells must either get broken up or killed.

Dr. K. Douwes Dekker stated that he worked with a disintegrator similar to used by Payne and Mahon. He used a 600 g. sub-sample and a water dilution which gave a much higher pol reading with the liquid extract than used by Foster. He agreed with Foster's conclusions and was also interested in finding a uniformly distributed factor like osmotic pressure, as suggested by Dr. Doss.

Dr. H. W. Kerr described his work on applying compressed air to blow juice containing only 0.4 to 0.6% Brix from the xylene vessels of sugar cane. He estimated that this represented about 3% in cane and therefore explains why there is a drop in% brix and pol from first expressed to total juice of cane, upon which the factors 3 and 5 used in Australian C.C.S. formulae are based. If we accepted Mr. Foster's findings regarding hygroscopic water, it should be added to the percent fibre in cane ; but this could not be justified on the present data before us.

Dr. K. S. G. Doss had also found the brix content of fibro-vascular water to be very low. Tests with gum arabic between 80 and 100 degrees humidity indicated that there were only two molecules on each side of the cell walls.

Mr. Foster thought that the effect of a rise in temperature from 25°C. to 80°C. at hundred %humidity would decrease the absorbed moisture content of cane fibre from 30.7% to about 25%, as in spruce wood fibre. He did not agree with Dr. Kerr that hygroscopic water should not be added to the % fibre content of cane for factory control purposes.

In the absence of the author Dr. H. W. Kerr presented the following paper.

Paper

THE POL RATIO METHOD FOR EVALUATING CANE QUALITY

John H. Payne and Henry I. Mahon

Experiment Station, HSPA, Honolulu, Hawaii

INTRODUCTION

Since 1914, cane quality in experimental work in Hawaii has been calculated in terms of Quality Ratio. This is the estimated tons of cane required to produce one ton of 97.5 pol sugar based upon the analysis of first expressed juice. The formula is :

$$\text{Quality Ratio} = \frac{79.3126\,(j-1)}{(j-1)-35.5} \div \text{Pol \% First Expressed Juice}$$

Where j=Purity of first expressed juice.

In this formula the following values are assumed :

Java Ratio 80.0

Extraction 98.0

Sugar pol 97.5

Boiling House Recovery calculated by the s-j-m formula using 98.0 purity sugar, 35.5 purity final molasses, and purity of syrup=purity first expressed juice minus 1, Quality Ratio has served as a useful guide over the years and has been of great value in the evaluation of new hybrids and in the establishment of agronomic practices. On the average, figures calculated by this method agree reasonably well with the results obtained by the factory, although in recent years the calculated values have been consistently lower. In individual cases, however, the calculated values can deviate rather widely. This is due, of course, to the arbitrary factors used in the Quality Ratio formula. Most important of these are Java Ratio, final molasses purity, and extraction.

Evidence on the variation of Java Ratio from variety to variety and field to field is well established. An important factor in this variation is fibre. In experimental canes, fibre values range from 10 to 20 percent which means a large variation in the quantity of juice present in the cane.

Fibre, likewise, has an important effect on extraction. The 98 extraction figure in the formula was approximately the average obtained in Hawaii prior to mechanical harvesting. Now our average extraction lies closer to 95, so allowances must be made for this.

Finally, it is also well established that other factors being equal, final molasses purity is dependent upon the nature of the non-sucrose components of the cane juice. Juices high in ash, for example, give higher purity molasses. Composition of juices varies not only from variety to variety, but also from area to area, and field to field.

It is apparent, therefore, that it is highly desirable, especially in experimental work, to get away from any method of evaluation of cane quality requiring arbitrary factors and to arrive directly at Pol% Cane and Fibre%Cane. This has been done in the Pol Ratio method, a term applied to a method developed to analyze cane directly.

The procedure was developed in the course of a study made on sugar losses occurring in mechanical harvesting and cane cleaning. In this case, losses had to be related to an entity which was constant in these operations. Weight certainly was not, but fibre was reasonably so. Losses, therefore, were based on variations in the Pol-Fibre ratio and direct determination of pol and fibre became necessary.

PROCEDURE

The procedure for evaluating cane quality was developed to meet three basic requirements :

First, a method of obtaining a large representative sample of cane from the experimental plot was required.

Secondly, adequate means of sub-sampling had to be provided. This necessitated some method of chopping the cane.

Finally, a procedure for analyzing the sub-sample for pol and fibre content was necessary.

The method developed to meet these prerequisites is described below.

CANE SAMPLING

The principal problem in any method of ascertaining cane quality lies in sampling. A procedure based on selection of stalks is unsatisfactory. To avoid human bias, the sample should be taken mechanically, if possible, and relatively large quantities of cane should be included.

As a first approach, it was considered that the equipment should be of sufficient size to handle all of the cane in a one-fortieth-acre plot. This was at least one ton, more often two or more tons, of cane. Later, it was established that a sample of approximately 400 pounds was adequate, if it was obtained in a manner such that it was representative of all the cane in the plot.

In some areas in the Hawaiian Islands, cane in experimental plots is hand-cut and piled in windrows. The procedure developed for obtaining the 400 pounds sample was to use a small mechanical grab. The grab must take cane all the way to the bottom of the windrow to get a representative sample. If the windrow is large, 400-500 pounds of cane will be taken in one grab. This limits the number of grab loads that can be obtained.

In other areas, the practice in harvesting experimental cane is to hand-cut and bundle. In this case 6 to 8 whole bundles, each weighing about 70 pounds, are selected at random within the plot as the sample. Another practice is to take the sample before the cane is harvested. In this case, the sample is obtained by slash-cutting small squares at several points in the plot and taking all the cane within the squares.

Most important is that the sample taken for analysis should represent the cane weighed for yield. That means that if the cane weighed has trash and extraneous material, the cane chopped for analysis should not be stripped or cleaned.

CANE CHOPPING

An ensilage cutter serves as a means of reducing the cane sample to a representative two pounds sample for laboratory analysis. Flywheel type commercial units are satisfactory and inexpensive. Excessive blowing action is reduced by removing some of the fan blades on the flywheel. Adjustment of the flywheel speed relative to the speed of the feed conveyor can be made to give the fineness of cut desired. Views of such a machine are shown in Figures 1 and 2.

A chute built inside the discharge chute from the cutter deflects a portion of the chopped cane into a sample container. This is shown in Figure 2. The amount deflected may be varied by adjusting the sample chute. The size of the sub-sample thus obtained varies likewise with the size of the cane sample. It is necessary, therefore, to quarter down to a convenient two pounds sample of chopped cane.

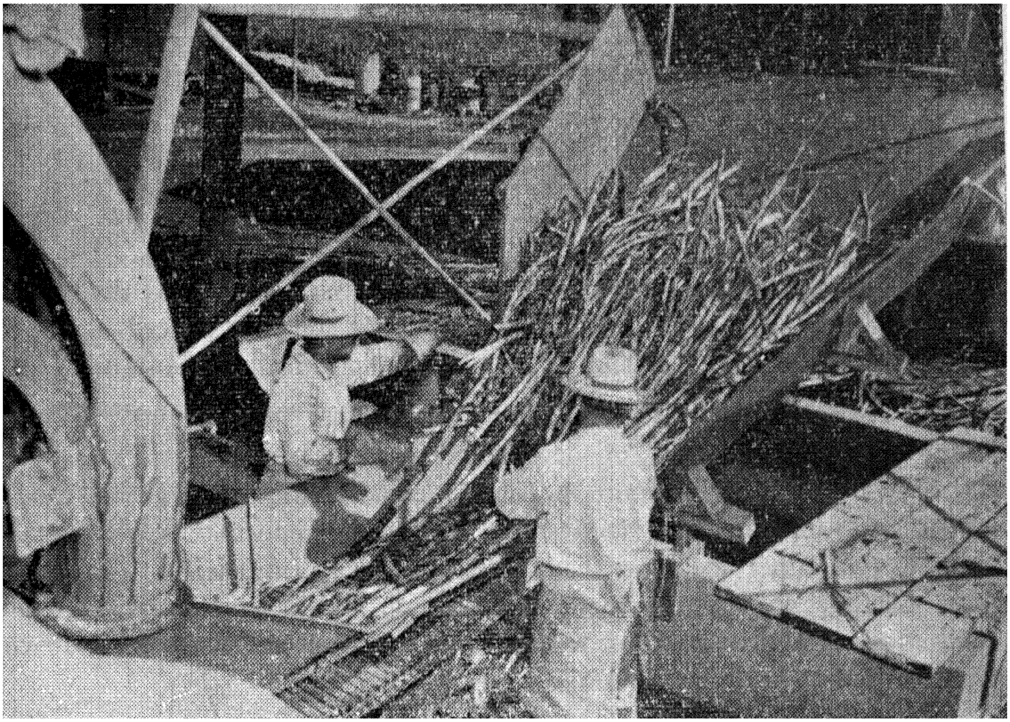


Fig. 1. Feeding Cane Sample into Ensilage Chopper.

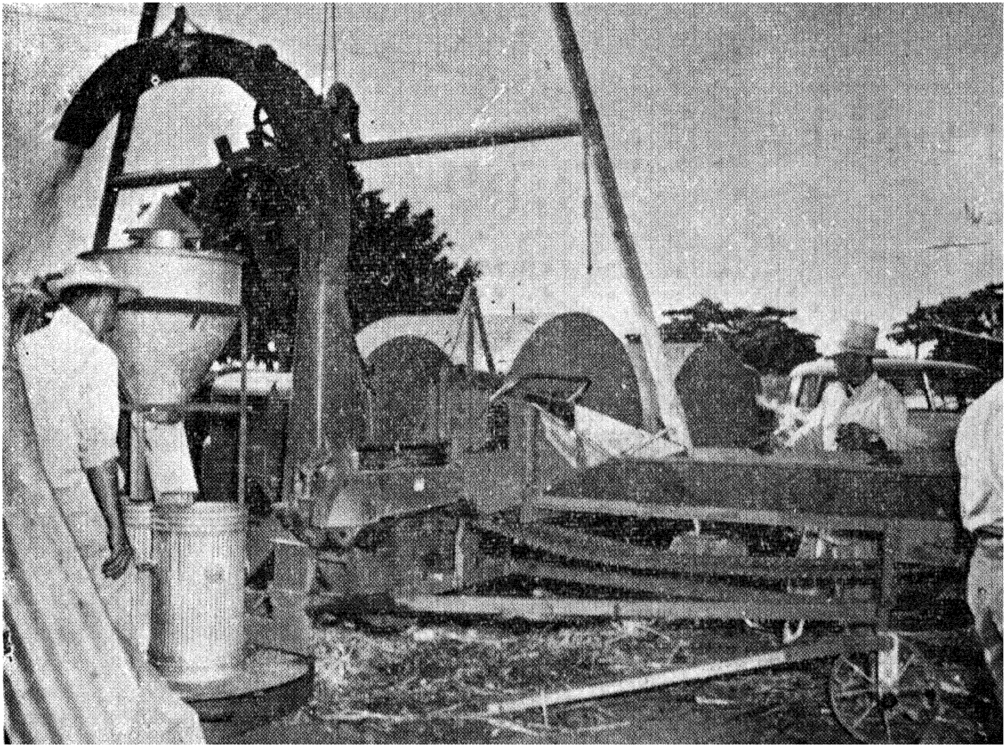


Fig. 2. View of Chopper Showing Sub-sampling Chute and Cyclone Collector.

These samples are sealed at once in polyethylene or vinyl plastic bags or in more rigid polyethylene containers. They are then stored in a freezer until the time of analysis. Experiment has shown that the samples suffer no deterioration if frozen promptly. Storage up to 30 days produces no significant change.

LABORATORY ANALYSIS

The laboratory analysis is designed to process the two pounds chopped cane samples and provide Pol % Cane and Fibre % Cane figures. The direct analysis of the pol content is achieved by thoroughly disintegrating the chopped cane in a water slurry. The action is such that the sugar in the cells is released either by disintegration or diffusion and distributed uniformly in the slurry.

The HSPA Disintegrator was designed for this purpose and has proven satisfactory in routine work. A view of the machine is shown in Figure 3 and a line drawing is shown in Figure 4. The unit consists essentially of two rotating blades fitted in the ends of a stainless steel cylinder of approximately one gallon capacity. Two other machines have been tried experimentally. The 5-quart Waring Blendor gives satisfactory disintegration but does not appear rugged enough in its present form for routine work. Another machine, the Rietz Varigrator, is under development and appears promising.

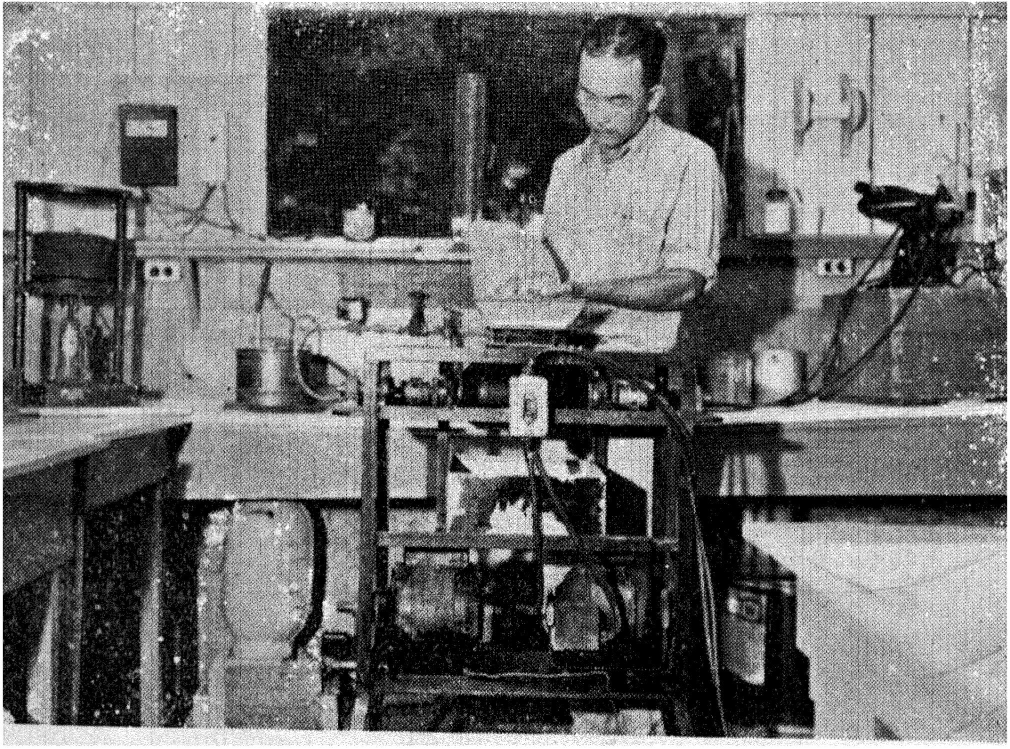


Fig. 3. Laboratory View Showing Use of HSPA Disintegrator

Briefly, the analytical procedure consists of a 10-minute disintegration of the weighed cane sample in a given weight of water. The amount of water is normally about twice the weight of the cane sample. After disintegration, a juice sample is withdrawn and analyzed. The pulp residue is washed free of soluble solids, pressed and dried to constant weight to give the weight of fibre. The weight of sample less the weight of fibre equals the weight of juice from the analysis of which the percentage pol in cane is calculated. Pol Ratio is defined as the reciprocal of Pol % Cane or tons cane per ton pol.

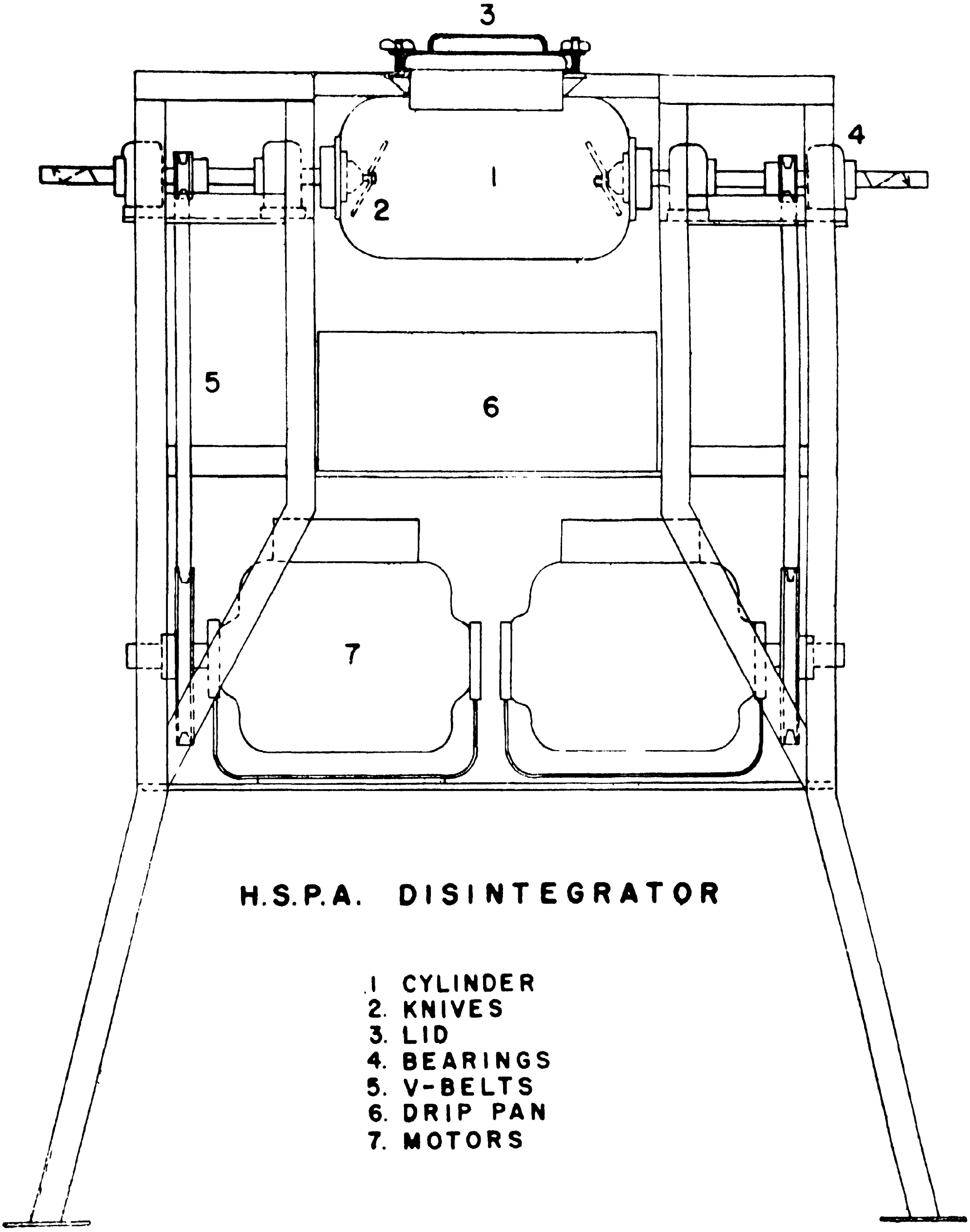


Fig. 4. HSPA Disintegrator.

RESULTS

Examples of studies on the application of this method are shown in Tables I, II and III.

In general, the results obtained by this method have a lower co-efficient of variation than results based upon analysis of first expressed juice. In addition the method has the following advantages :

1. Freedom from empirical factors.

A direct determination of pol in cane is made. In order to obtain recoverable sugar, each plantation may apply its own recovery figures. Recoveries vary not only due to differences in factory equipment but also due to growing conditions and harvesting procedures. A cane that may be best in one area may fall down in another due solely to lower over-all recovery.

2. Information on fibre content.

Wide variations in fibre content are found, not only from variety to variety, but from area to area with the same variety. This is an important factor in evaluating cane quality which was not measurable by Quality Ratio procedure.

3. Procedure is independent of factory operation.

In many cases, sample cane must be grounded in the factory in order to obtain juice data. This is a costly procedure due to lost time in milling. The Pol Ratio method is entirely independent of the mill.

4. Samples may be stored before analysis.

The chopped cane samples can be frozen as prepared and stored until a more convenient time for analysis. This makes possible the processing of a larger number of field samples per day during rush seasons. Samples have been stored for four weeks without deterioration. They probably can be left for much longer periods.

FIELD CONTROL

In addition to value in determining the quality of cane in experimental plots in all types of varietal and agronomic tests, the Pol Ratio method offers a new approach to the problem of field distribution. The determination of pol per unit area in the fields being harvested can be used to distribute, for field record purposes, the sugar recovered at the factory.

TABLE I

EXAMPLE OF SUB-SAMPLING STUDY
OLAA SUGAR COMPANY SEEDLING STATION 53-9

Object : To measure the variation between duplicate two pounds samples of chopped cane.

Procedure : A representative sample of approximately 400 pounds of cane was taken from each variety plot. The cane sample was chopped in the ensilage cutter and a continuous sub-sample collected. Duplicate two pounds samples of chopped cane were withdrawn and analyzed separately. Duplicate samples were labelled " A " and " B ". X=Check variety.

TABLE I

Plot No.	Variety	Pol % Cane	Fibre % Cane	Pol Ratio
1—A	A	11.54	10.81	8.67
B		11.63	11.20	8·60
2—A	X	14.03	11.48	7.13
B		13.42	11.78	7.45
3—A	B	11.21	11.42	8.92
B		10.92	10.99	9.16
4—A	C	12.04	12.32	8.31
B		11.63	11.89	8.60
5—A	X	15.13	12.00	6.60
B		15.12	12.15	6.61
6 A	D	11.22	10.38	8.91
B		11.44	9.63	8.74
7—A	X	10.60	11.46	9.43
B		10.40	10.80	9.62
8- A	E	12.22	10.76	8.18
B		11.45	11.09	8.73
9—A	F	12.63	11.61	7.92
B		12.39	11.39	8.07
10—A	X	13.61	12.03	7.35
B		13.71	12.43	7.29
11—A	G	11.91	11.11	8.40
B		12.04	10.64	8.31
12—A	H	10.87	10.03	9.20
B		12.00	9.99	8.33
13—A	X	13.39	12.82	7.47
B		13.41	12.35	7.46
14—A	I	11.62	12.16	8.61
B		11.81	12.04	8.47
15—A	J	11.41	11.62	8.76
B		11.73	11.68	8.53
16—A	X	12.46	11.24	8.03
B		11.94	11.31	8.38
17—A	K	11.83	11.90	8.45
B		12.02	12.35	8.32
18—A	L	12.73	12.63	7.86
B		12.09	12.80	8.27
19—A	M	11.78	11.24	8.49
B		11.25	11.30	8.89
20—A	X	13.90	12.12	7.19
B		13.84	12.28	7.23
21—A	N	12.02	11.64	8.32
B		12.21	11.26	8.19
22—A	O	10.92	10.83	9.16
B		10.78	11.15	9.28
23—A	X	11.60	11.72	8.62
B		11.78	11.58	8.49

TABLE I (Contd.)

Plot No.	Variety	Pol % Cane	Fibre % Cane	Pol Ratio
24—A	P	8.63	11.64	11.59
B		8.51	11.52	11.75
25—A	Q	11.21	11.84	8.92
B		11.17	11.97	8.95
26—A	R	9.37	11.48	10.67
B		9.85	11.39	10.15
27—A	X	13.15	11.72	7.60
B		13.53	11.68	7.39
28—A	S	12.43	10.97	8.05
B		12.02	11.40	8.32
29—A	T	12.52	11.25	7.99
B		12.56	10.76	7.96
30—A	X	13.12	12.01	7.62
B		13.18	11.99	7.59

STATISTICAL SUMMARY FOR POL % CANE

Mean squares for error for the between-duplicates test = 0.0744 Co-efficient of variation = 2.3 %.

CONCLUSION

The between-duplicates variance (0.0744) is small in relation to the plot-to-plot variance in replicated tests (generally in the range 0.30 to 0.80). This result was confirmed in other similar tests. Therefore it was concluded that a two pounds sample was adequate for the analysis and evaluation of the quality of cane from experimental plots.

TABLE II

EXAMPLE OF CANE SAMPLING STUDY
PEPEEKEO SUGAR CO. VARIETY EXPERIMENT NO. 85V

Object : To study influence of bundle sampling procedure on plot-to-plot variation.

Procedure : In a replicated test on one-fortieth-acre plots determine the effect of :

1. An 8-bundle (50-80 pounds each) sample taken from the centre of each plot (" A " sample).
2. An 8-bundle sample taken from dispersed points within each plot (" B " sample).

Plot No.	Pol % Cane A	Pol % Cane B	Fibre % Cane A	Fibre % Cane B	Pol Ratio A	Pol Ratio B
			Variety A			
1	13.24	12.67	14.08	13.87	7.55	7.89
8	13.17	14.09	14.36	13.95	7.59	7.10
10	12.42	12.17	14.12	13.53	8.05	8.26
15	13.03	13.04	13.76	13.81	7.67	7.67
17	12.81	12.37	14.22	14.32	7.81	8.08
24	13.84	13.78	13.49	14.77	7.23	7.26
Average	13.09	13.02	14.01	14.04	7.64	7.68

TABLE II (Contd.)

Plot No.	Pol % Cane A	Pol % Cane B	Fibre % Cane A	Fibre % Cane B	Pol Ratio A	Pol Ratio B
			Variety B			
2	11.08	11.57	13.63	14.16	9.03	8.64
7	11.74	12.68	13.61	14.47	8.51	7.89
12	13.67	13.62	16.11	14.84	7.32	7.34
13	12.48	12.39	15.65	15.25	8.01	8.07
18	12.87	11.81	14.34	14.87	7.77	8.47
23	13.03	11.88	14.36	15.25	7.67	8.42
Average	12.48	12.33	14.62	14.81	8.01	8.11
			Variety C			
3	14.41	14.06	14.69	14.43	6.94	7.11
5	14.26	13.97	15.36	15.17	7.01	7.16
11	14.07	14.63	15.33	14.58	7.11	6.84
14	11.60	12.82	15.02	14.48	8.62	7.80
20	15.77	15.34	15.80	15.65	6.34	6.52
21	14.68	12.24	14.95	12.85	6.81	8.17
Average	14.13	13.84	15.19	14.53	7.08	7.23
			Variety D			
4	13.31	14.19	12.94	13.99	7.51	7.05
6	10.99	13.06	12.95	12.98	9.10	7.66
9	12.79	13.43	12.95	13.47	7.82	7.45
16	13.09	13.32	12.14	13.80	7.64	7.51
19	12.07	13.04	12.54	13.49	8.29	7.67
22	12.67	12.93	12.77	12.96	7.89	7.73
Average	12.49	13.33	12.72	13.45	8.01	7.50

STATISTICAL SUMMARY

	Pol % Cane "A" Samples Centre of Plot	Pol % Cane "B" Samples Dispersed Points
Mean squares for error	0.8164	0.4381
Co-efficient of variation	6.9%	5.0%

CONCLUSION

The procedure in which an 8-bundle sample is taken from dispersed points within each plot gives a lower plot-to-plot variation. This illustrates the importance of space distribution in representative sampling.

TABLE III

EXAMPLE OF VARIETY QUALITY ANALYSIS BY THE POL RATIO METHOD HELEMANO SUB-STATION—FIELD 1

Object : To determine the relative quality of experimental cane varieties.

Procedure : One-fortieth-acre plots were analyzed for pol and fibre by the method outlined to give Pol Ratio.

Plot No.	Variety	Pol % Cane	Fibre % Cane	Pol Ratio
1	A	12.06	15.55	8.29
2	B	13.46	13.53	7.43
3	X	13.31	11.16	7.51
4	C	14.15	12.86	7.07
5	X	12.20	12.96	8.20
6	D	11.76	16.05	8.50
7	E	13.59	15.02	7.36
8	X	13.59	13.18	7.36
9	F	15.26	14.15	6.55
10	X	13.72	13.67	7.29
11	G	12.05	14.05	8.30
12	H	14.25	14.16	7.02
13	I	11.64	14.28	8.59
14	J	10.68	15.51	9.36
15	X	12.89	14.06	7.76
16	K	11.63	13.18	8.60
17	X	13.71	14.71	7.29
18	L	13.94	19.67	7.17
19	M	14.36	16.54	6.96
20	X	11.98	13.61	8.35
21	N	13.13	13.89	7.62
22	X	12.99	13.28	7.70
23	O	13.30	13.62	7.52
24	P	13.09	13.27	7.64

X = Check variety

CONCLUSIONS

The figures illustrate how varieties vary in pol and fibre content. Particularly outstanding is the wide variation in fibre. These data combined with cane weights per plot are used in comparing new hybrids with established varieties.

DISCUSSION

Dr. A. J. Mangelsdorf pointed out that this method was more time consuming than the old method, two men handling about 20 tests per day as compared with 80 before. He was satisfied that the 2 lbs. sub-sample is reasonably reliable, but would prefer a 10 lbs. sample if facilities were available. He was giving thought to the possibility of disintegrating the sub-sample further and completing analysis without the use of dilution water.

The Chairman said that considerable attention was being given to direct methods of cane analysis and this paper is a note worthy contribution in this direction. Great care is needed to obtain reliable samples due to the extremely variable nature of sugar cane.

Mr. C. W. Davis suggested the possibility of snap freezing the subsamples and then grinding it.

Dr. K.S.G. Doss said that the question of accurately evaluating cane was a very important one. There was one approach to this problem by applying an accurate analysis to a small sample ; and another approach was to apply a very rapid sample test to a very large sample.

Dr. C. W. Waddell agreed with Dr. Payne's findings of wide variations in fibre content of cane. It seems desirable, wherever possible, to make use of factory equipment to reduce the material to a stage where reliable bulk samples can be obtained. Regarding the ensilage cutter he had found that the cutting blades of any such equipment require a good deal of attention to keep them sharp when any large scale routine work with them is undertaken.

Mr. J. D. R. St. Antoine said that a considerable amount of work on the bulk sampling and disintegration of cane for determining its sucrose and fibre content was being undertaken in Mauritius.

In the absence of the author Dr. Douwes Dekker presented the following paper. This was discussed along with the next two papers.

Paper

BOILING HOUSE EFFICIENCY AND THE PURITY OF FINAL MOLASSES

PIETER HONIG

West Indies Sugar Corporation, New York

> The owl very gravely got down from his perch
> Walked round and regarded his fault finding critic
> (who thought he was stuffed) with a glance analytic.

The existing methods to express the boiling house efficiency numerically are many and to a certain extent confusing for the sugar technologists who have as their duty to calculate the boiling house efficiency to compare their efficiency number with the results obtained in other mills and in other countries.

At recent meetings of the International Society of Sugar Cane Technologists two papers have been presented, covering the subject of boiling house efficiency indicators, with concrete proposals to change the methods as adopted by the International Society and which are in use in most of the cane sugar producing countries. These papers are : " Boiling House Efficiency Indicators " by S. N. Gundu Rao, Proceedings 7th Congress I.S.S.C.T., 1950, p.665, and " Judging Boiling House Work " by K. Douwes Dekker, Proceedings 8th Congress I.S.S.C.T., 1953, p. 671.

THE BOILING HOUSE EFFICIENCY NUMBERS TO COMPARE THE ACTUAL YIELD IN THE FORM OF MANUFACTURED, COMMERCIAL SUGAR WITH THE THEORETICAL YIELD, OR IN OTHER WORDS THE RATIO OF THE ACTUAL RECOVERY TO THE BASIC OR IDEAL RECOVERY

It is a common practice to use as the starting point for the calculation of the ideal recovery or recoverable sugar, the weight and analysis of the mixed juice, although some countries are using other starting points as for instance the amount of pol in mixed juice as it is determined by weighing and analysis but using for the purity, the purity of the evaporator syrup as it is subjected to the manufacturing process. A few countries and sugar companies are not using pol but sucrose values and compare the amount of sucrose in mixed juice with the amount of sucrose as it is recovered and or recoverable as commercial product.

It has to be realized that the determined weights and analyses in a sugar factory have an error as a result of the unavoidable imperfections of calibration and weighing technique and equipment and in the standardized methods for analyses of sugar house products.

The tolerances and accuracies, using the best available equipment and methods, and with the understanding that scales and analytical equipment have been calibrated and are checked regularly, are as follows :

PRECISIONS AND ACCURACIES OF WEIGHTS IN TECHNICAL CONTROL IN CANE SUGAR FACTORIES

Mixed juice	± 0.1 %*
Commercial sugar	± 0.05 %
Final molasses	± 0.2 %

ACCURACIES OF ANALYSES

Pol mixed juice	± 0.1 %
Pol syrup	± 0.1 %
Pol commercial sugar	± 0.15 %
Pol molasses	± 1.0 % **
Brix mixed juice	± 0.1 %
Brix syrup	± 0.2 %
Brix sugar	± 0.1 %
Brix molasses	± 1.5 %

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* ±stands for the maximum error of the average of at least 10 determinations.

** It is recommendable to correct the pol reading at temp. T of final molasses to a normal temperature of 20°C. The correction is :

$$\text{Clerget sucrose \% molasses} \times \frac{0.03\ (T-20)}{100} + \text{red. sugars \% molasses} \times \frac{0.5\ (T-20)}{100}$$

The temperature correction of the pol is for final molasses, polarized at 28°C., approximately + 1.0 to 1.5°V.

ERRORS IN CALCULATED PURITIES

	As average of a large number of analyses	For a single analysis
Mixed juice	± 0.1 %	± 0.2%
Syrup	± 0.15 %	± 0.3%
Sugar	± 0.1 %	± 0.2%
Molasses	± 2.0 %	± 2.5%

For this reason it does not make sense to report technical data in daily and periodical reports with many digits behind the decimal point.

Some of the errors are of a systematic character as the result of errors in calculations or method of reading of the control equipment. Others vary at random plus or minus, and a large number of readings averaged show a reduced error. The deviations given in Table I are considered to be the inevitable errors in averages, resulting from a large number of readings taken over a long period during a sugar crop.

THE DETERMINATION OF THE POL AND PURITY OF MIXED JUICE

The starting point of the control system on boiling house efficiency is the sample of mixed juice as passing the scales ; in some countries it is screened to remove suspended bagacillo through a screen of 40 mesh per linear inch before analysis. Theoretically, it is necessary that if the juice sample is screened before analysis, the determined amount of suspended matter in mixed juice is applied as a correction factor to the weight of the mixed juice. The simplest way is to take for analysis a composite sample of the mixed juice without screening for the pol determination, and to use the determined pol without correction by multiplying by the weight of the mixed juice as the quantity of pol at the beginning of the manufacturing process. This last method is to be recommended only in those cases where the amount of insoluble matter in mixed juice is less than 0.03%.*

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*If the quantity of insoluble settling matter in mixed juice is high as e.g., in countries where mechanical harvesting is used, a correction has to be made for the pol in mixed juice for the volume of insoluble matter if the normal weight method is used. The weight of insoluble matter has to be deducted from the gross weight of mixed juice to obtain the net weight of mixed juice.

Example : Calculated error in determination of pol in mixed juice with large quantity of suspended solids in mixed juice ;

g. of suspended matter per kg. of mixed juice = 6.2 g.

corrected net weight of juice per kg. gross =993.8 g.

spec. gravity suspended solids 1.9, volume suspended solids 3.3 ml.

uncorrected pol determined by normal weight method = 16.20

$$\text{corrected pol} = \frac{1000}{996.7} \times 16.2 = 16.25.$$

Uncorrected pol per kg. of mixed juice = 162.0 g.

Corrected pol per kg. of mixed juice = 161.4 g.

Percent pol correction = 0.37

For clarification with Horne's dry lead, the only correction to be applied is for the weight of suspended settling matter, being = 0,62%.

The determination of the amount of *recoverable* sugar in product is based on the assumption that no pol (and sucrose) is lost in filter mud, and that no undetermined losses are suffered. All the non-sugars present in the mixed juice are found back in the final molasses and to a limited extent in the manufactured sugar. The application of the Noel Deerr SJM formula, using the purity of the mixed juice with an assumed purity of the final molasses, is incorrect*. During clarification a considerable amount of non-sugars is eliminated in the filter mud and a certain amount of lime salts added to the juice.

THE USE OF "BRIX–POL" IN MIXED JUICE FOR NON-SUGARS PROCESSED IS INCORRECT

According to published data it has been found in some countries that taking as an expression for the amount of non-sugars : brix minus sucrose, 85% of the non-sugars present in mixed juice are found in clarified juice.

For Java over a number of years it has been found that with the normal liming process in raw sugar manufacture, 88% of the non-sugars (brix—pol) in mixed juice were found in clarified juice, in final molasses and sugar respectively. In applying special purification methods as for example carbonatation or the middle juice carbonatation it was found that 70 to 77% of the non-sugars present in mixed juice were found in final molasses and manufactured sugar.

Comparing in one country for different mills grinding the same cane variety (2878 P.O.J.), by calculation from the determined analytical data, the non-sugar removal with the simple liming process, it was found in Java that this could vary from 8 to 20 %, depending on the purity of the mixed juice. The percentage removal of non-sugars was greatest in juices of high purity. It is for this reason not admissible to introduce a standard correction factor to calculate the amount of non-sugars present in clarified juice in relation to the amount of non-sugars in mixed juice.

The purification of mixed juice is a technological operation, showing its own efficiency and by the introduction of modifications such as double or hot liming, addition of phosphates, the use of SO_2, etc., it is possible to influence the non-sugar removal and in this way to affect the amount of recoverable sugar.

Hawaii has introduced for the ratio of pol in mixed juice to the amount of non-sugars to be handled in the boiling process the purity of the syrup. This decision is rational and an improvement compared to the use of the purity of the mixed juice. It can be applied, however, only in those cases where no products are returned to the clarified juice as for instance remelted sugar, washings and steamings from pans and supply tanks on the pan floor. The syrup sample must be representative for an unmixed clarified juice, resulting from the clarification of the mixed juice.

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* The SJM formula is based on the distribution of sucrose and non-sugars present in a raw material between sugar and molasses, with the assumption that the quantities of sucrose and non-sugars remain unchanged or that dry solids in raw material (or brix)=dry solids in manufactured sugar+dry solids in molasses.

THE VALIDITY OF THE SJM FORMULA

The SJM formula is based on a rational mathematical foundation. It does not, however, take into consideration changes of the polarization, if we are using for the purities in this formula the apparent purities, resulting from changes in the optical rotation of the reducing sugars. It is at this moment the best method we have at our disposal. The application is simple and it is a method that can be recommended for technical control purposes.

A simplified form of the SJM formula is the Winter-Carp formula, based on an apparent purity of the final molasses of 28.57. The SJM formula is then reduced to :

$$\text{Recoverable sugar} = \text{pol} - 0.4\,(\text{brix} - \text{pol})$$

If this theoretical yield, calculated with brix and pol of mixed juice, is compared with the actual amount of commercial sugar, expressed as *crystal*, we obtain the Winter rendement.

The amount of crystal in commercial sugar is determined by the formula :

$$\text{Recovered crystal} = \text{weight of commercial sugar} \times \left[\text{pol} - (\text{brix} - \text{pol}) \times \left\{\frac{\text{actual apparent molasses purity}}{100 - \text{actual apparent molasses purity}}\right\}\right]$$

This is the simplest form to calculate the boiling house efficiency.

The main objection against this formula is that we have to introduce for the calculation of recoverable sugar the brix of the mixed juice. When applying the SJM formula we should preferably use the apparent purity of the syrup, which is more accurate and realistic.

THE PURITY OF THE FINAL MOLASSES IN THE SJM FORMULA

A discussion point among technologists is the purity of the final molasses to be used in the calculation of the amount of recoverable sugar. The assumption to use an apparent target purity of 28.57, which was once a technical ideal for the purity of final molasses, is not valid any more with the modern equipment we have at our disposal. Lower molasses purities have not only been obtained in laboratory experiments, but have been obtained in many mills under normal operational conditions on the factory scale. It is for this reason that in recent times a number of proposals have been presented to arrive at a target purity, being the purity of the final molasses as obtainable under ideal technological conditions of crystallization and centrifuging.

The approach in Java has been the determination of the amount of sucrose in solution at different temperatures 50°C. and 35°C., at different true solids content (or water content) and to find the relationship between the purity of the final molasses at 35°C. and a water content in the final molasses separated from the crystals between 14 and 16%. The water content in the final molasses of 14 to 16% was taken as a standard, as this represented a concentration, at which the final massecuite was manageable in the centrifugal process. The standards taken for the technically applicable conditions of centrifuging were that the molasses sugar with an average grain size of 0.30 mm. linear subjected to a centrifugal force, being 1600 to 1800 times the force of gravity (corresponding with a centrifugal of 40″ diameter with a number of revolutions of 1600) in a 4″ layer, had to produce a C-sugar, containing at least 85% crystal or corresponding with a polarization of 88-90 in a centrifugal cycle of 10 minutes. This empirical foundation corresponds with the conditions of centrifuging as practicable in the factory, correlated to a certain extent with a viscosity of the molasses at 35°C. between 500 and 1000 poises.

It was the opinion of Java sugar technologists before World War II that the highest exhaustion of final molasses could be obtained by cooling the molasses boilings to a low temperature and it was for this reason that a standard temperature of 35°C. was introduced. The results of exhaustibility tests as performed under thermostatically controlled conditions are represented in Figure 1.

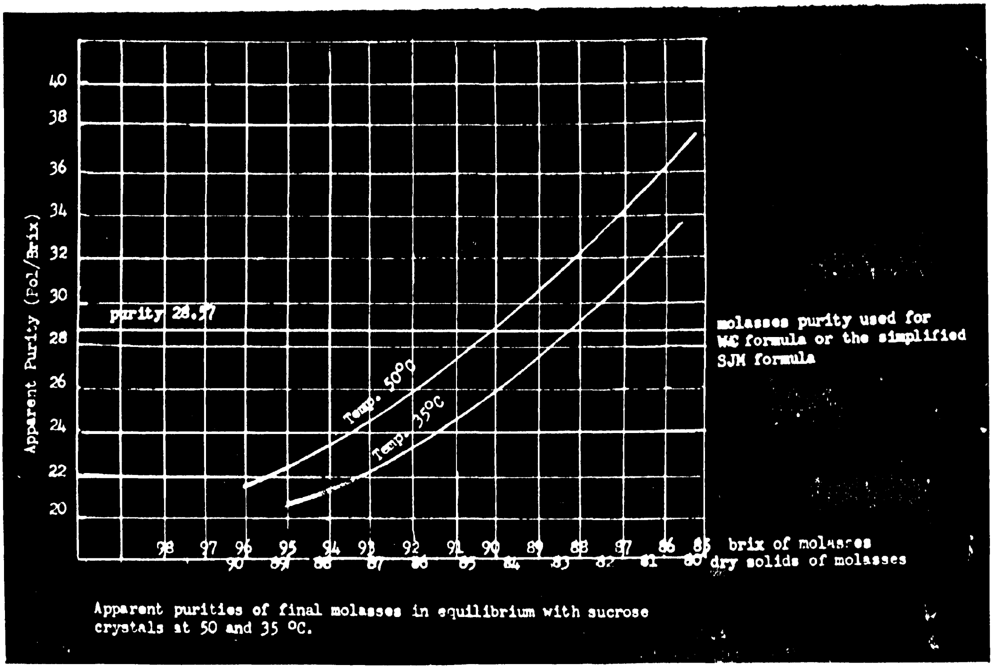

Figure 1.

An attempt has been made to correlate these results with the variations in the composition of the final molasses. A detailed statistical study on this subject has been made by C. Sijlmans, who found that the main factor determining the purity of exhausted final Java molasses, was the amount of reducing sugars. The variations of reducing sugars in the Java molasses were between 15 and 32, average 24.5, and the variations in the amount of uncorrected sulphated ash in Java molasses were between 10.5 and 18, average 13.0.

The application of the Sijlmans formula based exclusively on the variation in the percentage of reducing sugars was not satisfactory for the calculation of the exhaustibility of final molasses.

A second Java study has been made by K. Douwes Dekker, also based on a large number carefully analyzed final molasses, but taking into consideration also the ash content, and calculating the sucrose solubility for ideal factory conditions for the C-boilings as to crystallization, cooling in the crystallizers and centrifuging, which has given the formula :

True purity of well exhausted molasses $= 35.9 - 0.081\ r + 0.26\ a$
where $r =$ red. sugars % true non-sugars (true solids—Clerget sucrose)
$a =$ sulphated ash % true non-sugars (true solids—Clerget sucrose)

Hawaii has used a method to determine the exhaustibility, the solubility of sucrose in concentrated impure solutions, given as the ratio of sucrose and refractometric solids, using the amount of reducing sugars and the ash content as given by the conductance of the molasses, diluted to 28 refractometric solids at a temperature of 20°C., and taking as the target purity the solubility of sucrose in the molasses, having a viscosity of 600 poises at a temperature of 50°C.

The reducing sugars in the Hawaiian molasses studied varied between 14 and 27%, the uncorrected sulphated ash varied between 16 and 27%.

On an average there is an essential difference between Java molasses and the Hawaiian molasses, namely that the Java molasses is lower in ash, has approximately the same or somewhat higher percentage of reducing sugars, and is higher in organic non-sugars. It must be understood that the Java cane is practically all grown under irrigation in a tropical country as a crop of 14 to 15 months, all plant cane. Hawaii is in the sub-tropics, also using irrigation but most of the cane results from a so called long plant crop of 20 to 22 months, and furthermore consists for the greatest part of ratoon cane.

There are, of course, still a number of other factors responsible for differences in the non-sugar composition of the cane juices, such as soil conditions, fertilizer technique and cane varieties, and last but not least, the harvesting method and the cleanliness of the cane.

WHAT IS EXHAUSTED MOLASSES ?

The essential points in these studies are that we are able to get an impression by carefully conducted experiments of the level of the purity of the final molasses obtainable under ideal conditions of processing. There does not exist a great difference of opinion that the maximum viscosity applicable in the final C-boilings at the moment of centrifuging, using high gravity centrifugals, is somewhere between 400 and 1000 poises, if we try to limit the time for the centrifugal cycle to 12 to 15 minutes, using a massecuite layer in the centrifugal basket of 5″ or a massecuite charge of 600 pounds massecuite in a 40″×20″ centrifugal and that we wish to obtain a molasses sugar with a polarization of approximately 90.

It is, of course, possible to talk about extreme conditions by using still higher densities of the final molasses, corresponding with higher viscosities with lower temperatures in the final stage of cooling, but we have to realize that it makes no sense to discuss a theoretical molasses purity, if we are not able to get a satisfactory separation between crystals and molasses by the methods we have at our disposal.

We can state that the maximum centrifugal force we are able to use in modern centrifugals is for a 40″ centrifugal 2200 revolutions per minute, corresponding with a gravity factor of approximately 2700.* The ideal crystal we are able to obtain has a size of approximately 0.25 to 0.30 mm. linear. If this crystal has a perfect regularity, we have a surface in the sucrose crystals of 40 m^2 per kg. of sucrose.

It is undoubtedly true that using the Java formula as developed by Douwes Dekker we arrive at a higher target purity for the final molasses than we obtain with the Hawaiian formula. It is certain that using either one of these two formulae we arrive at apparent purities for the final molasses lower than 28.57. It is no longer permissible to apply under these conditions the Winter-Carp or the SJM formula with a target molasses purity of 28.57.

WHAT DO WE UNDERSTAND TODAY AS "RECOVERABLE" SUGAR?

The time has come that we have to consider whether we ought not to change the formula for calculating the boiling house efficiency. The following statements can be made in this respect :

(a) The calculation of the Winter rendement as the expression for the boiling house efficiency, using the analysis of the mixed juice, gives in modern factories in many cases, a result higher than 100. To use this expression for judging the efficiency or the ratio between actual recovered and recoverable makes no sense.

(b) It is recommendable to use the syrup purity with the SJM formula in those cases where the sampled evaporated syrup is not mixed with returned sugar house products from the crystallization station.

(c) It is recommendable to introduce as the target purity, the purity of the final molasses that is based on the non-sugar composition in the final molasses. It is unfortunate that the Douwes Dekker formula and the Hawaiian formula use as an expression for the purity in the first case sucrose divided by dry solids or the true purity, and that the Hawaiian formula uses sucrose divided by refractometric brix. The control systems in the overwhelming majority of the cane sugar mills are based on pol and brix, and only in exceptional cases do we use dry solids or the sucrose content in mixed juice as the starting point for our technical control.

(d) It is also certain that it is not justified to use one new target purity

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* The gravity factor is calculated by the formula :
$14.2\ (\text{basket diameter in inches}) \times (\text{revolutions per minute}/1000)^2$.

expressed as apparent purity for all kinds of molasses. A molasses high in reducing sugars and low in ash is much easier to exhaust to a low purity than a molasses high in ash.

It is not possible at this stage to propose to the I.S.S.C.T. a new standard for the target purity of final molasses adaptable to all cane sugar producing areas. The simplest formula derived from a number of determinations, where the analysis of molasses have been made with great accuracy and based on reducing sugars% non-sugars and sulphated ash% non-sugars, where non-sugars are given as brix minus pol, is the following :

Apparent target purity of final molasses (Java standards) =

$$24.0-0.11 \text{ red.sugars } \% \text{ nonsugars} + 0.26 \text{ ash } \% \text{ non-sugars}$$

and for Hawaiian standards :

$$20.0-0.13 \text{ red.sugars } \% \text{ non-sugars} + 0.28 \text{ ash } \% \text{ non-sugars}$$

$$\text{where non-sugars} = \text{brix} - \text{pol}$$

This formula is applicable for molasses having a non-sugar composition varying between :

red. sugar	35-57 %	non-sugars
sulphated ash	12-32 %	non-sugars

(e) It is possible to calculate with this formula a new boiling house efficiency given as recovery divided by recoverable or r/R with a predetermined target purity of the final molasses as follows :

EXAMPLE :

Weight of mixed juice 473,125 tons

Pol 16.7, Brix 19.3, Purity 86.2

Syrup purity 87.3

Pol in mixed juice 79,012 tons

Target purity molasses, using Hawaiian standards (non-sugar composition red. sugars % non-sugars 43, ash % non-sugars 31), pol/brix 22.0, actual apparent purity final molasses 27.9.

Recoverable crystal by SJM formula, using the mixed juice analysis,

$$= \frac{100\,(86.2-22.0)}{86.2\,(100-22.0)} = 95.48$$

Recoverable in product = 75,440 tons.

Recoverable crystal by SJM formula, using the apparent purity of the

$$\text{syrup} = \frac{100\,(87.3-22.0)}{87.3\,(100-22.0)} = 95.90$$

Recoverable in product = 75,772 tons

Commercial sugar made 75,300 tons

Pol 97.3, Moisture 0.45, Brix 99.8

Apparent purity 97.5

$$\text{Crystal content \% commercial sugar} = \text{pol} - \left[(\text{brix} - \text{pol}) \frac{m}{100 - m} \right]$$

$$= 97.3 - (99.8 - 97.3) \left(\frac{27.9}{100 - 27.9} \right) = 96.3$$

Weight crystal in commercial sugar $= 75{,}300 \times 96.3 = 72{,}514$ tons

$$\text{Efficiency or } \frac{\text{recovery}}{\text{recoverable}} = \frac{72{,}514}{75{,}440} = 96.1$$

$$\text{Now } r/R = \frac{72{,}514}{75{,}772} = 95.7$$

IN OUR CONTROL SYSTEM WE MUST ADOPT A UNIFORM BASIS FOR THE PURITIES OF JUICE, SUGAR AND FINAL MOLASSES TO CALCULATE THE RECOVERABLE SUGAR BY THE SJM FORMULA

The time has come to eliminate from our technical discussions proposals that have been made in the past, such as " virtual " molasses purity and similar other kinds of complicated systems to calculate boiling house efficiency and we have to introduce a new conception based on pol analysis exclusively and apparent purities, but using as the apparent purity of the starting material the apparent purity of the syrup, and to use as the target purity of the final molasses the purity as calculated by empirical formula as given above. In this way it will be possible to judge the technical performance of cane sugar mills and to see in how far it will be possible to increase the efficiency, mainly by perfecting the processing of the C-massecuites in pans, crystallizers and centrifugals.

The author presented the following paper.

Paper

SOME OBSERVATIONS ON RECENT DEVELOPMENTS IN BOILING HOUSE EFFICIENCY FORMULAE

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The formation in 1927 of the Special Committee on Uniformity in Reporting Factory Data by the International Society of Sugarcane Technologists represents the most important land mark in the development of uniform methods of technical control and reporting factory data for international comparisons. The publication in 1942 of the system of cane sugar factory control of the International Society of Sugarcane Technologists edited by F.W. Zerban, Chairman of the above Special Committee, brings till that date under one cover the results of the deliberations of the Special Committee from time to time and its recommendations. The Special Committee considered the following formulae for comparing boiling house performances :

1. **Boiling House Performance, Winter Rendement, Boilin House Efficiency Number, etc.**
2. Comparison Figure of Java Experiment Station.
3. The New Comparison Figure of the Java Experiment Station " Technical Result ".
4. Reduced Boiling House Recovery by Noel Deerr.

In Judging the formulae the Committee were guided by the three main objectives enunciated by S. S. Speck, viz., accuracy, clarity and simplicity. The Committee recommended adoption of Reduced Boiling House Recovery of Deerr, as they found it simple, a better comparison figure for measuring the boiling house performance, which could be used directly for international comparisons. The objections against the formulae that were rejected were :

1. The performance figures depended on mixed juice purity.
2. Lack of simplicity.

The above recommendations of the Uniformity Committee were subjected to a detailed examination by E. M. Copp (1), who arrived at inconsistent data in respect of boiling house efficiency figures under the same efficiency conditions by adopting the Reduced Boiling House Recovery formula of Deerr. He observes " in fact the same virtual purity of molasses always yields the same reduced retention since the latter has but one variable no matter how the other data may vary." Hence he arrived at the conclusion that according to the I.S.S.C.T. method, all factories having the same virtual molasses purity will be doing the same quality of boiling house work. Further, Copp observed " the newly adopted Reduced Boiling House Recovery is superfluous as a criterion for boiling house performance since virtual purity of molasses could be used instead ". He concludes " both the Reduced Boiling House Recovery and the Virtual Molasses Purity are of questionable value as indicators of boiling house work. The former apparently favours juice purities below 85 and penalises juice purities above 85 ". Unfortunately, it did not occur to Copp that it is the virtual purity concept that is responsible for making the Reduced Boiling House Recovery Formula of Deerr faulty. He, therefore, adopted the virtual purity for modifying the Boiling House Efficiency Number. The modified formula is called the Copp's formula.

S. N. Gundu Rao (2) found that the reason for the inconsistent data while using the Reduced Boiling House Recovery Formula of Deerr was in the concept of the constancy of the virtual purity of molasses under the same boiling houses efficiency conditions under all juice purity conditions. He in his paper worked out examples and showed the dependence of virtual purity of molasses under conditions of varying juice purity, while the efficiency remains the same. His paper also contains very clear graphs to which attention is drawn. The above publication by Gundu Rao was followed up by a series of publications by Noel Deerr (3) and Gorden Smart (4). These also have been answered and further clarification brought about by Gundu Rao (5), who has also presented a new formula for

Reduced Boiling House Recovery, which is free from the drawbacks in the previous formulae. Kripashankar (6) made a comparative study of the various boiling house control formulae and showed the degree of influence of juice purity on the results obtained by the different formulae when manufacturing efficiencies remained the same. He found the following variations in boiling house efficiency indicators for a range of 20 units in raw juice purity (74.0 to 94.0) :

R.B.H.R. E.S.G. Deerr	...	5.40
B.H.P. Deerr	...	4.45
Comparison Figure, Java	...	2.87
R.B.H.R. E.S.G. (Gundu Rao)	...	Nil.

Kripashankar concludes that " with different raw juice purities the Reduced Boiling House Recovery E.S.G. calculated according to Gundu Rao's formula is constant and therefore appears to be a most reliable formula for comparing boiling house work ".

S. N. Gundu Rao (7) presented a paper on boiling house efficiency indicators before the 7th Congress of the International Society of Sugarcane Technologists 1950. After discussion, the Chairman referred the formula to the Special Committee of Uniformity in reporting factory data. F.W. Zerban (8), the Chairman of the Special Committee sent the following questionnaire along with reprints of S. N. Gundu Rao's paper to the 14 Regional Committees.

> " Reduced Boiling House Recovery E.S.G.
>
> Are you in favour of retaining Deerr's formula or do you recommend adoption of Copp's formula or of Gundu Rao's formula ? If you favour any other formula, please so state. Give reasons for your recommendation".

On the basis of replies received the Chairman commented as follows :

> " Seven of the fourteen Regional Committees (Cuba, India, Mauritius, New South Wales and Fiji, Peru, Puerto Rico and Queensland) expressed themselves in favour of adopting Gundu Rao's formula in place of or in addition to Deerr's. But it is generally recognized that both formulae suffer from the disadvantage that the results are affected not only by the quantity, but by the varying composition of non-sugars. The exhaustibility of molasses, which is being extensively studied, should be considered in this connection. It will be advisable not to make any change in Deerr's formula, previously adopted, until a decided improvement based on further studies can be made. The Chairman so recommends."

The observation of the Chairman that both the formulae are influenced by the quantity of non-sugar is obviously incorrect. It has been clearly shown that Gundu Rao's formula is not influenced by the quantity of non-sugars and particularly seeks to correct this drawback in Deerr's formula.

At the meeting of the Special Committee during the 8th Congress of the I.S.S.C.T. it was unanimously decided to retain Deerr's Reduced Boiling House Recovery E.S.G. until such time as a formula which took into consideration the composition of the non-sugars was developed. It was further recommended that the Special Committee should continue the work of Dr. Douwes Dekker in establishing the relations between molasses purity and non-sugars composition.

From the very beginning, the various formulae that have been presented have been evolved with a view to allowing for the influence of non-sugars on the recoverable sugar. It has also been appreciated that both the quantity as well as the nature of non-sugars influence the results. Attempts have been made to determine the influence of various non-sugars on the exhaustibility of molasses. While there is general agreement that Glucose/Ash ratio considerably influences the exhaustibility, there have been several instances where other non-sugars have played a more determinative role on the exhaustibility. Geerligs (9), McClery (10), Behne (11), and Douwes Dekker (12), laid greatest stress on the influence of reducing sugars and ash on exhaustibility. Salts of organic acid, particularly aconitic acid, are reported to influence the rate of crystallisation of sucrose and also to have considerable melassigenic effect. Nitrogenous non-sugars, particularly the amino acids and amides are said to adversely affect the exhaustibility of molasses. Farnell (13) pointed to the adverse effect of the hydrolysis products of hemicelluloses on sugar crystallisation and formation of molasses. He found that even 0.5 percent pectin has a significant melassigenic effect. In Hawaii the ratio of reducing sugars to ash and more recently the reducing substances to specific conductance ratio has been used on a quantitative basis in determining exhaustibility, but many anomalous cases have been reported indicating that there are other factors. L. S. Birkett (14) studying the exhaustion of cane molasses in Trinidad found that the Reducing Sugar/Ash ratio is not in itself the major factor influencing the final purity. The concurrent variations in the organic non-sucrose are considered to be of greater importance. Douwes Dekker (15) observes that "we are able to calculate with fair accuracy the purity to which final molasses should be exhausted provided we know the composition of non-sucrose, i.e., reducing sugars percent non-sucrose, sulphated ash percent non-sucrose." He thus lays greatest stress on reducing sugars and ash and based on data collected by him in Java and Natal gave certain factors to modify the Winter-Carp formula for judging boiling house results. It has been observed by others that these factors are arbitrary and cannot be accepted by all countries without further work. Gundu Rao and Kulkarni (16) found exhaustibility of molasses to be greatly influenced by other non-sugars present in drought affected cane. Even when Reducing Sugars/Ash ratio was very favourable and the control technique and equipment were much superior from the point of view of obtaining better exhaustibility, it was very difficult to exhaust molasses due to the influence of other organic non-sugars. The relevant data are given in Tables I and II. The data presented in Table I clearly show that the exhaustibility during the season 1953-54 is much poorer as compared to the season 1952-53, though the composition in respect of Glucose and Ash during the season 1953-54 is definitely more favourable. The reducing sugar content is much higher 24.94 to 23.41 as against 22.87 to 21.3 percent in 1952-53. Similarly the Ash percent is much lower from 9.58 percent to 8.9 percent as compared to 12.24 to 11.45 percent in 1952-53. The Glucose/Ash ratio is also much higher in 1953-54 being from 2.8 to 2.44 as against 1.94 to 1.74 in 1952-53. Inspite of these favourable conditions, the sucrose purity of molasses was from 34.9 to 39.00 in 1953-54 as against 30.00 to 32.2 in 1952-53. During the season 1954-55, the experience was very similar as could be seen from the weekly detailed analytical data compiled in Table II. The sucrose purity of final molasses was consistently very high, from 38 to 43, though the Glucose percent was as high as 21.24 percent. The ash percent was quite low from being 9.4 percent to 11.46 percent and the Glucose/Ash ratio varied from 1.86 to 2.94. These experiences, together with those of others like Birkett, confirmed the view that apart from Glucose/Ash ratio, there are other factors of an organic nature, which play a more determinative role in the exhaustibility and sometimes even counteract to a considerable extent favourable Glucose/Ash ratios.

Our knowledge of the non-sugar components of cane juice and their variations is not sufficiently advanced. No doubt work in this connection is being accelerated and is making good progress on account of improved analytical technique such as chromatography. Even so, it will be a matter of considerable time before we are in a position to know in greater detail the non-sugar composition of the juice and the influence of these non-sugars on sugar crystallisation both independently as well as in the presence of each other. To be able to evolve an overall factor which takes into account the effect of all or the more important components from the point of view of exhaustibility, it will no doubt take considerable time.

Even assuming that the influence of the quality of non-sugars on the exhaustibility of molasses will be found for incorporation in any formula, it has to be admitted that the influence of the quantity of non-sugars has still to be correctly accounted for. It does not appear to be reasonable to ignore the quantity aspect with the feeling that the quality aspect has yet to be found out.

TABLE I

	Season 1952-53			Season 1953-54		
Analysis	Jan. first week	Jan. second week	Jan. third week	Jan. first week	Jan. second week	Jan. third week
Brix	92.90	94.00	93.70	95.90	95.60	94.60
Pol	32.30	31.20	29.20	31.70	28.10	29.10
Purity	34.74	33.29	31.16	33.05	29.39	30.76
Sucrose	31.00	32.20	30.00	37.80	34.90	39.00
Gr. Purity	33.37	34.25	32.02	39.45	36.51	40.36
Reducing Sugar %	22.87	22.25	21.30	24.94	23.41	23.75
Fructose %	7.90	8.81	—	10.03	10.75	9.47
Ash %	11.76	11.45	12.24	8.90	9.58	9.22
Gl./Ash Ratio	1.94	1.94	1.74	2.80	2.44	2.57

TABLE II

FINAL MOLASSES WEEKLY COMPOSITE SAMPLES—SEASON 1954-55

Date		Analysis		Sucrose		Glucose	Ash	Glucose/Ash	Nitrogen	Levulose	Mixed Juice
	Brix	Pol	Purity	%	Purity	%	%	%	%	%	Purity
3-12-54 to 19-12-54	94.80	29.20	30.80	35.20	38.18	23.95	10.45	2.29	0.393	7.46	83.72
20-12-54 to 26-12-54	92.50	30.70	33.19	37.80	40.86	22.85	9.63	2.37	0.252	7.93	83.77
27-12-54 to 2-1-55	91.90	32.80	35.69	38.00	41.34	22.82	9.42	2.42	0.111	9.10	82.60
3-1-55 to 10-1-55	91.40	27.70	30.31	39.40	43.11	23.60	9.27	2.54	0.104	10.45	82.93
11-1-55 to 17-1-55	93.50	32.70	34.97	40.30	43.10	22.09	9.80	2.25	0.059	9.16	84.43
18-1-55 to 23-1-55	95.50	33.20	34.76	40.00	41.88	22.81	10.48	2.18	0.371	10.18	84.85
24-1-55 to 30 1-55	92.80	29.20	31.46	39.80	42.89	22.16	10.19	2.17	0.312	10.57	84.26
31-1-55 to 6-2-55	94.10	30.25	32.15	39.30	41.76	21.91	10.48	2.09	0.366	8.77	84.90
7-2-55 to 14-2-55	93.80	28.70	30.60	38.80	41.36	20.76	11.16	1.86	0.354	8.52	85.49
15-2-55 to 20-2-55	95.10	31.70	33.33	39.10	41.11	21.35	11.46	1.86	0.305		85.66
21-2-55 to 27-2-55	94.10	32.20	34.22	40.80	43.36	20.25	10.68	1.89	0.341		84.77
14-3-55 to 20-3-55	93.50	33.80	36.15	40.40	43.20						
21-3-55 to 23-3-55	91.60	34.30	37.44	38.70	42.25						
24-3-55 to 27-3-55	93.60	33.70	36.00	38.20	40.81						
28-3-55 to 3-4-55	94.60	32.25	34.09	38 30	40.49	22.09	10.34	2.94			82.76
3-4-55 to 10-4-55	93.70	32.20	34.36	37.40	39.91	21.41	10.66	2.01	0.385		81.99
11-4-55 to 17-4-55	92.70	31.75	34.25	38.30	41.32	22.52	10.29	2.19	0.381		82.29
19-4-55 to 30-4-55	93.60	33.20	35.47	38.40	41.02	21.34	10.64	2.00	0.391		
1-5-55 to 13-5-55	94.00	31.70	33.72	37.50	39.89	24.03	10.04	2.39	0.332		79.57

QUANTITATIVE BASIS AND THE VIRTUAL PURITY CONCEPT

Appreciating the influence of the quantity of non-sugars or the juice purity on the recovery and in order to eliminate this influence while comparing the recorded recoveries, Deerr developed the formula for reducing them to a standard juice purity, which was selected as 85.0. For arriving at this formula he developed the concept of Virtual Purity. Virtual Purity is that purity of molasses, which results when to the total molasses produced by the factory, a quantity of sugar corresponding to the (press cake losses+undetermined losses) is added. Noel Deerr assumed that so long as the Boiling House Efficiency of a factory remained the same, the virtual purity remained unaltered at all juice purities. Based on this concept in his procedure he calculated the virtual purity of molasses, at the actual juice purity and using the same virtual purity at 85 juice purity obtained the Reduced Boiling House Recovery. S. N. Gundu Rao has shown how this concept of constancy of virtual purity is incorrect in so far as under the same efficiency conditions, the almost similar (press cake and undetermined) losses, when absorbed into the quantities of molasses, which vary with juice purity, result in widely differing virtual purities. It is somewhat the same type of influence that Douwes Dekker refers to when he observes that " the relative effect of losses in filter cake and undetermined on the total loss is greater at high purities". Even when efficiency conditions are the same, the virtual purities will be less than the virtual purity at 85, with lower juice purities, and the virtual purities will be much higher at higher juice purities than 85. If, therefore, the case of two factories handling juice purities of 80.0 and 90.0 are considered, and the virtual purities obtained at the respective purities are utilised for calculating R.B.H.R. at 85 in the formula, naturally the efficiency figures will be much lower in the case of high purity juices and much higher in the case of low purity juices. Thus the concept and procedure result in widely different figures of Reduced Boiling House Recovery even under the same efficiency conditions.

It has been shown by Gundu Rao and confirmed by Kripashankar that the R.B.H.R. of Deerr is thus influenced to a much greater degree by the mixed juice purity, than the other previous performance figures. The Reduced Boiling House Recovery concept of Deerr aims at achieving an actual recovery scale corrected for juice purity, which thus would become an International scale for comparison without any reference to a basic figure. But in deriving the formula, the faulty concept of constancy of virtual purity has rendered the formula incorrect. If the Reduced Boiling House Recovery could be calculated, without the concept of virtual purity, as has been done by Gundu Rao, the resulting formula would provide figures, which can directly be used for International comparisons, without the necessity of a basic or ideal recovery. In case an efficiency figure is sought, in view of the inevitable variation in the basic figure with juice purity, which has been the objection for the basic figures of all the previous formulae, it is but a logically correct step, to pin down the basic figure to a standard juice purity such as 85, and to reduce the actual recorded values to the standard juice purity without the efficiency being influenced by the calculation procedure. Considered from these points of view, it is obvious that the B. H. P. (Rao) is the most logical and correct figure of efficiency, and the R.B.H.R. (Rao) is the most correct figure for International comparisons, so far as the quantity of non-sugars are concerned. Further correctness on the quantitative basis, which is immediately possible, should be realised and when it becomes possible to assign reasonable factors of influence on exhaustibilily for the non-sugar composition, suitable correction factors could be incorporated in any formula, which is primarily correct on the quantitative basis. Further, it is very necessary that a concept should be correct.

CONCLUSION

A study of the recent developments in boiling house efficiency formulae and the views expressed by various workers show that the decision of the Special Committee of the I.S.S.C.T. on the uniformity in reporting factory data needs further thought and reconsideration. It is obviously incorrect to ignore the influence of quantity for present difficulties in assessing the quality factor. In all circumstances, the mistakes on the quantitative basis will have to be first corrected, and suitable factors incorporated for the quality factor, when it comes to be decided. When a concept is wrong and the attention of the Committee has been drawn to it, it is necessary that the same be corrected. We are at least sure of the quantity factor, on which we can be correct.

It has to be further appreciated that what is aimed at is a figure for International comparison and not for any individual country. A formula which is correct in concept and applicable to all the countries in the world is desired. Using a particular factor or formula, a country which is handling juices in a narrow range of purities and soil conditions may not find much deviation. But when it comes to a comparison of data from different countries involving a very wide range of purities and soil conditions, it would be necessary to have formulae, which are correct mathematically and in concept. Further, any factors used for the influence of non-sugar composition should be applicable to all countries.

REFERENCES

1. Copp, E.M. 1943. I.S.S.C.T., *System of Cane Sugar Factory Control, I.S.J.* 207.
2. Gundu Rao, S.N. 1944. New Formulae for Reduced Boiling House Recovery E.S.G. and Boiling House Performance, *Ind. Sugar.* 13.
3. Deerr, N. 1944. Formulae for Reduced Boiling House Recovery. *Ind. Sugar.* 100.
4. Deerr, N. and Smart, S.G. 1946. Reduced Boiling House Recoveries, *I.S.J.* 46.
5. Gundu Rao, S.N. 1944. Virtual Purity of Molasses, Reduced Boiling House Recovery and Boiling House Efficiency Number, *Ind. Sugar.* 184.
   1946. Reduced Boiling House Control, *Proc. 14th Annual Convention (Part II) Sugar Technologists' Association, India.*
6. Kripashankar. 1945. Boiling House Control Formulae, *Sugar*, May 37.
7. Gundu Rao, S.N. 1950. Boiling House Efficiency Indicators. *Proc. VII Congress of I.S.S.C.T.* 665.
8. Zerban, F.W. *Report of Special Committee on Uniformity in reporting factory data. Proc. VIII Congress of I.S.S.C.T.* 684, 700-702.

9. Prinsen Geerligs, H.C., " *Cane Sugar and its Manufacture* ".
10. McClery, M.C. 1936. *I.S.J.* July 277.
11. Behne, E.R. *Queensland Proceedings*, VI, Ann. Conf. 109.
12. Douwes Dekker, K. 1950. *I.S.J.* May, 122.
13. Farnell. " *Principles of Sugar Technology* " by P. Honig. 188.
14. Birkett, L.S. 1944. Studies in the Exhaustion of Cane Molasses. *Sugar* Nov. 38-39.
15. Douwes Dekker, K. Judging Boiling House Work. *Proc. VIII Congress of I.S.S.C.T.* 677.
16. Gundu Rao and Kulkarni. 1954. Exhaustibility of molasses from drought affected cane. *Proc. 23rd Ann. Con. S.T.A. (India) Part II*-281.

Mr. S. N. Gundu Rao presented the following paper.

Paper

FURTHER STUDIES ON BOILING HOUSE EFFICIENCY INDICATORS

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It is now recognised that B.H.E.N., B.H.P. and Winter Rendement are similar in form and derivation and have the same drawback of dependence on juice purity. The Java Experiment Station (1) did not favour the Winter Rendement as a comparison figure due to this drawback and evolved the " Old Comparison figure of the Java Experiment Station ", the so-called " Technical Result ". This comparison figure is the first to recognise the importance of referring the molasses loss to a standard juice purity of 85, and is the forerunner of the Reduced Boiling House Recovery. Noel Deerr used the principle involved in the " Technical Result " of Java Experiment Station in arriving at a recovery figure at 85 juice purity. But in this procedure of arriving at the R.B.H.R., a wrong concept of virtual purity was involved and hence the resulting figure favoured factories having low purity juices and handicapped factories having high purity juices. This has been overcome by the procedure evolved by Gundu Rao (2) and we have now a correct method of finding the actual recovery at 85 juice purity.

The old comparison figure of the Java Experiment Station was discarded in favour of the New Comparison Figure of the Java Experiment Station. In this figure, instead of the ratio of actual recovery to ideal recovery as in Winter Rendement, the difference between the ideal recovery and the actual recovery was used to arrive at the comparison figure. This was a decided improvement over the Winter Rendement as the influence of mixed juice purity in a range of 20 units (74 to 94) was reduced from 4.45 in the case of B.H.P. to 2.87 in the case of New Comparison Figure as shown by Kripashankar (3). Even so, the influence of juice purity thus remained.

This drawback in the New Comparison Figure could be overcome, if the actual and the basic recoveries are referred to a standard fixed juice purity 85. The improved comparison figure, which is free from the drawbacks of the Winter Rendement and the new comparison figure of Java would be :

100—(Basic Recovery at 85—Actual Recovery at 85)

This new figure thus combines the essential principles sought to be applied in the Old and New Comparison Figures of the Java Experiment Station and the Reduced Boiling House Recovery concept of Noel Deerr. In this formula, the Basic Recovery at 85 would be calculated by the usual formula, taking J as 85 and M as 28.57. The Actual Recovery at 85 would be the R.B.H.R. as obtained by Gundu Rao's formula. So long as the quantity factor only is considered, the R.B.H.R. (Gundu Rao) can be directly used for international comparison. However, if any efficiency figure is required, the modified Java procedure would be better.

INTRODUCING THE QUALITY FACTOR

The next step would be to make this efficiency formula correct in respect of the quality of non-sugars. Considering the difficulties involved in assessing the influence of non-sugar components, individually and in the presence of each other, on the recovery and the wide variation of these non-sugars, with soil and climate, it would not be in the immediate future that quality factors applicable to different countries are found. Even assuming that such factors are found out, the best way of allowing for the variation in the quality of non-sugars and their influence on exhaustibility (or recovery) is to arrive at the target purity of final molasses corresponding to the non-sugar composition. *It is obvious that the envisaged quality correction should be incorporated into a formula which is quantitatively correct.* As we have established the Modified Java Comparison Figures quantitatively correct, we proceed to correct this figure for quality as follows :

When the target purity of final molasses is fixed for the particular non-sugar composition, the basic recovery 85, in the new formula, which can now be called the target recovery, could be calculated by the usual procedure by using the target purity of molasses in place of the fixed figure of 28.57. The new efficiency figure which is thus corrected for quality and which we propose to call " International Comparison Figure " would be :

100—(Target Recovery at 85 Purity—Actual Recovery at 85 Purity)

This can be further reduced as follows :

International Comparison Figure
=100—(Target Recovery 85—Reduced Recovery 85)
=100—Target Recovery 85+Reduced Recovery 85
But 100—Target Recovery 85=Target Loss.
Therefore, International Comparison Figure
=Reduced Recovery 85+Target Loss.

The target loss at various target purities of molasses is given in Table I.

TABLE I

SHOWING (i) TARGET RECOVERY, (ii) TARGET LOSS and(iii) QUALITY CORRECTION FOR R.B.H.R.

Target Purity of Molasses	Basic Recovery or Ideal	Target Recovery	Target Loss	Quality Correction for R.B.H.R.
28.57	92.94	92.94	7.06	0.00
30	92.94	92.44	7.56	0.50
32	92.94	91.70	8.30	1.24
34	92.94	90.91	9.09	2.03
36	92.94	90.07	9.93	2.87
38	92.94	89.18	10.82	3.76
40	92.94	88.24	11.76	4.70
42	92.94	87.22	12.78	5.72
44	92.94	86.13	13.87	6.81

This new efficiency figure is superior to the figure of B.H.P. previously suggested by Gundu Rao. This is because, when varying target purities are used in calculating the Basic Boiling House Recovery at 85 juice purity, it will influence the final figure in the same manner as varying juice purities influenced the Winter Rendement or B.H.P. In this connection, it is pointed out that, when target purities begin to be considered in B.H.P. or B.H.E.N.or Winter Rendement, apart from the accepted influence of varying juice purity, the influence of varying target purity further complicates the accuracy of the result. The influence of juice purity is eliminated in the new figure by taking 85 standard purity and the influence of variation in target purity, which, however, is smaller, is further reduced by taking the difference in recoveries and not the ratios. From all points of view, therefore, the best efficiency figure is the "International Comparison Figure" now suggested. It is further pointed out that till such time as it becomes possible to fix target purities on the basis of non-sugar composition, the constant figure of 28.57 will continue to be the molasses purity figure in calculating the Basic Recovery in the "International Comparison Figure".

CORRECTING R.B.H.R. FOR QUALITY

It has already been mentioned that the Reduced Boiling House Recovery Figure on a quantitative basis can be directly used for efficiency comparisons, but with the quality factor being introduced, it becomes necessary to correct the figure for quality differences, if direct comparison is to be made of the recovery figures. This can be done by adding to the R.B.H.R. obtained a figure which corresponds to the difference between the target recoveries. In order to be able to have such a correction standardised, the procedure suggested is to add to the R.B.H.R. figure, the difference between the Basic Ideal Recovery, at 28.57 and the target purity under consideration. In Table I are also given these quality factors to be applied to the R.B.H.R. to make it a direct comparison figure of recovery in which both the quantity and quality of non-sugars have been considered.

REFERENCES

1. Zerban, F.W. *Report of Special Committee on Uniformity in reporting factory data.*
2. Gundu Rao, S.N. Boiling House Efficiency Indicators—*Proc. 7th Congress of I.S.S.C.T.* 665.
3. Kripashankar. 1945. Boiling House Control Formulae-*Sugar*, May. 37.

DISCUSSION

Dr. Douwes Dekker drew attention to the last paragraph of Dr. Honig's paper. He said that he was amazed that Dr. Honig should recommend a factory control based on apparent analysis. The System of Factory Control aimed at control on a sucrose basis and the proposal to revert to pol for control purposes was revolutionary. Why, he asked further, should determination of Boiling House Efficiency be based on the purity of the syrup. Whilst this procedure would eliminate the problem of how to deal with clarification, it would have the effect of divorcing the Boiling House Efficiency from the clarification process. He added that, in many factories, the syrup was not truly representative of the raw material entering the sugar boiling process.

Mr. Gundu Rao agreed with Dr. Douwes Dekker. He felt that pol did not provide a reliable basis for the evaluation of boiling house results. It was most desirable that sucrose be used, but there was great need for an easier method of determining sucrose. He was emphatic that the measurement of Boiling House Efficiency should start with the mixed juice. If the calculations were based on clarified juice or syrup, then it would be necessary to take account of the method of clarification although this would not be involved directly in the efficiency results. He believed that the clarification process should be incorporated in the stages over which Boiling House Efficiency was measured.

Dr. Douwes Dekker commented that, perhaps, Dr. Honig proposed that clarification should not be included and that Boiling House Efficiency should be applied only to the results of actual sugar boiling.

Mr. Gundu Rao considered that the formula proposed by Dr. Honig was similar to the Winter formula with a target purity of final molasses. As such, it had the disadvantage of being a ratio, which was unsatisfactory for varying purities of original material. The adoption of various target purities for final molasses would complicate the issue further.

Mr. Kelly expressed the opinion that, for satisfactory control, it was necessary to concentrate on sucrose figures. Variations in the quantity and nature of the reducing sugars made pol figures unreliable. He was concerned about the target purity of molasses which he thought must be based on sucrose. Dr. Honig's formula was statistically satisfactory but could not be reconciled with the theoretical approach. He cited the formula devised in Taiwan wherein the target purity of molasses was expressed as a constant plus a multiple of the reducing sugars plus a multiple of the ash. This could be reconciled with theory which indicated that the target purity should vary as a function of the dextrose in the reducing sugars and the conductivity ash measured as potassium chloride. He hoped that any formula adopted for target purity of molasses would be in a form which would satisfy both theory and practice.

Dr. Douwes Dekker emphasised that boiling house results represented the comparison of certain actual losses with theoretical or standard allowances. The losses were undetermined loss, loss in filter cake and molasses loss. Would it not be better to evaluate and judge each of these separately?

In the absence of the author Dr. Doss presented the following two papers.

Paper

A NOTE ON CORRELATION OF TRUE SOLIDS IN MOLASSES WITH REFRACTOMETRIC BRIX AND CONDUCTOMETRIC ASH

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INTRODUCTION

The total solid determination in sugar products has been a problem for a long time. The usual methods of dry substance determination are time-consuming and require special equipment and often the procedure is elaborate. Attempts to correlate absolute solids with refractometric or densimetric solids have been made by a number of workers. For converting brix readings into percentage of dry substance numerous methods have been proposed, the principle behind them being that the nature and proportion of the various non-sugars are sufficiently constant to get a general statistical correlation.

Davies (1) calculated correlation factors between °Brix (hydrometer), °Brix (refractometer) and dry substance in final molasses purely by statistical considerations.

Sijlmans (2) showed that the dry substance in Java molasses can be calculated by multiplying the sulphated ash (uncorrected) by a factor and subtracting the product from the brix of the molasses (obtained by diluting 1 : 9 by weight and multiplying the brix by 10). The average figures for the factor are 0.72, 0.74 and 0.86 for defecation, carbonatation and sulphitation molasses respectively.

Haddon (3) gave an average factor of 0.875 for Natal molasses by which the carbonated ash must be multiplied to calculate the correction to the gravimetric brix (100 g. molasses diluted to 500 ml.)

For Philippine molasses, King (4) found that the logarithm of the carbonated ash is a straight line function of the difference between the dry substance and the brix determined by diluting the molasses to the approximate density of mill juice. He also observed that the brix of the molasses was an approximately rectilinear function of the dry substance.

Fort (5) obtained a similar relation for Louisiana raw juices.

An examination of physical properties of a number of Queensland molasses by Praeger and Heron (6) yielded no practical relationship between densimetric brix, refractometric brix and dry substance. The average factor obtained by Sijlmans was found to be inapplicable for these molasses. However, a general correlation was seen to exist between refractometric brix and dry substance represented by $R=0.934\,D+7.2$, giving an error in dry substance amounting to the extent of 1%.

All such equations give only approximate results and the constants varying with location, variety of cane and other factors. It may, however, be possible to establish a more precise regression equation holding for the molasses from a single mill or group of them under similar conditions.

With the development of a new vacuum oven (7) Gardiner and Farmiloe (8) determined solids in cane molasses and obtained a correlation between the refractometric solids and total solids given by the equation.

$$\text{True solids}=\frac{\text{Refractometer solids (Sucrose tables)}}{1-0.00025\ \text{invert sugar}+0.0043\ \text{sulphated ash}} \qquad [1]$$

In the present work an attempt is made to examine the limits of error that may arise in determining the total solids from refractometric and conductance measurements.

CONDUCTOMETRIC ASH BY C—RATIO

Extensive data are available from the work of Sattler (9) on American molasses. These data were used to determine the mean C—ratio. The difference between conductometric ash (making use of the C—ratio) and chemical ash was worked out. The maximum error came up to 0.78%. The percent cases lying within the various limits of error are given in Table I. An examination of the equation [1] reveals that an error of 1% in ash would result in an error of 0.4% in true solids. Thus the maximum error if one uses C—ratio conductometric ash instead of sulphated ash in equation [1] comes out to be about 0.3%. Since the C—ratio method gives 92% cases within 0.5% of the correct ash content, the error in the true solids would amount to not more than 0.2% in 92% cases. Thus it is seen that with a single conductance measurement and substituting the conductometric ash in place of chemical ash in equation [1], the true solids can be conveniently calculated fairly accurately.

CONDUCTOMETRIC ASH BY TWO CONDUCTANCE METHOD

Summary statements of data from the work of Doss and Gupta for Indian molasses and of Sattler on American molasses are given in Tables II and III.

These results show that for American molasses, where the error in ash content by the two conductance method does not amount to more than 0.3% in most of the cases, the error in true solids will not exceed 0.1%. Hence two conductance measurements will be quite satisfactory, for American molasses.

It is no advantage to go on to three or four conductance measurements for this purpose.

For Indian molasses, which have a high ash content, the two conductance method would be all right. From Table III, it is found that the error in ash is not more than 0.8% for 86% of the cases. Hence the two conductance method would give an error of 0.3% in true solids. For smaller regions or for a single factory, the correlation would be much better.

ACKNOWLEDGEMENT

The author wishes to thank Professor K.S.G. Doss, D.Sc., F.R.I.C., F. Inst. P., F.A.Sc., Director, National Sugar Institute, Kanpur, for suggesting this problem and for his keen interest in the work.

TABLE I

DIFFERENCES BETWEEN PREDICTED AND DETERMINED VALUES OF CHEMICAL ASH (AMERICAN MOLASSES)

Checking within limits	Percentage of cases C—ratio method
0.125	28.9
0.250	60.4
0.375	77.9
0.500	92.6
0.625	98.0
0.750	99.3
0.875	100.0

TABLE II

DIFFERENCE BETWEEN PREDICTED AND DETERMINED VALUES OF CHEMICAL ASH (AMERICAN MOLASSES) (10)

Checking within limits	Percentage of cases Two conductance method
0.05	17.7
0.10	36.7
0.15	55.8
0.20	72.1
0.25	85.7
0.30	95.3
0.35	100.0

TABLE III

DIFFERENCES BETWEEN PREDICTED AND DETERMINED VALUES OF CHEMICAL ASH (INDIAN MOLASSES) (10)

Checking within limits	Percentage of cases Two conductance method
0.20	30.6
0.40	52.7
0.60	66.7
0.80	86.1
Above 0.80	100.0

REFERENCES

1. Davies. 1932. *Trop. Agri.*, 9, 218.
2. Sijlmans, C. 1932. Arch. Suikerind., 40, II, 993, cited from *Chemical Abstract*, 27. 1778 (1933).
3. Haddon. 1932. *Rev. Agr. Maurice No.* 66, 229.
4. King. 1931. *Ind. Eng. Chem., Anal. Ed.*, 3, 230.
5. Fort, C. A. and McKaig, N. 1936. *Ind. Eng. Chem., Anal. Ed.*, 8, 333.
6. Praeger, A.H. and Heron, J.L. 1940. *Bur. Sugar Expt. Station, Queensland, Tech. Commun. No.* 9, 149-70 (1939) Cf. I.S.J., 252.
7. Gardiner, S.D. 1953. Analyst. 78, 709—711.
8. Gardiner, S.D. and Farmiloe, F.J. 1954. Analyst. 79, 447-453.
9. Cf. Reference 10.
10. Doss, K.S.G. and Gupta, K.K. *Proc. S.T.A. India* 1950. *Part* II, 212—218.

DISCUSSION

The Chairman (Mr. Clayton) in opening the discussion stated that while he was satisfied with apparent figures for routine work, the analysis of final molasses should be determined by true methods. Accurate methods of determination of dry substance could be very tedious, and any method of a less time consuming nature giving satisfactory results would be of some importance. He requested Dr. Doss to give his views on refractorometric brix.

In reply Dr. Doss stated that he was more satisfied with hydrometer brix determinations, and to correlate true solids with conductivity.

Dr. Douwes Dekker asked the type of refractometer with which the work was carried out. Dr. Doss in reply stated that the Abbe Refractometer was used by him.

Mr. Jenkins endorsed the Chairman's remarks on the interest shown in less tedious methods of determining true solids. With the refractometer on undiluted final molasses, there will be errors due to any crystal present and if as recommended by I.C.U.M.S.A., the molasses is slightly diluted, a further error occurs. He recommended that delegates follow up the work presented in the paper.

The Chairman made mention of the improvement in the manufacture of refractometers giving more scope for determinations of undiluted materials.

Dr. Kerr referred to the errors due to the presence of crystals of calcium sulphate, silica and dirt in final molasses especially with the high total solids of Queensland molasses.

Dr. Douwes Dekker mentioned his preliminary experiences with the Karl Fischer method of determination of dry substance, the results of which were sufficiently promising to warrant further work on this method.

In reply to Dr. Kerr, Mr. Anderson mentioned that this method was found to be less satisfactory than the vacuum oven method, only the latter giving consistent results. Vacuum drying had therefore been adopted in preference to the Karl Fischermethod.

Mr. **Gundu Rao** in reply pointed out that this was certainly desirable, and was already common practice. Nevertheless one liked to composite the separate performances into an overall result. If this was to be achieved satisfactorily it would be necessary for the Society to adopt better formulae than those which were now officially accepted.

Paper

USE OF ALCOHOLIC SOLUTIONS IN POTENTIOMETRIC ESTIMATION OF CHLORIDE AND ITS APPLICATION TO CANE JUICES

By

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INTRODUCTION

Potentiometric determination of chloride has long been established by a number of workers. R. Behrend (1) was the first to apply the silver electrode to the analytical estimation of chloride. According to Liebich (2) the potential very rapidly assumed a constant value in the titration of chloride with silver nitrate. Using a calomel half cell, 10% ammonium nitrate bridge and a silver electrode, Lange and Schwartz (3) showed that the sensitivity of the method can be raised to 0.007% under favourable conditions.

In the titration of 0.1 N solutions, I.M. Kolthoff and L. Van Berk (4) obtained an accuracy of 0.02% without taking any special precautions. They used as a reference electrode a mercury-mercurous sulphate electrode filled with 0.25 molar potassium sulphate. A saturated potassium sulphate solutions was used in the salt bridge. The equivalence point could be found within the 0.01%. E. Zintl and K. Betz (5) discussed the titration of very dilute halide solutions. Addition of sulphuric acid to dilute the solution of chloride has a favourable effect. 0.001 N chloride in about 0.2 to 0.4 N sulphuric acid could be determined with an accuracy of at least 1%. Addition of alcohol did not improve the accuracy.

Rubert J. Best (6) used a silver wire coated with silver chloride in a solution containing chloride ions in series with quinhydrone reference electrode connection being made by a 3% agar saturated potassium nitrate bridge for determining chloride in soils.

W. Clark (7) and Rudolf Jivkovsky (8) applied bimetallic electrodes in chloride estimation.

F. Sierra and O. Carpena (9) used calomel and platinum electrodes for the determination of halides (Chloride) in neutral and sulphuric acid medium potentiometrically. They claimed that the limit of sensitivity is much greater in dilute sulphuric acid than in neutral solutions.

Katsuki Takagi and Yukimi Shimiza (IO) titrated chloride with silver nitrate using Ta--Pt electrodes.

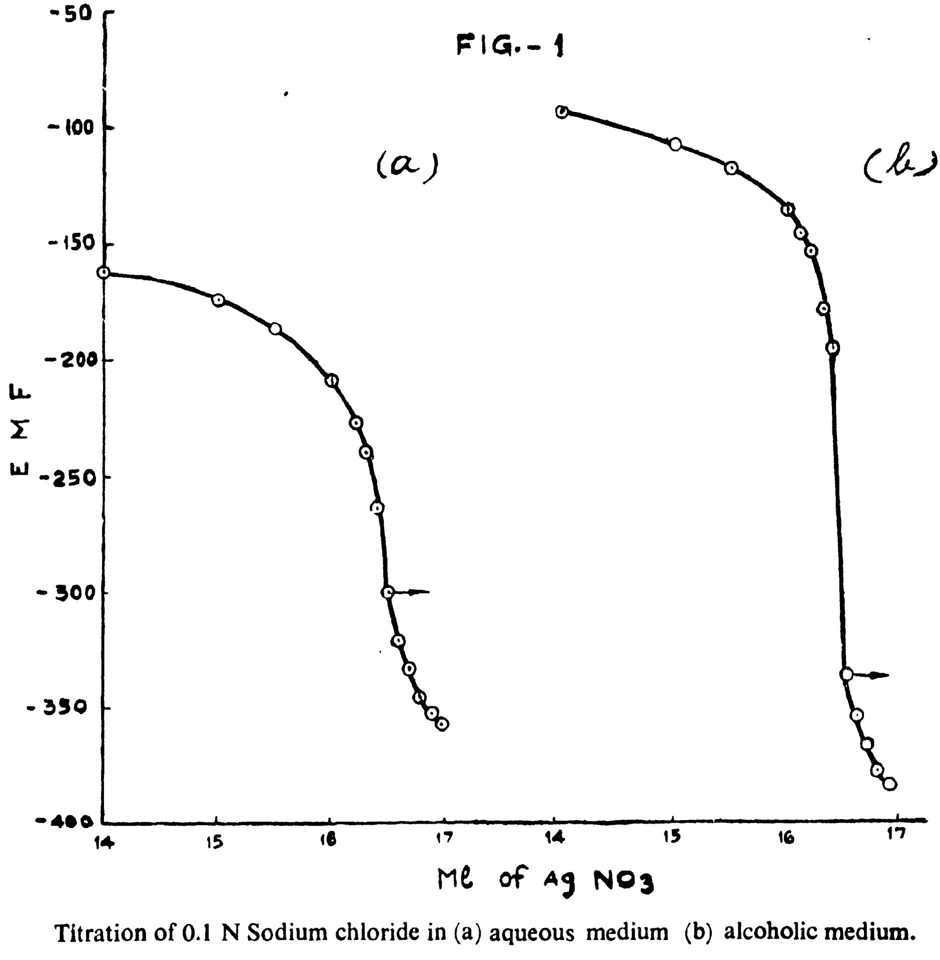
E. Bishop (11) replaced standard cell and salt bridge arrangement by indicator electrodes of antimony, glass and platinum and performed argentometric titration in aqueous and amphiprotic media. In absolute alcohol medium argentometry gave remarkably good results with electrodes of glass, antimony and platinum.

The object of the present work is to investigate the possibility of enhancing the precision of potentiometric titration of chloride, by adding rectified spirit to the mixture being titrated.

EXPERIMENTAL RESULTS AND DISCUSSION

All the chemicals used were of C.P. quality. The rectified spirit was distilled twice over sodium hydroxide and fractionated to remove the aldehydes etc.

Potentiometric titration was done by using Beckmann pH meter for measuring the e.m.f. A saturated calomel electrode was used as the reference electrode, connected with a saturated ammonium nitrate bridge to the titrating mixture. A silver electrode in the form of a spiral was used as the indicator electrode. Silver nitrate was taken in the burette and sodium chloride was taken in the titration vessel. Constant stirring of the solution was done by a magnetic stirrer element.



Titration of 0.1 N Sodium chloride in (a) aqueous medium (b) alcoholic medium.

For a comparative study, 20 ml. of chloride solution was diluted with (a) about 80 ml. of water and (b) about 80 ml. of redistilled ethanol and the titration conducted. Readings were taken at time intervals and equilibrium was considered complete, when the potential was unaltered after a minute. The results are given in Figures 1 (a) and (b).

An examination of the figures shows that the inflection in presence of alcohol is much higher than in a pure aqueous medium. Addition of alcohol is found to be particularly advantageous at low concentrations (of the order of 0.02 N sodium chloride).

It was found however that an appreciable amount of irreproducibility was observed especially at high dilutions. This was traced to the presence of impurities in the rectified spirit. This difficulty could however be completely eliminated by titrating the rectified spirit with silver nitrate to get inflection potential and using the resultant mixture for dilution.

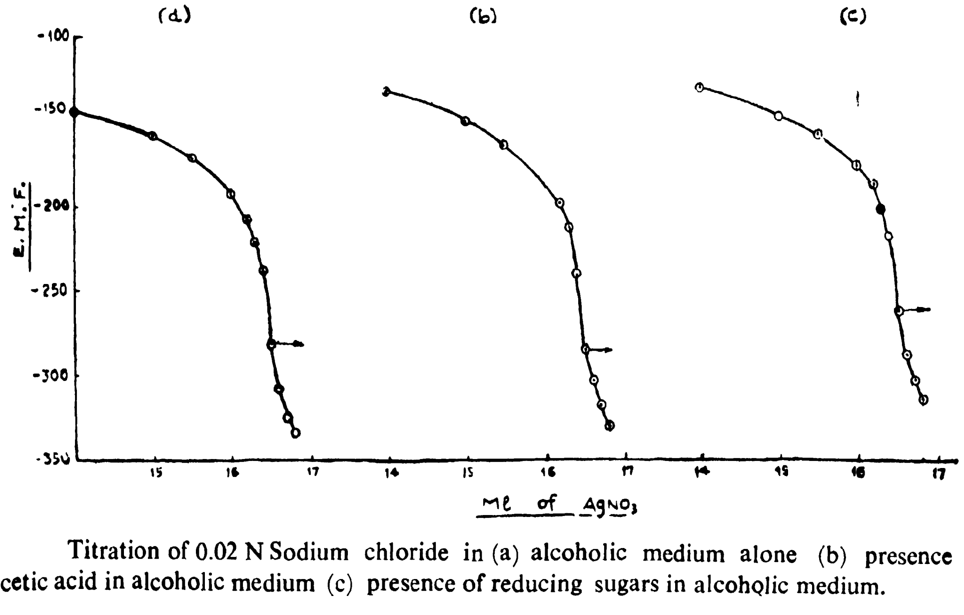
Addition of acetic acid so as to lower the pH from 6.0 to 3.2 had no beneficial effect on the indication of the end point.

It was found that presence of reducing sugars (5% glucose and 5% fructose in 0.02 N sodium chloride) did not appreciably alter the end point. This is of special interest since this method becomes applicable to determination of chloride in sugar-house products.

It was also found that presence of aldehydes even in traces in the rectified spirit upsets the titration.

Typical graphs are given in Figures 2 (a), (b) and (c).

Fig - 2.



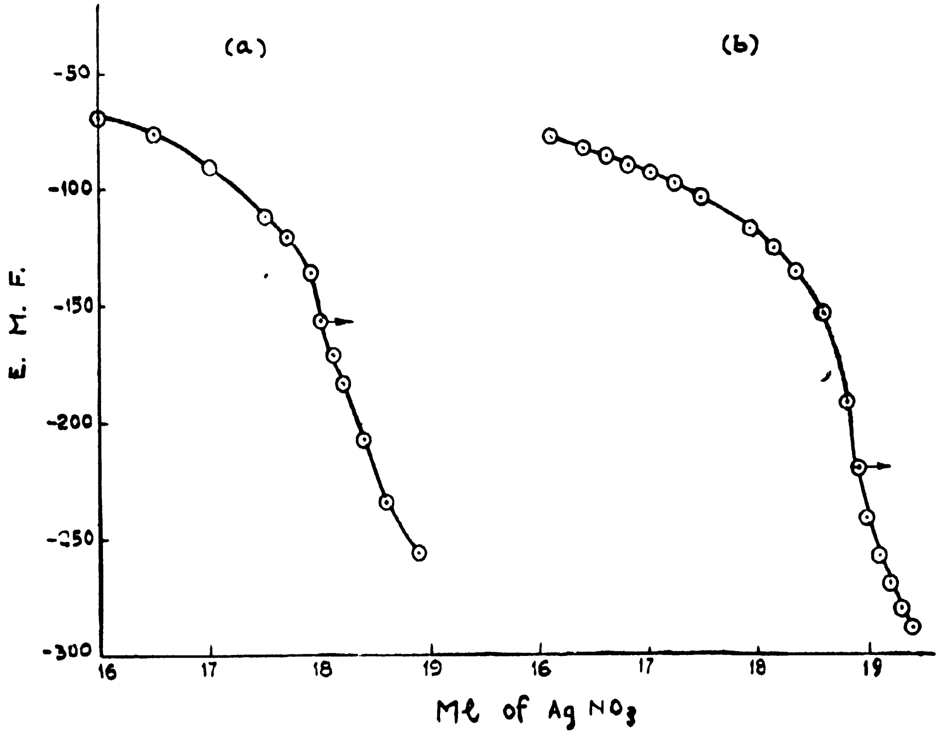
Titration of 0.02 N Sodium chloride in (a) alcoholic medium alone (b) presence of acetic acid in alcoholic medium (c) presence of reducing sugars in alcoholic medium.

EXTENSION TO SUGAR CANE JUICES

This method was extended to determination of chloride in cane juices. 500 ml. of cane juice was taken and concentrated to about 100 ml. in volume. This concentrated juice was made up with distilled rectified spirit to 200 ml. ; 40 ml. of this made-up solution were taken in the titrating vessel and titration conducted with decinormal silver nitrate.

Good indication of the end point was obtained both in mixed and clarified sugar cane juices as can be seen from a few typical curves in Figure 3 (a) and (b). This method is more convenient than the usual chemical method for the chloride estimation, as it does not require preliminary treatment such as oxidation of colouring matter etc., and is quick for routine determinations.

FIG.- 3.



Titration of chloride in (a) mixed cane juice ; (b) clarified cane juice.

ACKNOWLEDGEMENT

The author wishes to thank Professor K.S.G. Doss, D.Sc., F.R.I.C., F. Inst. P., F.A. Sc., Director, National Sugar Institute, Kanpur for his valuable guidance and keen interest in the work.

REFERENCES

1. Behrend, R. 1893. Z. *Physik Chem.* 11 : 466.
2. Liebich, C. Die Potentiometrische Bestimmung von. Chlor, Brom, und Jod Dissertation, Dresden (1920). Schindler, Dissertation, Dresden (1920).

3. Lange, E. and Schwartz, E. 1926. Z. *Elektrochem*, 32 : 240.
4. Kolthoff, I. M. and van Berk, L. 1927. Z. *Analyt. Chem.* 70 : 369.
5. Zintl, E. and Betz, K. 1928. Z. *Analyt. Chem.* 74 : 330.
6. Best,Rupert J. 1929. *J. Agr. Sci.* 19 : 533-40.
7. Clark, W. 1926. *J. Chem. Soc.* (*Lond.*), p. 749.
8. Jivkovsky, Rudolf. 1940. *Chem. Listy*, 34 : 159-62 ; 1941, Chem. Zentr. 375-6.
9. Sierra, F. and O. Carpena. *Anales real soc. espan. fis. Y. quim.* 46 B, 627-38 (1950). cited from *C. A.* 1951, 45, 5068 f. *Pubs. inst. quim.* "*Alonoso Barba*" (Madrid) 4, 291-4, (1950). cited from *C.A.*, 1951, 45, 9422 b.
10. Katsuki Takagi and Yukimi Shimiza, 1950. *J. Electro. Chem. Soc. Japan.* 18 : 150-2.
11. Bishop, E. 1952. *Analyst* 77 : 672-84.

BY-PRODUCTS SECTION

BY-PRODUCTS SECTION

Session—Saturday, 28th January, 11-15 A. M.

Prof. J. M. Saha, *Chairman*

The *Chairman* delivered the following opening address.

Gentlemen,

I have great pleasure in welcoming you to the By-products section of the 9th Congress of the International Society of Sugarcane Technologists. I feel greatly honoured by the privilege given to me of presiding over this session and thank you most sincerely for it. I do hope, with your co-operation, we shall make this seminar interesting enough and bring it to a successful conclusion.

The principal by-products of the sugar industry, as you are all aware, are bagasse, molasses and press cake, and these three together amount to about 40% on the weight of the cane crushed or about four times the weight of sugar produced from a certain quantity of cane. It is, therefore, very necessary that increasing attention should be given to better utilisation of these by-products.

Myriads of uses have been suggested for the various by-products of the sugar industry with which you are no doubt fully acquainted. I am sure every one present here has seen the beautifully illustrated chart prepared by the Sugar Research Foundation of America (Chart exhibited at the seminar). I wish an up-to-date chart was now prepared supplemented with data relating to the industrial production of each and every item of the chart in the different countries of the world.

But the search for new uses goes on. We are a body of research workers and it is our want to explore new possibilities. Our deliberations in this session may therefore largely be confined to discussing new possibilities or newer aspects of previous findings but in so far as the actual utilisation of the by-products is concerned, the problem to my mind is to assess which of the various well known avenues of utilisation are best suited for a particular country and which of them would incidentally yield the best return. It would be an interesting study if it were possible to know how the different countries have used their by-products and what investigations have been carried out by them on this very important subject. In so far as India is concerned, the position is as follows :

Starting with bagasse which is the main by-product of the cane sugar industry, its production and average analysis in India during the last four years are given below.

Particulars	1950-51	1951-52	1952-53	1953-54
Cane crushed (Million Tons)	11.0	15·5	13.2	9.9
Bagasse produced (-do-)	3.7	5.2	4.4	3.2
Bagasse % Cane	33.4	33.3	33.3	32.6
Pol % Bagasse	3.08	3.16	3.04	3.07
Moisture % Bagasse	47.9	48.1	47.8	48.1
Fibre % Bagasse	47.9	47.5	48.4	47.8

Quite a large number of factories in this country are steam driven plants and strict economy in the matter of steam consumption is not usually observed in several factories. Furthermore, steam generating plants of some factories are not properly designed. Therefore the entire bagasse produced and in some cases some extra fuel has to be consumed in these factories. Very few factories are left with surplus bagasse after the crushing season is over and much of this surplus bagasse available in these few factories is utilised as fuel in the boilers during the off-season.

The only industrial use that is being made of bagasse at present is for the production of boards at Meerut and Saharanpur (West Uttar Pradesh). Besides the above, efforts are being made for the production of news-print. A large scale trial was carried out at the Shree Gopal Paper Mills at Jagadhari (E. Punjab) for the production of news-print using 70 percent bagasse and 30 percent wood-pulp. A fairly good quality of news-print was made which was found to run well on news paper printing machines.

In the direction of research, investigations have been made on the utilisation of bagasse for the production of alcohol (1), furfural (2 & 9), activated carbon (3 & 4), insulation and pressed boards, wrapping paper and straw boards (3 & 6), resin to be used as a plasticiser (7), lignin (8 & 11), paper pulp (10) and news-print (12). (The numbers within brackets are the serial numbers of the bibliography appended hereto.)

The best method of utilisation of surplus bagasse in India seems to be in the direction of making news-print as almost 70.0 percent of India's requirement of news-print is being imported at present. A fairly good market also exists for wall-boards and activated carbon. But as far as can be judged from the present state of affairs, very small quantities of bagasse are found to be surplus after meeting the fuel requirements of sugar factories to be available to feed a paper factory. It is also not possible to use coal or other fuel as a substitute for bagasse which may be diverted for paper factories as this involves transport of the coal far off coallieries. As the transport system will not be able to cope with the high demands on it except for one or two factories which are situated close to coal production centres, the prospects of substituting coal for bagasse does not appear to be so bright. Moreover, this will necessitate the not so easy conversion of bagasse furnaces into coal furnaces of sugar factory boilers and will involve considerable expenditure.

MOLASSES

The production of molasses in India during the last four years is given below.

Season	Production of Molasses
1950-51	3,99,000 tons
1951-52	6,06,000 „
1952-53	5,08,000 „
1953-54	3,43,000 „

It is estimated that almost 60 percent of the total molasses produced is used by the power-alcohol, industrial alcohol and potable spirits distilleries. The remaining 40% or so is utilized for preparing smoking-tobacco, and for other miscellaneous uses. It is being burnt as fuel in one factory.

Research. A very large volume of research work has been done on molasses with a view to utilising it in various ways as will be apparent from the attached bibliography. Conditions under which it can best be used as manure and the mechanism of reactions taking place when it is applied to the soil for manurial purposes have been studied as will be apparent from abstracts at serial numbers 13, 17, 18, 21, 24 & 26. With a view to minimising the cost of transport from the factory to fields for use as manure, attempts have been made to solidify it or convert it into a suitable solid manure (25 & 40) and it has also been used for composting (30). Its use has also been advocated for reclaiming alkaline soils (38). Work has been done regarding its use in the preparation of cattle feed (14), extraction of food yeast (23, 41 & 54), recovery of sucrose only (19, 28, 32 & 43) or sucrose glucose and fructose, each separately (51), and for treating it suitably so as to make edible syrup (29, 33 & 49). Methods have been suggested for the recovery of potash and other potassium salts from it (27, 35, 53 & 57) for the recovery of aconitic acid (47 & 55), and production of glycerine (37), levulinic acid (58), calcium lactate and lactic acid (45 & 50). Investigations have also been made in' the direction of Butyl-acetonic-fermentation (20, 31 & 36) and for the production of acetic acid and acetone (34). Work has been done on preclarification of molasses with a view to increasing the yield of ethanol (56). Its use for the production of active carbon (52), dyestuffs (42), resins for making plastics (46, 48 & 59) has been studied ; some other miscellaneous uses such as for road surfacing (15 & 16), stabilised mud plaster (44), for solubilising the P_2O_5 of bone and rock phosphate (22) and for the production of a combustible gas (60) have also been suggested.

Its most reasonable utilisation in India appears to be in the direction of making alcohol, largely power-alcohol, for using it as motor fuel after mixing with petrol in the proportion respectively of 20 : 80. The entire production of Indian Sugar factories can be easily utilised in this way and India can in this manner substantially reduce its imports of petrol. Work is now indicated on the utilization of spent-wash of distilleries and using the sludge as fodder yeast for cattle.

PRESS-MUD

The production of press-mud during the last four seasons is given below.

Particulars		1950-51	1951-52	1952-53	1953-54
Sulphitation factories	(Tons)	2,36,000	3,11,000	2,71,000	2,08,000
Carbonation factories	,,	1,4,0000	2,36,000	2,03,000	1,69,000
Total	(Tons)	3,76,000	5,47,000	4,74,000	3,77,000

The present use of press-mud of sulphitation factories is for manuring purposes. It is sold by the sulphitation factories to cane cultivators who use it as manure, The utilisation of the press-mud of carbonation factories is a problem. It is at present thrown to waste and is used to fill up ditches in the land round about carbonation sugar factories. At some places it is burnt to produce an inferior quality of lime which is used for building construction purposes.

Research. Fair amount of research work has been done on the utilisation of press-mud and the most promising avenues of its utilisation appear to be in the extraction of wax. There are at present only two factories where cane wax is being commercially manufactured from sulphitation press-mud, viz., Vuyyuru and Ravalgaon. The crude wax made, however, needs to be modified in order to make it as good as Carnuba wax for the manufacture of carbon paper, boot polish etc. It is this aspect which is withholding progress in the industrial utilisation of press-mud for the recovery of wax.

As regards research on utilisation of press-mud, conditions have been studied under which its use as manure gives the best results (61, 63 & 80) and methods have been suggested for preparing composts from it in conjunction with bagasse, cane trash, molasses, oil cake, cowdung etc. (62). Work has been done for the recovery from it of cane wax (66, 67, 71, 76, 77 & 78), sulphur compounds (65), preparation of sulphur dyes (68), active carbon (64 & 73), distemper (69), inferior quality of lime (79) and filter aid, metal polish, board chalk etc., from carbonation muds (74). An attempt has also been made to prepare briquettes with sulphitation mud and bagasse, sun-dry them and use as fuel (70).

Observations. The utilisation of sulphitation press-mud is hardly any problem but potentialities are indicated for the extraction of wax from it. Incidently, dewaxed press-mud can still be utilised as manure with better results.

As regards carbonation mud, work has been done at the Sri Ram Institute for Industrial Research, Delhi, for the production of mineral wool. This use for carbonation mud appears to be good and should be developed.

The Development Council for Sugar Industry which has recently been set up by the Government of India has appointed a sub-committee for going into the question of more systematic utilisation of the by-products of the sugar industry and it is hoped that as a result of the deliberations of this committee, a positive lead would be given to the question of utilisation of the by-products of the sugar industry in this country.

I thank you all, gentlemen, for the patient hearing given to me and I have also to thank Shri N.C. Varma, Assistant Professor of Sugar Technology and Shri N.C. Jain, Technical Assistant of the National Sugar Institute, Kanpur, for assisting me in compiling the bibliography of the researches done in India on by-products of the sugar industry during the last two decades or so which is appended herewith,

BIBLIOGRAPHY

BAGASSE

1. Fowler, G.J. and Bannerjee, B. (J. Indian Inst. Sci. 4, pt. 15, 241-60 (1921)—T. S. 75, 60 ; C. A. 16, 1504) investigated the use of bagasse for the production of power alcohol and paper pulp and found that the best conditions for the hydrolysis of bagasse were obtained with 0.35-0.5% sulphuric acid and a ratio of acid to fibre not exceeding 6% of the weight of the latter. A large proportion of acid tends to destroy the fibre to produce non-sugars which interfere with subsequent fermentation. The maximum yield was obtained in 15-30 minutes but there was not much loss when the heating was prolonged to 2 hours. The pressure used was 65 pounds per square inch. The best yield was 36% of sugar recovered, of which about 30% is calculated as being produced by hydrolysis of the cellular tissues. The sugar solution obtained was not readily fermented, even after clarification with lime. However, a large percentage of it can be fermented when diluted with an ordinary fermentable solution of sugar. The net yield of alcohol was from 8 to 9%, which compares favourably with results obtained from wood waste. The fibres obtained under favourable conditions of hydrolysis of bagasse can then be pulped by heating under pressure with sodium hydroxide and form quite satisfactory material for the manufacture of the cheaper and thicker grades of paper and for mixing with the better grades of pulp.

2. Subramaniam, K.S. and Rao, B.S. (Proc. Soc. Biol. Chem. India 1, 5(1936)-C.A. 32, 3651) showed that on digestion, bagasse yielded 10—12% of furfuraldehyde. The dried residual material may be utilised as fuel or for cardboard manufacture.

3. Rao, A. N. and Gundu Rao, S. N. (Current Sci. 6, 616-7, 1938) prepared a highly activated form of carbon from sugarcane. Treat the bagasse with a sufficiently strong solution of zinc chloride, with the use of heat, to obtain a highly gelatinous mass, heat to near dryness at low temperatures, and heat to a definite temperature in an ignition furnace. When the evolution of steam and other gases has stopped completely, and after maintaining the furnace at the optimum value for 30-60 minutes, slowly cool the mass, crush, treat with hydrochloric acid solution, filter, and wash with water until the wash water is no longer acidic. After drying, the carbon is ready for use. The zinc chloride can be largely recovered and reused.

4. Rao, A.N. and Gundu Rao, S.N. (Jour. Indian Chem. Soc. Industrial and News Ed. II-161-70, 1939) tried two entirely different methods to prepare the active carbon using a number of activating agents like zinc chloride, phosphoric acid, H_2SO_4 and others. Carbon made from bagasse, paddy husk, ground-nut husk, coconut shell and coir and molasses when treated with sodium hydroxide or hydrochloric acid solutions and activated with steam at 800-850° C., showed little activity for decolourizing caramel solutions. Impregnation and digestion of the raw materials with

activating agents, like sulphuric acid, zinc chloride, and aluminium chloride, followed by suitable treatment after carbonization, yielded carbon possessing marked decolourizing properties towards caramel solutions and other colouring and colloidal matter that may be present in sugar liquors.

5. Bhargava, M.P. and Nayer, A.N. (Intern. Sugar J. 45, 45-7 (1943)—B. C. P. A. 1943, II, 181 : B. I. P. C. 14, 4) gave the details for the preparation of the stock, using the Asplund defibrator, for the moisture—and fireproofing, and preservation of boards, and for the manufacture of wrapping boards and straw boards from bagasse. Estimates of the cost of production and profits of insulation board (0.5 inch) and pressed board (0.25 inch) are presented. Santobrite with rosin is the preservative recommended in the manufacture of boards.

6. Chattar Singh, S. (J. Sci. & Ind. Research (India) 3, 399-403 (1945)—C.A. 40, 4544) investigated the application of Asplund defibrating process to bagasse for the preparation of pulp for insulation and wall board. The resulting product compares favourably in strength, sound absorption coefficient and resistance to moisture with similar foreign products. The yield is 60 to 80% of air dry bagasse (10% moisture). Satisfactory moisture-proofing was obtained with 3 to 4% rosin and sufficient alum to give a pH of 4.5 to 5.5. Still better results were obtained with 2 to 3% of an emulsion of 10 parts of wax, 1 part of oleic acid, and 0.15 part of 25% ammonium hydroxide, precipitated with a sufficient quantity of alum. A mixture of rosin and wax sizing made the boards waterproof. Treatment with 10% of sodium pentachlorophenate and 4% of rosin, or with 5% of sodium pentachlorophenate, 5% of copper sulphate and 4% of rosin protects the boards from attack by fungi and by insects such as termites. To render the boards fireproof they are impregnated with 20 to 25% of a mixture of 15 parts of ammonium sulphate, six parts of di-ammonium phosphate, two parts of tri-sodium phosphate, and two parts of borax, or with a mixture of eight parts of magnesium chloride, nine parts of di-ammonium phosphate and three parts of ammonium hydroxide. The cost of the board is only about 57% of that of imported Celotex. The manufacture of wrapping paper and of strawboard is technically feasible but not promising economically.

7. Narain, Prakash and Bhatnagar, S.S. (J. Sci. & Ind. Research (India) 3, 396-9 (1945)—C.A. 40, 4543) prepared a resin from bagasse. The raw material is washed with cold and then with hot water, and the residue is dried in the sun. It is chopped into small pieces, mixed with six parts of water and hydrolyzed with 2% acid at 300 pounds pressure for three hours. The resulting mass is washed successively with cold and hot water and 2% calcium hydroxide solution, strained through cloth, and dried. The product is refluxed twice with 3.5 parts of alcohol for four hours each. The alcohol is distilled from the extract and the resinous residue is dried at 100°C. ; the yield based on the bagasse, is 20%. The resin is black, lustrous

and soft ; it melts at 165°C., has a specific gravity of 1.008 to 1.054, is 89% soluble in hot alcohol, and exhibits a faint fluorescence in ultraviolet light. The resin can be used as a binder for laminated jute fibre, plywood, or paper, for the manufacture of molding powder, for waterproofing and for making varnishes and paints.

8. Dutt, A. K. and Mukherjee, B.K. (Proc. S.T.A. (India) XIV, 1945, part II, pp. 40-44) suggested a method for the extraction of lignin from bagasse industrially. The lignin was extracted and destructively distilled. The distillation products were containing high percentage of phenol. The residual materials, cellulose and carbon could also be utilised. This source of lignin proved satisfactory as compared with jute waste which is a rich source of lignin. The authors also studied the products, specially tar and aqueous layer from destructive distillation of lignin obtained from bagasse and jute waste.

9. Jagadish, T.V. (J. Sci. and Tech. Sci. Soc. N.S.I. and H.B.T.I. Kanpur, 9, pp. 42-48, 1949 ; C.A.—1953, p. 9037) compared the yields of furfural from bagasse under different conditions. Unshredded dry bagasse yielded 1% furfural, well shredded material gave 2.5% and pressure—digestion of the acid—bagasse mixture before distillation yielded 3.2%.

10. Dhingra, D.R. , Mittal, B.B. and Joshi, G.C. (Proc. S.T.A. (India) XIX, 1950, part II, p. 242-46) investigated the use of bagasse for the production of paper pulp. Bagasse disintegrated to 1 mm. size was washed, dried and subjected to cold and hot 190°—100° F. treatment with different concentration of HNO_3 and HCl solutions respectively for different lengths of time and at different temperatures. It was then boiled with alkali (2 % NaOH) for two hours, washed, bleached and dried. Highest α-cellulose content (90.7%) was obtained by the hot HNO_3 treatment. Pulp yield with 5% HNO_3 and HCl (hot treatment) were 34.3 and 36.3% on the weight of bagasse respectively. The HCl treatment gives a pulp with a lower ash content, suitable production of rough fibre, cellophane and cheap films and lacquers.

11. Jatkar, S.K.S. and Bendale, D.S. (Proc. D.S.T.A. (India) IX, 1952, part I—pp. 109-12 ; C.A. 1955 p. 5011) got a yield of 52 g. of nitrogen per lb. of bagasse by nitration and digestion of the product with aq. 1% NaOH. The viscous brown material has solubilities : 20% in 95% Ethyl Alcohol, 23% in Acetone and 20% in Acetic acid. On refluxing 20g. with 100 ml. of aq. 10% NaOH for 2.5 hrs., cooling, neutralizing with HCl, and adding concd. aq. $CaCl_2$, a white cryst. compd. is obtained in 12% yield. The uses of lignin are reviewed.

12. Bhat, R. V. (Indian Sugar—September 1953, p. 269-77) had a pilot plant trials at Forest Research Institute, Dehra Dun, to manufacture the Newsprint from 100% bagasse using the developed process of manufacture. The trials of bagasse pulp mixed with bamboo pulp in the ratio 70 : 30 were also taken at Shri Gopal Paper Mills Ltd., Jagadhri, on the 12th May 1953. The report given by the mill about this trial says "No trouble was experienced in

running the machine smooth and steady, without any abnormal breakage of paper." An entire dak edition of " The Statesman " dated July 22, 1953, was printed on the bagasse paper in the presence of Dr. Punjabrao Deshmukh, Minister for Agriculture, Government of India and other Government officials. The trial was declared a success. Estimated cost of production of printing paper from 100% bagasse, mixture of bagasse and bamboo in the ratio of 70 : 30 ; and 100% bamboo has been given Rs. 714 ; Rs. 783 and Rs. 924 per ton respectively. (Abstract Nos. 1, 2, 3, 4, 5, 6 and 7 have been taken from the Annotated Bibliography edited by C. J. West on the utilisation of Sugarcane Bagasse, Scientific Report Series No. 3 Sugar Research Foundation, Inc. New York, 1946)

MOLASSES

13. Dhar, N.R. and Mukherji, S.K. (Proc. S.T.A. (India) V, 1936, p. 15-24) investigated the use of molasses and press-mud for reclamation of alkali soils. They found that highly alkaline soils (pH upto 10.8) can be reclaimed by the application of molasses. The acids present neutralise the alkali in the soils. The lime present in molasses is rendered soluble and deflocculate the alkali soil and make it pervious. Nitrogen content increases as also activity and growth of micro-organisms. The nitrogen content of soil increases from 0.008 to 0.05 percent.

14. Chaturvedi, H.S. (Proc. S.T.A. (India) V, 1936 p. 277-281) suggested the use of molasses in combination with bagasse and oilcake as cattle fodder, the proportion by weight of the three constituents being 2 : 1.0 : 1.5 respectively. The analysis of the composition was as follows :—

Moisture	percent	...	6.90
Crude protein	,,	...	17.50
Fat	,,	...	3.30
Crude fibre	,,	...	12.50
N. free extract	,,	...	52.00
Ash	,,	...	7.80

15. Sen, H.D. and Joshi, K.C. (Proc. S.T.A. (India) V, 1936, p. 289-302) prepared a road surfacing composition from molasses in combination with quick lime and tar, the cost of which as compared to Asphalt was less by 50 percent.

16. Rao, A.N. (Proc. S.T.A. (India) VI, 1937 p. 286) investigated the use of molasses as a stabiliser in emulsification, with the object of emulsifying bitumen for road surfacing purpose. Emulsification of a simpler system such as benzene was tried and it was found that a stable benzene—water emulsion could be produced with the help of molasses.

17. Mukherjee, B.K. (Proc. S.T.A. (India) VI, 1937, p. 294) reported that field experiments tried at Kanpur for assessing the value of molasses as a manure, did not show any significant increase in the out-turn of the cane crop. With wheat crop the yield was found to have been depressed. His

experiments did not reveal any nitrogen fixation either. In so far as the use of molasses for reclaiming alkaline soils is concerned, he reports that 10 and 15 tons of molasses per acre produced luxurious crops of paddy. Pot culture experiments however showed that gypsum and sulphur were much better than molasses and gave higher yields of wheat crop.

18. Sen, H.D. and Dutt, G.S. (Proc. S.T.A. (India) VI, 1937 p. 333) attempted rapid conversion of molasses into a solid form of manure by bacterial fermentation of molasses under vigorous aeration and intermittent addition of lime in order to solve the difficulty of transport of molasses to the fields. The nitrogen was found to increase on account of biological oxidation.

19. Sen, H.D. and Khanna, N.R. (Proc. S.T.A. (India) VI, 1937, p. 359) tried selective fermentation of molasses with a view to increasing its purity by destroying the reducing sugars with the help of pure cultures of non-investing yeasts *S. Marxianus*, *S. Citrus* & *S. Mali Duclauxi.* The last named yeast had the highest efficiency bringing down the reducing sugar content from 27.1 to 5.01 and raising the purity by 16.87 units.

20. Sen, H.D. and Shukla, J.P. (Proc. S.T.A. (India) VI, 1937, p. 371) carried out experiments with the object of finding a strain of butyl alcohol organism, acclimatised to tropical condition which will ferment molasses with the minimum addition of starchy material. A powerful strain of Granulo-bacter saccharo-butylicum was obtained from coarsely ground unsifted barley meal and was acclimatised to ferment molasses.

21. Subrahmanyan, V. and Bhaskaran, T.R. (Proc. S.T.A. (India) VI, 1937, p. 389) studied the transformation of organic matter during fermentation of molasses in the soil and found that important products of decomposition in cane molasses are lactic, acetic, propionic and butyric acids; minute quantities of ethyl alcohol, acetaldehyde & fusel oil ; CO_2, H, and CH_4 and other hydrocarbons. At low concentrations the sugars disappears in four days yielding acid products. The buffering capacity of the soil system increases for a time and then decreases rapidly. Bacterial numbers increase for first two days followed by rapid fall. Subrahmanyan and Iyenger, B.A.S. showed that fairly large quantities of iron are reduced in the soil system and brought into solution in the ferrous condition and can be toxic to plant growth. It is, however, precipitated or oxidised after some time and becomes non-toxic and may prove even beneficial. The conditions under which such dissolution takes place were studied. Subrahmanyan and Narsimhamurti studied the distribution of organic matter in cane molasses during its decomposition in swamp soils and how they are retained in it. Subrahmanyan and Bhaskaran again investigated whether sugars are directly utilised by the mixed flora in the soil in fixing atmospheric nitrogen and if so whether the nitrogen so fixed is proportionate to the organic carbon utilised.

22. Bhaskaran, T.R., Pillai, S.C. and Subrahmanyan, V. (Proc. S.T.A. (India) VI, 1937, p. 433) investigated whether acid fermentation of molasses can convert bone and rock phosphate into soluble products and thus make them more available

for plant nutrition. They found that in presence of fermenting molasses there is marked dissolution of phosphate from bone while rock-phosphate is only sparingly attacked and the dissolution increases with decomposition of sugar and with the increase in the fineness of the division of bone. There is proportionately greater acid production and more dissolution of bone at lower concentrations of molasses and by successive fermentations of fresh batches of molasses almost the entire quantity of phosphate in bone can be brought into solution.

23. Rajagopal, S. (Proc. S.T.A. (India) VI, 1937, p. 443) carried out investigations with a view to determinating the optimum conditions under which maximum yields of yeast could be obtained from cane molasses. It was shown by him that heavy seeding led to slightly higher yields, addition of ammonium sulphate and peptone led to improvement in yields, addition of dilute acids led to depression of yields and the addition of calcium carbonate was found to be useful.

24. Rajagopal, S. and Iyengar, A.W. (Proc. S.T.A. (India) VI, 1937, p.451) investigated the use of molasses as a biological starter in the decomposition of cellulosic waste materials, bagasse and cane trash were used for composting, nitrogen being supplied externally by the use of ammonium sulphate. The vegetable matter on fermentation gave out large quantities of CO_2 and the final product weighed less than the original containing a high percentage of nitrogen. Moisture content in the decomposition material was found to be an important factor which should be controlled.

25. Bhaskaran, T.R., Pillai, S.C. and Subrahmanyan, V. (Proc. S.T.A. (India) VI, 1937, p. 459) rendered molasses into a solid form for easy transportability by reacting one part of freshly burnt and powdered quicklime with three parts of molasses whereby moisture is driven off and fairly stable compounds with sugar are formed.

The product obtained is immediately grounded in a ball-mill. The product has the composition 4.5% moisture ; 24.2% carbon ; 0.3% nitrogen ; 26.2% CaO ; 3.5% K_2O and 0.08% P_2O_5. The solid product can be used as a fertiliser, in plastic industry, for acetic, lactic, citric and other types of industrial fermentation, for road-surfacing ; as an adhesive and for the recovery of sugar from it.

26. Bhaskaran, T. R., Pillai, S. C. and Subrahmanyan. V. (Proc. S.T.A. (India) VI, 1937, p. 491) investigated the possibility and determined the condition under which a major part of the organic carbon in molasses can be converted into mixed calcium salts of different organic acids. The use of soil not only facilitated fermentation at very high concentrations but also helped in quicker drying. Fermentation in presence of sand has been suggested. The largest production of organic acid takes place at pH 7.0, followed by pH 8.0, 6.0 and 5.0, and when sodium or calcium hydroxide was used for neutralisation. Increased concentrations of molasses, except when mixed with soil, and increased concentrations of calcium acetate affected the acid production and maximum production of acid was observed when the soil-molasses paste was left undisturbed.

27. Iyengar, A.W. (Proc. S.T.A. (India) VII, 1938, p. 193-205) considered the method of recovering potassium from molasses as cream of tartar feasible and studied the conditions influencing the precipitation and separation of cream of tartar.

28. Rao, K.A.N. and Ramchandran (Proc. S.T.A. (India) VIII, 1939, p. 277-283) following the earlier work of Watson, Mukherji, Gupta and Chaturvedi established conditions for the recovery of sucrose from molasses with lime. They found that the miximum amount of sucrose is precipitated from a 14% solution of molasses cooled to 5°C. by gradual addition of lime powder of 200 mesh, equal in weight to the weight of sucrose in solution, the solution being kept vigorously stirred for one hour at 5°C. and then filtered. The filtrate was then boiled when further precipitation was obtained. The two precipitates are mixed together with minimum quantity of water and carbonated. On filtering solution of sucrose is obtained. The expected recovery of 18 tons of sugar from 100 tons of molasses by this process.

29. Awasthi, H.N. and Walawalkar, D.G. (Proc. S.T.A. (India) VIII, 1939, p. 323-333) investigated the comparative merits of the cynide, the alum and the tartaric acid processes for purification of molasses with a view to removing its non-sugars and making it edible or better fitted for the recovery of sucrose and found that the alum method gave the highest (true) purity rise (about 12.8 units) and highest CaO removal.

30. Srivastava, R.C., Rao, K.A.N. and Gupta, G.N. (Proc. S.T.A. (India) X, 1940 part II, p. 83-85) prepared the composts by " Hot Fermentation " from air dried press mud, cane trash and air dried bagasse mixed in suitable proportions and well turned with a thin slurry of cowdung and molasses. The method in which first aerobic fermentation should proceed for 7-8 days, then anaerobic fermentation continued until the composts were ready, was proved to be the best.

31. Sen, H.D. and Shukla, J.P. (Proc. S.T.A. (India) X, 1940 part II, p. 97-120) studied the different aspects of butyl acetonic fermentation of cane molasses such as effect of nutrients, growth of culture, distillation, rectification, recovery of the solvents etc.

32. Rao, K.A.N. and Ramchandran (Proc. S.T.A. (India) IX, 1940, p. 251) continuing their earlier work on recovery of sucrose from molasses tried Baryta and Strontia for the purpose. Baryta gave a recovery of 74.4 percent of sucrose present in molasses raising the purity of recovered solution to 90.1 when a quantity of barium oxide equal in weight to twice the weight of sucrose present in molasses was used. Strontia method gave a recovery of 73.6% of sucrose in molasses, purity of recovered solution being 89, when strontium oxide 3.1 times the weight of sucrose in molasses was used. Comparative results obtained by them with

lime, Baryta and Strontia were as follows :

Precipitant	Quantity of precipitant	Temp. of precipitation	Duration of reaction	Sucrose recovered	Purity of recovered solution
Quicklime powder sieved through 200 mesh (heated and cooled)	Twice the weight of sucrose in solution	0°-5°C.	60 mins.	77.5%	77.0
Barium oxide suspended in water	,,	Boiling point	5-10 minutes	74.4%	90.1
Strontium oxide suspended in water	3.1 times the weight of sucrose in solution	Boiling point	45 mins	73.6%	89.0

33. Rao, K.A.N. and Ramchandran (Proc. S.T.A. (India) IX, 1940, p. 255) showed that table syrups could be manufactured from molasses by using the quicklime powder (200 mesh) method advocated by them earlier (loc. cit.)

34. Sen, H.D. (Proc. S.T.A. (India) IX, 1940. p. 327-46) had laboratory experiments on the recovery of acetic acid and acetone from molasses by the fermentation process. Glacial acetic acid, acetone and various salts of acetic acid may be manufactured economically by the fermentation process which can successfully compete with the wood distillation or synthetic process. The practical yield of pure water—white glacial acetic acid B.P. 117°C. and having the property of congealing when kept in ice-salt mixture, comes to 331 lbs. acetic acid per ton of molasses is usually 55 gallons or 440 lbs. absolute alcohol and the corresponding yield of acetic acid expected to be produced works out to 574 lbs. The practical efficiency therefore is 57.9 or approx. 60%. An appreciable economy in the cost may be affected by redeeming some of the by-products as Na or K-Sulphate which may be converted into caustic potash or soda with milk of lime and reused in the process.

35. Walawalkar, D.G. (Proc. S.T.A. (India) IX, 1940, p. 361-63) reported that potash content of Indian Molasses was 2.9 to 4.8, present in the form of sulphate out of which 75 to 80% could be recovered at about 20°C. during the winter season. If the lower temperatures were used higher yield could be obtained. The residue i.e., de-potashed molasses could be a better molasses for fermentation purposes as the lime salts detrimental to fermentation process have been removed.

36. Sen, H.D. and Joshi (Proc. S.T.A. (India) XI, 1942, p. 203-224) studied the condition under which high yields of butyl-alcohol and acetone could be continuously obtained from molasses using the *Clostridium Strain.*

37. Bhullar, A. S. (Proc. S.T.A. (India) XII, 1943, p. 195-98) showed the possibilities of glycerine manufacture by fermentation of molasses

which is quite similar to alcoholic fermentation differing only in that it is carried out in alkaline medium varying from 7 to 8.5pH using sodium sulphite or a mixture of sulphite and hydro sulphite or sodium carbonate. Yield has been reported upto 4% of the sugars present in the wort.

38. Dhar, Biswas, Seshacharyulu and Pant (Proc. S.T.A. (India) XII, 1943, part II, p. 107-115) tried the molasses and press mud and their mixtures for alkaline soil "Usar" reclamation. It has been found that the bacterial count is maximum in the case of maximum doze of molasses i.e., 10 tons/acre. The fall in pH is more marked wherever the dose of molasses and Kankar ($CaCO_3$) is higher (10 : 5 tons/acre). The average maximum gain in total nitrogen due to photochemical fixation has been observed in plots treated with 10 tons/acre molasses. Mixed treatment of press mud and molasses has also shown an average increase of nitrogen. The tilth and texture of treated soils has improved very much in its power to hold water and the best results. As regards the crop production, the best crop has been obtained from plots treated with 10 tons of molasses and 5 tons of Kankar per acre in respect of yield of paddy.

39. Ghatak, S. N. (Proc. S.T.A. (India) XIII, 1944, part I, p. 81-89) prepared the briquettes with molasses and charcoal dust mixing in different proportions. The briquettes with 30% molasses gave the maximum calorific value. The cost per maund of briquettes was far cheaper than that of charcoal. Other binding materials were also tried and compared e. g., gum, rosin, wheat, jwar flour etc., but molasses was found to be the best.

40. Sen, H.D. and Chakravarti (Proc. S.T.A. (India) XIV, 1945, part I, p.26-27) studied the practicability of conversion of liquid molasses into solid molasses for its supply to distilleries in the time of scarcity of the tank wagons during war time. There was no appreciable drop in the yield of alcohol as a result of solidification. The fermentation efficiency of the solidified molasses remains practically unaffected although as compared with liquid molasses, the less yield of alcohol is proportional to the drop in purity affected during solidification.

41. Sen, H. D. and Singh, S. D. (Proc. S. T. A. (India) XIV, 1945, part I, p. 32-48) developed the differential method of fermentations for the manufacture of food yeast from cane molasses. The underlying principle in this method is to produce 'air-yeast' by acclimatisation of any strain of yeast gradually to tolerance to inorganic nitrogen, starting initially from organic nitrogen. The strains from which air yeast was produced, were *Torula Utilis, Saccharomyces Careviciae and Endomyces Fibuliger*. The results obtained using the above strains have been tabulated.

42. Biswas and Athawale (Proc. S.T.A. (India) XIV, 1945, part I, p. 48-51) studied the possibility of the commercial utilisation of molasses in the preparation of a dye-stuff. It was found out that the most suitable proportion for obtaining the best results is 1 part of caustic soda, 2 parts of sulphur and 5 parts of molasses.

43. **Kloppenburg, C. A. (Proc. S. T. A. (India) XVII, 1948, part I, p. 67-73)** evolved a process for sugar recovery from cane molasses based on the formation of insoluble mono-calcium saccharate and calcium glucosate in a medium of diluted alcohol of approx. 70% strength and the subsequent separation of the salts which remain soluble in the alcoholic medium. Sucrose is to be separated by decomposing the Ca-saccharate by passing CO_2 in a suspension of the saccharate in 70% alcohol or water, filtering off $CaCO_3$ and evaporating the filtrate to a syrup out of which sugar is crystalised in the usual manner. The difference in the degree of solubilities of Ca-glucosate, fructosate and saccharate in alcohol at different temperatures is utilised to separate them from each other.

44. Dhingra, D.R. and Ghatak, S.N. (Proc. S.T.A. (India) XVII, 1948, part I, p. 86-94) carried a number of experiments for making a suitable plaster for applying over the surface of Kachha wall. Out of 36 different compositions the cheapest and the most suitable plaster, named as " Stabilised Mud Plaster A " having the following composition :—

1.	Talao (Kachha water pond) clay	10 cu. ft.
2.	Cow dung fresh	2.5 ,,
3.	Wheat straw	2.0 ,,
4.	Linseed fibre waste	1.0 ,,
5.	Sun hemp fibre waste	1.0 ,,
6.	Mud from Kachha cattle yards	1.0 ,,
7.	Molasses	10 seers

Another composition was prepared by mixing press-mud, bagasse and molasses and allowing to ferment for sometime. Both are then mixed well in a mixing machine or on a arastra driven by bullocks. This final product is better than previous and is meant for plastering the walls as well as for mud reinforcement roofing.

45. Narula, B.L. and Chawla, B.R. (Indian Sugar, July, 1948, pp. 115-118) studied the manufacture of Calcium-lactate commercially by fermentation of cane molasses. The strains of *Lactibacillus Delbrucki* gave the most satisfactory results between 42° to 46°C. The lactic acid thus produced was constantly neutralised by limestone (powder), $CaCO_3$ or powdered chalk which was previously added to molasses solution before setting up for fermentation. After fermentation is complete, which is tested by Ca-lactate percentage formed in the fermented solution coming to 24.26% ; the solution is cooled over night. The Ca-lactate thus crystallises out and is centrifuged. This Ca-lactate is purified by ferrous sulphate method.

46. Bhatnagar, M.S. and Rai, S. (Proc. S.T.A. (India) XVIII, 1949, part I, p. 52-54) showed that phenol 49.6 combines with 100 gms. of molasses having 35%sucrose and 17% invert sugar when autoclaved or refluxed in presence of 10% of H_2SO_4. The dark coloured resins obtained is thermoplastic at 100°C. and pressure 2000 lbs./sq. inch. It has low moisture absorption and good electrical properties.

47. Sen, H.D. and Srivastava, H.C. (Proc. S.T.A. (India) XVIII, 1949, part I, p. 54-56) extracted aconitic acid from molasses by the general method of extraction of organic acids i. e., precipitating the acid with lead acetate, decomposing the lead salt of the acid by H_2S extracting the free acid by a solvent and finally distilling off the solvent. Yield of aconitic acid was obtained from 0.5 to 1.25% on the weight of molasses.

48. Sen, H.D. and Srivastava, H.C. (Proc. S.T.A. (India) XVIII, 1949, part I, p. 57-59) determined the optimum conditions for the preparation of plastics of bakalite type from sugar and phenol. Resins from molasses were prepared by reacting molasses with phenol, creosote and coal-tar in the presence of H_2SO_4 as a condensing agent. The resins after mixing with suitable filters, hardening agents and lubricants gave moulding powders which on compression moulding gave thermosetting plastics comparable with the bakelite plastics. The cheapness of the raw materials viz. molasses and coal-tar might go a long way in the production of such plastics at a very nominal cost.

49. Sen, H.D. and Srivastava, H.C. (Proc. S.T.A. (India) XVIII, 1949, part I. p. 60-61) prepared edible syrups from molasses by two methods. (A) sucrose and invert sugars were precipitated from clarified molasses; the washed Ca-saccharate was decomposed by CO_2 ; excesss of CO_2 was boiled off and traces removed by sodium phosphate. (B) SO_2 was substituted for CO_2.

In 'A' the purity rise was from 31.8 to 57.9 and in 'B' from 31.8 to 61.2. The recovery of total sugars was 48.2% with 'A' and 42.3% with 'B'. The product from 'A' has a better taste.

50. Sen, H.D. and Kapoor, B.D. (Proc. S.T.A. (India) XIX, 1950, part I, p. 1-14) developed a technique for fermentation of molasses for the production of Ca-lactate and lactic acid as well as the purification of the products. Of the two strains used, *streptobacterium planatarum* is more suited for fermenting the molasses as compared to *Bacterium delbrucku.*

51. Kloppenburg, C.A. (Proc. S.T.A. (India) XIX, 1950, part II, p. 225-29) gave a flowsheet for the extraction of fructose, glucose and sucrose separately by maintaining the proper conditions and to produce a fertilizer rich of potassium salts.

52. Doss, K.S.G. and Ajit Singh (Proc. S.T.A. (India), XIX, 1950, part II, p. 230-32) prepared a high class decolourising carbon by mixing the molasses and $CaCl_2$ in the ratio of 1 : 1 by weight, igniting in a closed retort to expel volatile matter and leaching with acid to remove ash constituents. The order of diminishing efficiency of the activator is $CaO > CaCl_2 > NaOH > Na_2CO_3 > Na_2SO_4 > H_2SO_4 > NaCl$.

53. Awasthy, H.N.S. and Singh, S.D. (Proc. S.T.A. (India) XIX, 1950 part II, p. 238-40) tried the following three methods for the recovery of the potassium salts from the molasses.

(1) Chemical methods from molasses as such
(2) Base exchange methods from molasses as such
(3) Burning of molasses.

Molasses ash, containing about 64% of the potassium salts as sulphate, chloride and carbonate, is leached out with water. The extract treated with H_2SO_4 and K_2SO_4 is crystallized therefrom. The crystals are then separated and washed with alcohol to free it from chlorides. KCl is separately recovered from the mother liquor and converted into sulphate. The entire amount of sulphate may be converted into bi-sulphate which fetched a higher price. The products obtained are of a high degree of purity.

54. Padalkar, D.G. (Indian Sugar, August 1950, p. 158-59) showed the possibilities to manufacture the food yeast from molasses in a sugar factory with the existing plant. Only 1 oz. of yeast to our day's food can share 18% Proteins, 58% Vitamin B1 and all the requirements of B2 and B3 Vitamins. Calculation of cost per lb. of dry food yeast came to Rs. 0-8-0 per lb.

55. Mukherjee, S. and Srivastava, H. C. (Proc. S. T. A. (India) XX, 1951, part II, p. 78-79) extracted the aconitic acid from molasses using ethyl acetate as solvent and designed an apparatus for continuous extraction. The yield obtained was about 1% on the weight of molasses. The acid is obtained directly from molasses without any intermediate steps as in the lead aconitate or the calcium—magnesium aconitate methods.

56. Shukla, J.P. and Kapoor, B.D. (Proc. S.T.A. (India) XXI, 1952, part II, p. 129-33) examined the different methods of pretreatment of molasses for the ethanol fermentaion e.g., Treatment with alumina ; superphosphate ; K-Ferro-Cyanide ; Arroyo and Reich process. Superphosphate treatment comes out to be best. The authors modified this process resulting in giving higher yields and better fermentation efficiency as compared to untreated molasses.

57. Mukherjee, B. K. (Indian Chem. Soc. Ind. and News Ed. 15, p. 167-70, (1952) C.A. 1955, p. 5010) has given a method in which the recovery of potassium salts from cane molasses as potash-alum and as bi-tartarates is generally improved by first removing the Ca.-salts by the addition of H_2SO_4. The tartaric acid can be recovered and recycled either by precipitating it as calcium tartarate or by separating the potassium salts as potash alum.

58. Rao, N.S., Ramchandran, K. and Zaheer, S.H. (Indian Sugar May, 1953 p. 63-64) worked out a simple and direct method for the preparation of levulinic acid from cane molasses, giving yield upto 45% of levulinic acid based on sugar content of the molasses. Consistent yields of about 30% of levulinic acid were obtained using 42.7% sugar from molasses in the reaction mixture. In several experiments when a lower concentration of the sugar from molasses was used viz., 27.3% yield of levulinic acid upto 45% were obtained. Results were compared in which pure sugar or molasses was digested with hydrochloric acid with and without K-bromide.

59. Mukherjee, S. and Srivastava, H.C. (Proc. S.T.A. (India) XXIII, 1954, part I, p. 50-52) prepared the plastics from molasses and phenol, creosote and wood-tar phenols and tried the various compositions. The cheapest product is from molasses and wood tar phenol. The molasses and phenol plastics is considerably cheaper (approx. -/8/- per lb.) than Bakelite. As usual, first an " A " resin which is thermoplastic is obtained. This, on mixing with requisite quantities of filter, hardening agent and lubricant and on compression moulding gives insoluble and infusible thermosetting plastics.

60. Sen, Abhiswar, Rewari, R.B. and Vyas, N.D. (Science and Culture, India, 19, pp. 562-4, 1954 ; C.A.—1954, p. 12438) studied the effects of N, P and Ca on the production of combustible gas from molasses by biological fermentation. Max. yields of gas were obtained by addition of $(NH_4)_2SO_4$ 1 gm. Ca-phosphate 0.5 gm. and $CaCO_3$ 1 gm. per 10 gm. molasses. A 5% solution of molasses was suitable. Increase in temperature (20° – 40°c.) increased the fermentation rate. Analysis of the fermented liquid showed that little loss of N took place during the fermentation.

PRESS-MUD

61. Sen, P.C. and Basu, K.L. (Proc. S.T.A. (India) IX, 1940, p. 261-69) ascertained the effect of filter-press-cake as a manure and observed that plants are able to obtain their neutrient requirements from the filter-press-cake and that there is an optimum dose that causes the highest growth.

62. Srivastava. R.C., Chaturvedi, H.S. and Rao, K.A.N. (Proc. S.T.A. (India) IX, 1940, p. 271) prepared composts from press-mud and bagasse mixed with a slurry of cow-dung and molasses.

63. Mitra, A.K. (Proc. S.T.A. (India) IX, 1940, p. 271-292) reported that molasses and press-mud applied to sugarcane crop at the rate of 100 lbs. nitrogen per acre gave the highest yields as compared to other manures but their cost and carting charges were found to be prohibitive.

64. Rao, A.N. and Jain, N.S. (Proc. S.T.A. (India) IX, 1940, p. 293-302) prepared activated carbon from sulphitation press-mud which compared favourably with imported varieties of carbons. Its colour removal efficiency at 1 gm. per 100 ml. of molasses solution, was found to be about 83% as against about 87% of the imported carbons.

65. Rao, A.N. and Jain, N.S. (Proc. S.T.A. (India) IX, 1940, p. 303-12) evolved different methods for the recovery of sulphur, sodium thio-sulphate, sodium hydrosulphite or blankit and sodium sulphide from press-mud.

66. Rao, K.A.N. and Gupta, G.N. (Proc. S.T.A. (India) IX, 1940 part II, p.79-82) extracted the cane wax in laboratory to the extent of 10-15% on the weight of dried press cake using different solvents. The physical and chemical constants of the wax vary considerably with the solvents used for extraction. The composition and quantity of wax would vary with the type of cane, soil etc.

Yield of wax on the weight of dried press-mud is 10% ; solvent oil recovered is 92.5% ∴ Loss of solvent oil—7.5%.

67. Rao, M.N. and Vidyarthi, N.L. (Indian Sugar 4 No. 10 pp. 23-24, 1940 ; C.A.—1942, p. 2748) extracted the cane wax from dried press cake with various solvents. The yields were with CCl_4 green brown hard wax, 13.25% on cake ; with Benzene—13.8%. Alcoholic acetone and petrolium ether were less effective. The most successful method is, to boil with Na_2SO_4 soln. then with HCl and finally with CCl_4 in presence of active carbon at pH 7.5—8.0.

68. Rao, A. N. and Jain, N.S. (Proc. S.T.A. (India) X, 1941, p. 265-67) carried out some experiments to blend the sulphur dye obtained from press-mud with sulphur yellow and orange to yield the required shades. Sulphur dye could be prepared through a chemical reaction of organic matter of the press-mud with sulphur and caustic soda with or without sodium sulphide.

69. Gupta, C.P. (Proc. S.T.A. (India) XI, 1942, p. 199-202) found that sulphitation press-mud gives us a better base for the preparation of distemper than carbonation one. He designed a special furnace, where the press-mud is incinerated at very high temperature i.e., upto 850°C. without the use of any fuel from outside. The machinery is not at all complicated one and the investment is not much. All that is needed is a grinder or a disintegrator, a sifter with air separator, a roll mill and a mixer.

70. Anonymous. (Ind. Sug. June 1942, p. 256). The Chief Engineer of Maholi Sugar Factory made use of press-mud as fuel. The press-mud was mixed with bagasse and water, from which the cakes were made and dried in sun for 5 to 6 days and then used in furnaces of special design.

71. Venkatarao and Narsingarao (Proc. S.T.A. (India) XII, 1943, p. 191-94) extracted the cane wax from dried press-cake by carbon tetra chloride and separated into higher and lower melting wax (M.P. 82°C. & 53.64°C.). The soft wax was, found to contain all the sterol content of the wax.

72. Walawalkar, D.G. and Srivastava, R.C. (Proc. S.T.A. (India) XIII 1944, part I, p. 69-79) prepared the Filter-Aid utilizing the carbonation press-mud and compared its properties with Hyflo-supercel. A standard method for the preparation of the filter-aid is developed. The prepared Filter-Aid appears to be slightly inferior to Hyflo-supercel in flow rate and clarity. It has not adverse effects on colour and purity of the filtrate.

73. Doss, K.S.G. and Jain, N.S. (Indian Sugar—April 1944, p. 149) compared the decolourising power of two samples of carbons prepared from original press-mud (sulphitation) and wax-free press-mud respectively. It was found that the removal of wax hardly affects the decolourising power of the carbon.

74. Doss, Jain and Sen Gupta (Ind. Sugar, November, 1944, p. 345).

(1) Foaming composition for fire extinguishers—Extraction of sulphitation or carbonation press-mud with 10% Na_2CO_3 solution at ordinary or higher temperatures yields a product having foam stabilising properties and suitable for being used in fire extinguishers. It is found that 25 lbs. press-mud and 10 lbs. Na_2CO_3 yield sufficient amount of foaming composition for 1000 gallons of fire extinguishing fluid.

(2) Metal polishing powder from carbonation press-mud—Leaching the mud with water, drying and subjecting to air separation.

(3) Board chalk from carbonation press-mud—Leaching the mud with water, mixing with pigment (such as red, yellow ochre or organic dyes) and a binding agent (such as gypsum or Na-silicate) and moulding in pressure moulds.

(4) Putty-paste from carbonation press-mud—Mud mixed with linseed oil (1 : 5) in an edge runner.

(5) Tooth-powder from carbonation press-mud—Mud ignited at a suitable temperature (60°C.) ; the product leached with water, forms a suitable base for black tooth powder.

75. Shrikhande, J.G. (" Waste Products of the Sugar Industry " Part I, —Economic Utilization of Press Mud—Proc. Sci. & Ind. Research, Vol. III, p. 217-221, 1944) reviewed the possible uses of press-mud, cane wax, activated carbon, as fuel, as fertilizer, distempers, organic solvents, foaming solution, filter aid and other products.

76. Shrikhande, J. G. (Indian Sugar, Feb. 1945, p. 42-45) gave a successful demonstration of a Pilot Plant for the extraction of cane wax from press-mud and got the recovery of wax on mud upto 11-12%. The cost of production and the yield of wax with respect to each of the three solvents (i) Methylated Spirit, (ii) Rectified Spirit and (iii) Solvent Oil used in extraction, were compared. Solvent oil apparently the cheapest and the best, both in respect of the yield of wax and its cost. The complete sketch and flow diagram of the plant had been given.

77. Ram Dev and Shrikhande, J.G. (Proc. S.T.A. (India) XV, 1946, Part I.p. 32-38) examined the sugarcane wax chemically extracted from press-mud with solvent oil. It was found to contain 25% acids and 67.4% unsaponifiable material. The component acids consisted of 4.8% resin acids, 0.4% cerolic acid, 50.8% palmitic acid, 2.9% stearic acid, 5.48% oleic acid and 31.8% arachidic acid. The unsaponifiable matter consisted of 68.6% hydro-carbons with a M.P. of 68.0°C, 28% myristyl alcohol and 3% sterols.

78. Gundu Rao, S.N., Kulkarani, H.G. and Kulkarni, D.P.(Proc. S.T.A. (India) XVIII, 1949, part I, p. 62-69) extracted the sugarcane wax from sun dried press-mud with mineral terpentine B. P. range 135°-190°C. The fatty components of the crude wax were best removed with acetone which gave a product of 60% hard wax after the percolate is steam distilled. Yield of crude wax was about 7% of filter cake.

79. Walawalkar, D.G. (J. Sci. and Tech. Sci. Soc. N. S. I. and H. B. T.I. Kanpur, 9, pp. 38-41, 1949; C.A. 1953, p. 8396) regenerated the carbonation press-mud for the production of lime which was of lower quality (CaO-37.1 to 74.5%) than fresh market lime.

80. Pramanik and Misra (Proc. S.T.A. (India) XXII, 1953, Part II, p. 156-161) proved that sulphitation press-mud improves the nitrogen fixing capacity of the soil by increasing the azotobacter population. It has also been observed in field trials that on an average it increases the acre yield of sugarcane by 88 to 151 maunds when applied at the rate of 100 to 120 lbs. nitrogen per acre. Since the filter press-mud received from factory has proved to be a low nitrifier, it would be advisable to compost it before application to the field so as to get its maximum effect for crop yield.

Mr. J. P. Shukla presented the following paper.

Paper

GROWTH PROMOTING FACTORS IN CANE WASTE MOLASSES GROWTH AND FERMENTATION RESPONSE OF ELUATES FROM PRETREATMENT SEDIMENTS

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National Sugar Institute, Kanpur

In a previous communication the authors (1) have given evidence regarding the removal or destruction of growth promoting factors by treatment of molasses using ferrocyanide and superphosphate as developed by the authors (2). White and Munns (3) observe that blackstrap molasses is an excellent source of biotin, pantothenate and inositol, whereas high test cane molasses and refinery molasses, though extremely high in biotin, are deficient in pantothenate and inositol. The composition of cane molasses has been examined by the Sugar Research Foundation in their report (4) wherein the vitamin content of waste molases has been given. Biswas (5) has reported vitamin B_1 and B_2 contents of sugar cane, date palm, and *Khajur-patali* molasses. Paul Gyorgy (6) reports that cane molasses contain vitamin B_6 and lactoflavin. Owen and Denson (7) report poorer fermentation when the medium is filtered through carbon prior to inoculation. Sakurai and Hori (8) report adsorption of vitamin B_1 with acid clay. In the present paper

data have been collected to indicate that the growth promoting factors are adsorbed by the precipitates produced due to the pretreatment. These when eluted out show a response on the growth and fermentation rate. If the eluates are overheated the growth factors are destroyed.

EXPERIMENTAL

The waste molasses from a sulphitation sugar factory was treated according to the methods developed by the authors(2). The sludge obtained in each case was washed with distilled water to obtain colourless washings. The clean sludge was extracted in 4.2 pH acetate buffer repeatedly and allowed to sediment overnight. The supernatant liquid was concentrated in vacua. Any residue formed was removed, washed with distilled water to obtain a composite eluate used in the experiments.

The growth studies were made by directly measuring the turbidities due to yeast growth. White and Munns synthetic medium (9) with 12% sucrose as carbohydrate source, was used. Ten flasks of this medium were made. Different growth factors were made absent, one at a time, in each flask Nos. 1-8. The growth factors considered were (1) thiamine hydrochloride (2) niacin (3) d-biotin (4) riboflavin (5) calcium d-pantothenate (6) m-inositol (7) pyridoxin hydrochloride (8) p-aminobenzoic acid. The 9th flask was taken as a control with no growth factors. In the 10th flask all the growth factors were added.

Ten ml. of the above media were taken in each test tube to obtain three series of ten tubes. In one series eluate from the sludge of superphosphate was added. In the second series eluate from the sludge of potassium ferrocyanide treatment was added. In the third series no eluate was added and it served as a control. An extra tube was set up with all growth factors but without any eluate from the above treatments. The volumes in each case were kept constant. 0.1 ml. of eluate was used per 10 ml. of the medium.

A pure culture of *Saccharomyces Cerevisiae* N.S.I. No. 13 was grown on synthetic medium for four generations. The cells were removed by centrifuging, washed free of the medium, suspended in sterile distilled water and used for inoculation. Initial turbidity of the inoculum was kept at 310 in Klett-Summerson Photoelectric Colorimeter using the green filter No. 54. Equal volumes of this suspension (0.14 ml.) were used in each tube for inoculation. Initial turbidity and the turbidities developed after 24, 48 and 120 hours were measured. The zero in Klett in each case was set up with corresponding uninoculated blank medium.

Fig. Nos. 1—10 show the results obtained.

CONCLUSIONS

1. From the figures attached it will be seen that all the growth factors appear

to get adsorbed more or less by the sediments obtained by the pretreatment of molasses by superphosphate or ferrocyanide. The eluates show a response for the various growtrh factors made absent in different media set up.

2. From figure 9 it will be seen that the eluate from potassium ferrocyanide sediment gives a better response than from the superphosphate.
3. Figures 1,4,5 and 7 show that calcium d-pantothenate, niacin, p-aminobenzoic acid and m-inositol are removed more effectively by ferrocyanide treatment. Figures 2, 3, 6 and 8 show that riboflavin, d-biotin, thiamin hydrochloride and pyridoxin hydrochloride are removed more effectively by superphosphate treatment.

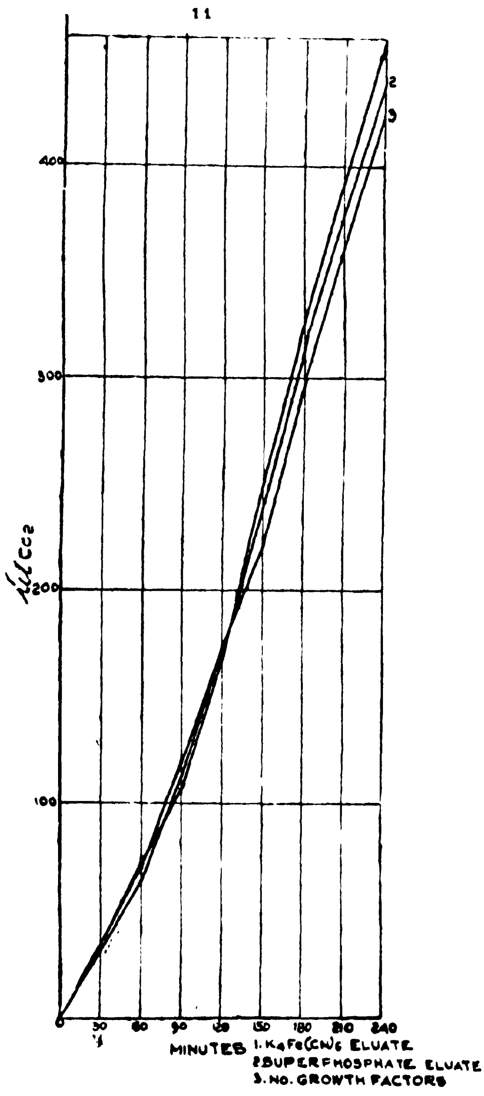


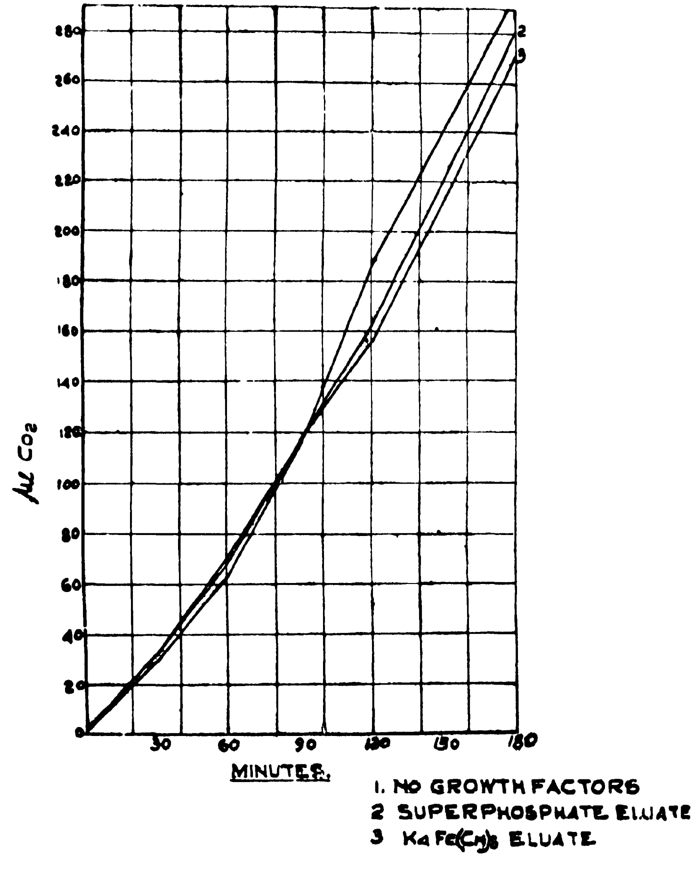
Fig. 11

4. Figure 10 shows that addition of eluate to the White and Munns medium with all growth factors increases the growth further.

EFFECT OF ELUATES ON FERMENTATION OF SYNTHETIC MEDIUM

Three Warburg's flasks were set up without adding any vitamins (1) with 0.9 ml. of White and Munns medium and 0.01 ml. of eluate from superphosphate treatment (2) with 0.9 ml. of White and Munns medium and 0.01 ml. of eluate from potassium ferrocyanide treatment (3) with 0.9 ml. White and Munns medium with 0.01 ml. distilled water to serve as control. Thermobarometer was set with 0.9 ml. White and Munns medium and 0.11 ml. of distilled water. In flask Nos. 1,2 and 3, 0.1 ml. of inoculum was put in the side arm and flask saturated in an atmosphere of carbondioxide for half an hour at 35.30±0·03°C., the working temperature of the bath. The inoculum was tilted into the medium to effect full mixing and flasks equilibrated for half an hour. The μl CO_2 evolved has been plotted in Fig. 11.

FIG 12



It will be seen that the eluates show a positive response on fermentation rate. The ferrocyanide eluate behaves better than superphosphate. This is in confirmation of the previous observations.

EFFECT OF HEAT TREATED ELUATES ON FERMENTATION

The eluates were heated at 25 lbs. per sq. inch for two hours to destroy the growth promoting factors. 0.01 ml. of each was put in two Warburg's

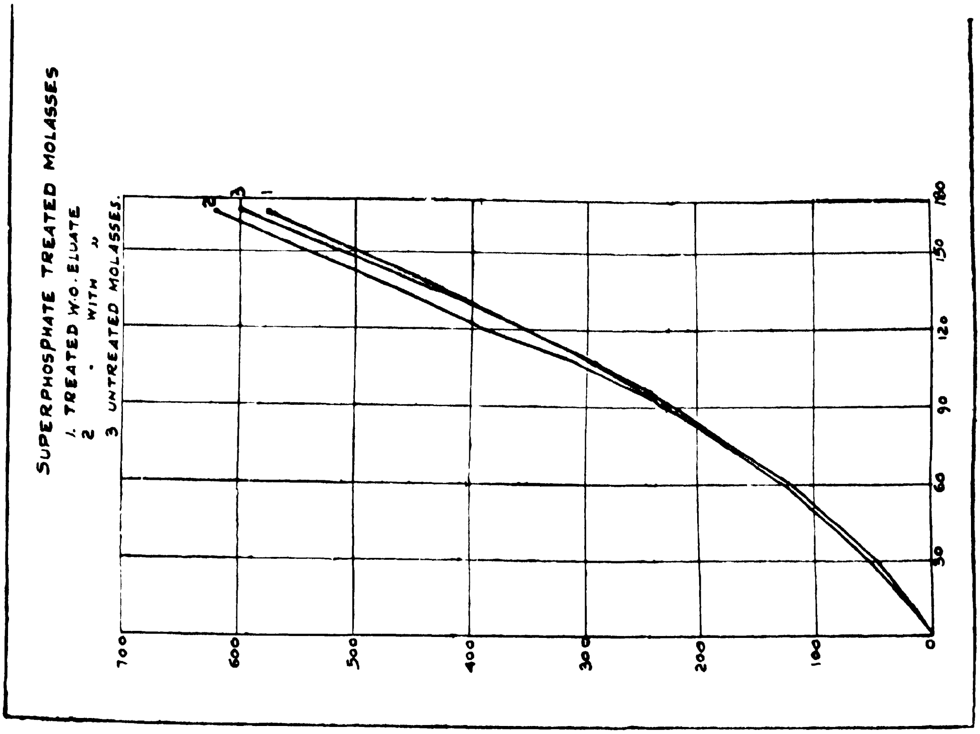


FIG 13

SUPERPHOSPHATE TREATED MOLASSES
1. TREATED W.O. ELUATE
2 " WITH "
3 UNTREATED MOLASSES.

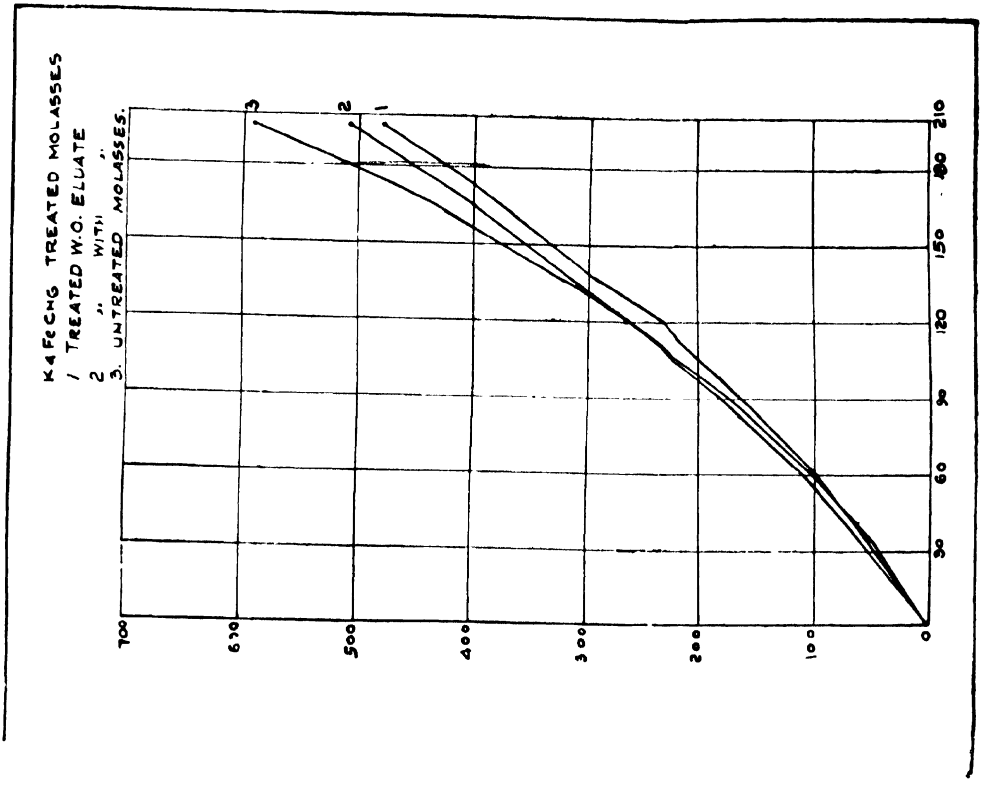


FIG 14

K4FeCN6 TREATED MOLASSES
1 TREATED W.O. ELUATE
2 " WITH "
3. UNTREATED MOLASSES.

flasks and dried at 105°C. for fifteen minutes. The third Warburg's flask was kept without any growth factor eluate. 0.9 ml. of the medium was added in each of the three above Warburg's flasks along with 0.01 ml. of distilled water to make up toequal volumes as in previous experiment. Thermobarometer was set up with 0.9 ml. White and Munns medium plus 0.11 ml. distilled water. Yeast inoculum (0.1 ml.) was prepared and added exactly as in the previous experiment. μl CO_2 was plotted as in Fig. 12.

It will be seen from the μl CO_2 curves that the superheated eluates depress the rate of fermentation due to growth factors getting destroyed. This depression may be due to the toxic effect of the eluates as such. It also shows that the growth factors are not of the nature of amino acids which should have remained intact on heating.

EFFECT OF ELUATES ON FERMENTATION OF TREATED MOLASSES

The Warburg's flasks and thermobarometers were set exactly as in the above experiment but White and Munns medium was substituted by the respective treated molasses in equal volumes of 0.9 ml. with untreated molasses kept as a control.

The quantity of eluate added was the same as would be got from the respective molasses solution on treatment.

μl CO_2 output of treated molasses without eluate, treated molasses with eluate from respective treatement and untreated molasses were plotted in each case and are given in Figs. 13 and 14.

From Fig. 13 it will be observed that the rate of fermentation is higher in superphosphate treated molasses with the respective eluate, added to it. From Fig. 14 it may be seen that in case of ferrocyanide treatment addition of eluate restores the fermentation rate only partially and it does not reach to the same level as in the untreated molasses. This is probably due to the toxicity of minor quantities of iron that may be present in the eluate.

ACKNOWLEDGEMENTS

The authors thank Shree J. M. Saha, Director and Dr. K. S. G. Doss, Professor of Sugar Chemistry for the very keen interest taken by them in this work.

REFERENCES

1. Shukla, J. P. and Kapoor, B. D. 1954. *Proc. S.T.A., India*, XXIII, pp. 232-238.
2. Shukla, J. P. and Kapoor, B. D. 1953. *Proc. S.T.A., India*, XXI, pp. 129-133.
3. White, J. and Munns, D. J. 1950. *J. Inst. of Brewing*, 194-202.
4. Binkley, W. W. and Wolform, W. W. 1953. Sugar Research Foundation, *Scientific Report Series*, No. 15, 1, p. 23.
5. Biswas, H. G. 1938. *Science and Culture*, 3,627-8.
6. Paul Gyorgy. 1937. *Proc. Soc. Expt. Bio. Med.*, 36, pp. 167-169.
7. Owen, W. L. and Denson, W. P. 1929. *Contr. Bakt. Parasitenk Part II cited from Chemical Abstracts*, 19, 77, pp. 481-523.
8. Sakurai, Y. and Hori, H. 1943. *Bull. Instt. Phys. Chem. Res.*, 22, p. 760-8.
9. White and Munns, D. J. 1951. *Wallerstein Lab. Communications*, XIV, No. 56, p. 206.

DISCUSSION

Mr. Zakkariasson of Messrs. De Laval & Company asked if yeast of proper activity was used.

Mr. Shukla replied that the usual method of assessing the activity of yeast, viz., measurement of CO_2 evolved per cell per hour was used. He added that if from the medium of molasses used in the distillery the growth promoting factors were removed the cell activity and its performance efficiency fell down. It was therefore necessary to replace the growth promoting factors to keep up fermentation efficiencies.

Dr. Mukherjee presented the following paper.

Paper

SUGAR CANE WAX—PART IV*

A SURVEY OF CANEWAX CONTENTS OF PRESS MUD FROM DIFFERENT SULPHITATION SUGAR FACTORIES OF INDIA

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This department has been actively engaged in studies on sugarcane wax, obtained from sulphitation press-muds, for the last fourteen years. The work was mostly directed to find a suitable solvent for economically extracting the wax, to purify and decolourise it. Work has also been done on the chemical composition and on the modification (2) of wax, so as to increase its solvent retentivity and hardness. It is well known that the wax-contents of press mud of different factories vary widely, but there are no data on record to show the percentage of wax in press-mud obtained from sulphitation sugar factories, situated in different parts of India. Moreover, different varieties of cane are crushed in mills situated in different parts of India and it would be interesting to know how the wax content varies with different varieties and different climatic conditions and varying methods of agriculture of sugarcane. It is well known that crude wax is a mixture of hard wax and soft fatty matter. The ratio of these two varies with different varieties of cane depending on the climatic and other agronomic conditions under which the cane has been grown. The most important part is the hard waxy matter of the crude wax, and this determines its usefulness in various industrial applications such as the manufacture of polishes, carbon papers etc.

India is entirely dependent upon foreign sources for its supply of hard plant waxes and imports annually about 25,000 cwt. of hard waxes. During the war, when imports ceased, industries dependent on these waxes suffered a lot and the price of carnuba wax went as high as Rs. 25 per lb. Even the present prices of hard vegetable waxes are high, carnuba about £600/ton, Curicuri about £640/ ton and Candilla about £600/ ton. It seems therefore appropriate

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*Parts I, II and III are published in the Proceedings of the Sugar Technologists' Association of India, 1952 and 1954.

to give proper consideration to sources of lesser known types, which may have commercial possibilities, if they are available in sufficient quantity and can be obtained at a competitive price. From this point of view sugarcane wax would seem to stand in a favourable position, since a sugar factory is a potential source of substantial amount of wax. The problem is of greater importance to India as she has no indigenous carnuba wax.

Sugar cane wax, which occurs as a whitish deposit on the surface of the sugarcane stalks is partially dislodged and finds its way in the cane juice during the milling operation ; more than 50% of the wax remains with the bagasse. During clarification of the juice, the wax is carried down with the heavy precipitate of lime salts and therefore there is an automatic concentration of wax in the filter press-mud and thus filter press-mud forms a very convenient source of sugar cane wax and it costs nothing from the point of view of wax extraction and is readily available at one place. The amount of wax which is present in filter press mud depends on many factors, of which the following may be mentioned. (1) The variety of the cane, (2) the severity of the milling process, (3) the type of filtration used, whether filter press or vacuum filters like the Oliver filter, (4) the temperature of the maceration water, (5) the climatic, soil and agronomical conditions under which the cane has been grown, (6) the process and efficiency of clarification, and (7) the method by which the trash has been removed from the cane *i.e.*, whether or not the cane is subjected to burning. It has been shown by Wiggins *et, al* 3, that burnt canes of the same variety, grown under the same conditions give muds containing less wax than those of unburnt canes and the loss of wax incurred on burning is considerable.

In India, about 90% of the sugar factories are using the sulphitation process for cane juice clarification and the percentage of press-mud is roughly about 2.5% on cane. Therefore in this present investigation a survey of wax contents of press-mud from sulphitation sugar factories situated in different parts of India was undertaken. The percentages of the hard waxy portion and soft fatty matter in the crude waxes were also determined. With this information it would be possible to plan as to where it would be most profitable to put up cane wax plant.

The extraction of crude wax from the press-mud is very simple, as the waxy constituents are very soluble in non-hydroxylic solvents e.g., benzene or petroleum hydrocarbons. Of the several solvents tried, benzene was found quite suitable. Thirty seven samples of air-dried press-mud from sulphitation factories situated in Bihar, Uttar Pradesh, Bombay and South India were collected during the crushing season 1953-54. The variety of the canes crushed from which the press-muds were collected, the type of filter used and date of collection were noted. In some cases samples were collected in the months of December, February and April to find out how the percentage of wax in the mud varies with the change of season. The wax contents were determined. The air-dried samples were finely powdered and exhaustively extracted in a soxhlet apparatus using benzene as solvent. The extract was filtered and the filtrate was evaporated to dryness and the residue was further dried in vacuum at 90-100°C. for several hours. The moisture contents of the air-dried samples were also determined to evaluate the percentage of crude wax on dry basis. The crude wax ultimately obtained was separated into hard wax and soft fatty matter, as described by Wiggins, *et. al* (loc.cit.). The crude wax 1 gm. is dissolved in hot benzene (15 ml.) and acetone (40 ml.) is added. The mixture is then kept over night at room temperature and the precipitated wax filtered off. The filtered wax is washed with a further quantity of acetone (5 ml.). The filtrate is then evaporated under vacuum and the product weighed as soft fatty matter. The hard wax content is then determined by difference. The results are given in Table I.

On examination of the figures of crude wax it will be observed that there are marked differences in wax yields from different territories as well as from factories employing different methods of filtration. Factories using Oliver filter have much lower wax content than factories using filter press for filtering the muddy juice, as in the former case the muds get diluted with bagacillo. It will be seen that crude wax content varies from 5.0% to 20.9%. Thus Godavari Sugar Mills, Sakarwadi, crushing mainly Co. 419 and 475 canes has only 5.0% crude wax in its Oliver filter mud, whereas the mud from Andhra Sugar Mills Limited, Tanuku, has 20.9% of wax in its filter press-mud. It may be observed in this connection that although the East India Distilleries and Sugar Agencies Limited, Nellikuppam is using Oliver filter for filtering the muddy juice, the wax content of the mud collected in the month of December, is very high, i.e., 18.1% and if the factory had used filter press for filtration, the wax contents would have been much higher than 20.9% as found in Tanuku.*

The wax content also varies with the season. Thus in most of the cases, where mud samples were collected in different months of the season, the wax content progressively diminished, as the crushing season progressed, e.g., in Mawana Sugar Factory, the wax content in the month of December is 13.45%, in February 12.9% and in April 8.6% and in Belapur Co. Ltd, Harigaon, Bombay, the figures are 12.2,10.8 and 6.8%respectively,except in the case of Walchandnagar Industries Ltd., Walchandnagar, the wax content of mud collected in February is higher than the mud collected in December, but the wax content of mud collected in April is lower than those of the mud collected in December or February. It may also be observed that press-muds from sugar factories situated in Bihar, Uttar Pradesh, Madras and Andhra have much higher wax content than those factories situated in Bombay Deccan.

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*However, one sulphitation sugar factory from Bombay Deccan gave only 1.55% wax in its Oliver filter mud and it was felt that it may be due to some error in sampling and has not been included in the table. It is proposed to do the analysis of the mud from that factory in the coming season.

TABLE I

S. No.	Source of mud	State	Type of filter	Date of collection	Variety of cane crushed	% of mud on cane	% of wax on dry mud	Composition. %of hard wax	Composition. %of soft wax
1.	New India Sugar Mills Ltd., Hasanpur Road	North Bihar	Filter press	Dec. 53	Ratoon Co. 313, 513, 458	2.1	17.1	76.0	24.0
2.	Lohat Sugar Work of the Darbhanga Sugar Co. Ltd.	,,	Oliver filter	Jan. 54	B.O. 11, & Co. 513	3.6	8.0	78.0	22.0
3.	-Do-	,,	,,	Feb. 54	B.O. 11, Co. 513 & Co. 313	3.8	4.2	—	—
4.	Samastipur Central Sugar Co. Ltd., Samastipur	,,	Filter press	Dec. 54	Co. 313— 0.3% Co. 453—37.4% Co. 513—11.6% B.O. 11—47.6% B.O. 10— 1.1% Other — 2.0%	1.1	12.4	72.0	29.0
5.	-Do-	,,	,,	Feb. 54	Co. 313— 0.3% Co. 453—37.6% Co. 513— 8·6% B.O. 11—52.1% B.O. 10— .2% Other — 0.2%	1.2	11.3	84.0	16.0
6.	Harinagar Sugar Mills, Harinagar	,,	,,	Jan. 53	Co. 453 B.O. 11 & B.O. 10	—	16.8	—	—
7.	Bharat Sugar Mills, Sidhwalia	,,	,,	Jan. 53	—	—	16.2	—	—
8.	Saraya Sugar Factory, Sardarnagar	East U.P.	,,	Jan. 53	Mainly Co. 453	—	11.9	—	—
9.	The Burhwal Sugar Mills Ltd., Burhwal	,,	,,	Jan. 53	Mainly Co. 453	—	13.2	—	—

TABLE I (*Contd.*)

S. No.	Source of mud	State	Type of filter	Date of collection	Variety of cane crushed	% of mud on cane	% of wax on dry mud	Composition	
								%of hard wax	%of soft wax
10.	The United Prov. Sugar Co. Ltd., Seorahi	East U.P.	Filter press	Dec. 53	Co. 513—90%	2.7	17.3	46.0	54.0
11.	-do-	,,	,,	April 54	Co. 513—75% B.O. 11—10%	3.0	10.1	46.2	53.8
12.	Experimental Sugar Factory, Kanpur	Central U.P.	,,	Jan. 53	Co. 312 Co. 453	—	17.0	83.0	17.0
13.	The Upper Ganges Sugar Mills Ltd., Seohara	,,	,,	Jan. 54	—	—	12.9	64.0	36.0
14.	-do-	,,	,,	April. 54	Co. 421, 453, 341, 186, 245	2.5	13.5	54.4	45.6
15.	The Kesar Sugar Works Ltd., Baheri, Bareilly	,,	,,	Dec. 53	Co. 313—15.4% Co. 421—34.7% Co. 300— 6.0% Cos. 76— 8.8% Cos. 146—25.2% Other — 9.9% } Ratoon-98.5% Virgin - 1.5%	2.8	18.2	66.9	33.1
16.	-do-	,,	,,	Feb. 54	Co. 312—30.5% Co. 313—13.2% Co. 421—40.0% Co. 300—11.8% Co. 290— 1.3% Cos. 76— 3.3% Cos. 146—19.7% Co. 419— 2.2% Co. — — 5.0% } Virgin-100%		14.4	79.9	20.1

TABLE I (*Contd.*)

S. No.	Source of mud	State	Type of filter	Date of collection	Variety of cane crushed	% of mud on cane	%of wax on dry mud	Composition	
								%of hard wax	%of soft wax
17.	L.H. Sugar Fys. and Oil Mills Ltd., Kashipur, Nainital	North U.P.	Filter Press	Dec. 53	Mostlly Co. 421 ndSmallamount of Co. 453, 331 and 313	—	18.2	64.5	35.5
18.	-do-	,,	,,	Feb. 54	Co. 421—65% Co. 453—25% Co. 527— 3% Other — 7%	2.2	12.6	67.8	32.2
19.	Mawana Sugar Works, Mawana	West U.P.	,,	Dec. 53	Co. 312 and Cos. 245	2.1	13.5	65.8	34.2
20.	-do-	,,	,,	Feb. 54	Co. 312 and Cos. 245	2.7	12.9	52.6	47.4
21.	-do-	,,	,,	April 54	Co. 312 and Cos. 245	2.6	8.6	66.7	33.4
22.	Simbhaoli Sugar Mills Ltd., Simbhaoli	,,	,,	Dec. 53	Co. 312 and Cos. 245	—	10.0	86.0	14.0
23.	-do-	,,	,,	March 54	Co. 312 and Cos. 245	—	11.1	80.0	20.0
24.	The Belapur Co. Ltd., Harigaon	Bombay	,,	Dec. 53	—	1.6	12.2	54.8	45.2
25.	-do-	,,	,,	Feb. 54	Co. 419	—	10.8	52.7	47.3
26.	-do-	,,	,,	April 54	Co. 419 (Adsali)	—	6.8	38.1	61.9
27.	Walchandnagar Industries Ltd., Walchandnagar	,,	Oliver filter	Jan. 54	Co. 419—99.0% P. O. J. 2878—1.0%	3.5	9.0	32.0	68.0
28.	,,	,,	,,	Feb. 54	,,	3.5	13.3	50.7	49.3
29.	,,	,,	,,	April 54	,,	—	8.4	47.1	50.9

TABLE I (*Contd.*)

S. No.	Source of mud	State	Type of filter	Date of collection	Variety of cane crushed	% of mud on cane	%of wax on dry mud	Composition	
								%of hard wax	%of soft wax
30.	Godavari Sugar Mills, Sakarawadi	Bombay	Oliver filter	Jan. 54	Co. 419 Co. 475	3.8	5.0	47.8	52.2
31.	,,	,,	,,	April 54	Co. 419 Co. 475	4.0	8.2	55.4	44.6
32.	Ravalgaon Sugar Farm, Ravalgaon	,,	,,	Feb.54	Co. 419	4.0	5.7	73.4	26.6
33.	Maharashtra Sugar Mills Ltd., Tilaknagar	,,	,,	Feb. 54	Co. 419	—	8.1	78.9	21.1
34.	Jaora Sugar Mills Ltd., Jaora	Madhya Bharat	,,	Jan. 54	Co. 419 Co. 453	3.6	10.05	36.0	64.0
35.	The Andhra Sugar Mills Ltd., Tanuku	Andhra	Filter Press	Jan. 54	Co. 419 - 70% Co. 527 - 30%	1.4	20.9	21.8	78.2
36.	The East India Distilleries and Sugar Agencies Ltd., Nellikuppam	Madras	Oliver Filter	Dec. 53	—	—	18.1	61.4	38.6
37.	,,	,,	,,	Feb. 54	—	—	16.6	57.0	43.0

It is very interesting to note, however, that there are distinct differences in the quality of crude waxes obtained from different parts of India. The products from Northern India in general are of better quality than those of other parts of India. It can be seen from the table that by and large, Bihar and Uttar Pradesh's crude wax contained about 70% of hard wax, whereas those from Bombay Deccan and Madras contained only about 50%. Although Andhra Sugar Mills Limited, Tanuku, press-mud has the highest percentage of crude wax, its hard wax content is lowest (21.8%) ; the press-mud from this factory is not therefore very suitable for the manufacture of cane wax. In this connection it is worthy to note that although the press-mud from Simbhaoli Sugar Mills, Simbhaoli, has crude wax contents of only 9.96%, the hard wax content of the crude wax is as high as 86%.

ACKNOWLEDGEMENTS

The author thanks Professor K. S. G. Doss, Director, National Sugar Institute, Kanpur for his kind interest in the work and to the managements of different factories for kindly sending the press-mud samples.

REFERENCES

1. (a) Rao, K.A.N. and Gupta, G.N. 1947. *Proc. S.T.A.* X (i), 337.
   (b) Chaturvedi, H.S., Gupta, G.N. and Sen Gupta, M.N., Nov. 1943. *Indian Sugar*, 1429.
   (c) Shrikhande, J.G. 1945. *Indian Sugar* (2), 42-45.
   (*d*) Doss, K.S.G. and Kripashanker. 1945. *J. Sci. and Ind. Research, India B*. 462.
   (e) Ramdeo and Shrikhande, J. G. *Proc. S. T. A. India* XV, Part I, 32.
   (f) Kapil, Y.P. and Mukherjee, S. 1952. *Proc. S.T.A.* 117-123.
   (g) Ibid. 1954. *Proc. S.T.A.* 220, 229.
2. Kapil, Y. P. 1955. *Fellowship Thesis of National Sugar Institute, Kanpur.*
3. Davison, B. K., Thomson, A.F., Wiggins, L.F. and Yearwood, R.D.E. 1953. *Proceedings of International Society of Sugarcane Technologists*, *8th Congress*, 663.

DISCUSSION

Shri Gundu Rao observed that at the Ravalgaon Sugar Farm Limited a wax extraction plant had been designed and put up by him which was producing crude wax from press-mud on a commercial scale. But the wax contained considerable proportion of soft matter. It was therefore necessary to devise a method and also a plant for modifying the properties of the wax so that the same could be used for manufacturing shoe polish, etc. He appreciated that the paper would serve as a guide for selecting a suitable site for locating a commercial scale unit for extraction of sugarcane wax.

Dr. Mukherjee observed that soft portion of the wax contained about 30% sterol, which might be recovered for manufacturing hormones.

Mr. J. P. Shukla presented the following paper.

Paper

PROCESS CONTROL IN INDIAN DISTILLERIES BY INSTRUMENTATION

J. P. SHUKLA AND K. S. TEWARI

National Sugar Institute, Kanpur

Instrumentation and automatic control in the industrial processes have assumed a vital importance of late to the executives, production engineers and plant operators. The application of automatic control equipment is being rapidly recognized as an important step in speeding up production and improving the quality of the product.

Every industry has some operation which involves control of temperatures, pressures, flows and other variables which can be improved by applying automatic controls. These improvements will result in higher quality of the product, increased throughputs and lower operating and manufacturing costs. The advantages of thorough instrumentation also lie in the avoidance of operators negligence. The instruction charts give the executives an opportunity to keep valuable check on daily operations. Fuel costs are always less when operating conditions are constant. The maintenance costs will be correspondingly reduced in so far as they will be less liable to extreme variations in temperatures and pressures. In fact it has been proved that large continuous process in chemical industry like that of alcohol can not operate efficiently without the aid of automatic control on feed rate, column temperatures and pressures.

The majority of Indian distilleries do not possess uptodate instruments and control devices. In the absence of adequate instruments uniform operating conditions are not achieved in the system and this results in higher maintenance and production costs, more fuel consumption and affects the quality of the products, in as much as our alcohol is rich in the acids, higher alcohols and head products and is thus of a much lower quality. It is thus becoming imperative that our plants should equip themselves with modern instruments and control apparatus.

The control of any process involves two steps—(1) measurement of variables and (2) their control devices. In a distillery operation the measurement of temperature, flow, pressure, liquid levels, speed etc., are extremely important. Variety of instruments both indicating and recording are available for these services.

The basic principles of control require the elementary physics of measurement and concept of heat transfer and the kinetics of flow. To raise the temperature of a fluid to a given point is comparatively simple but to maintain it within close limits involves a delicate balance between heat input, heat losses and heat absorption, The quantum of heat absorption will be influenced by conductivity, radiation losses, changes in the alcohol concentration of the vapours, atmospheric temperature changes and like factors.

In an industrial process the storage capacity as fluid volume or heat exchange has a tendency to keep the system in equilibrium. It may be of two kinds viz., demand side capacity and supply side capacity. Demand side capacity denotes the mass of material being heated. Supply side capacity refers to the mass and heat capacity of the heating medium.

Process time lags are of equal importance. Lag is the time interval which elapses between a process change and the time taken for its effect to be felt at the sensitive element. The shorter the time lag the simpler the problem of control.

The rate of heat transfer also plays an important part in controlling system.

Let us examine a standard fractionating column. In this case the velocities can not be increased beyond predetermined limits. These columns can be considered as heat exchangers, in which heat is absorbed and given up through a series of trays by condensation and evaporation, rather than by flow through pipes and tubes. Vapour velocities cannot be increased without affecting fractionating efficiency. Changes in temperature of the incoming vapour may well take minutes to reflect in the top of the column thermometers, depending on the number of plates. In such systems the load changes have to be kept down to a minimum for securing satisfactory control. If, however, a higher thermal potential is used in a system the size of the heat transfer equipment can be correspondingly reduced in so far as the rate of heat transfer from one medium to the other is proportional to the thermal differential. In this way a steam jacketted vessel can be heated by using high temperature steam more quickly than with a low temperature. In such cases the element should be allowed to move with greater velocity in tubular heaters to avoid burning. There is usually a reduction of lags in such systems and the advantage is offset by the reduction in heat storage capacity. The greater the thermal potential between supply and the demand the more difficult it is to serve an efficient control over the system. The oversizing of the control valves also gives similar effects. In both cases the main problem is to accurately position the control valve to accommodate the load changes.

Last but not the least important factor in a control system is the rate. It is defined as magnitude per unit of time. Every process whether it be heat treating or a distillery has a rate at which it comes to an equilibrium when heating or cooling is affected. In an alcohol distillery column the rate of heat input should be so regulated as to correspond closely to the heat absorbed. For various kinds of control devices, both instruments and valves influence the rate at which valves are opened or closed as against the magnitude of opening which is also important.

The magnitude of load change, rate of load change and rate of absorption of heat are all important factors and should be always considered while devising any system of control. The measurement of temperature can be made by electric pyrometers with thermo-couples or expansion thermometers with liquid or gas filled capillary systems. Measurements of flow, pressure, vacuum, liquid level and speed can be made by using suitable electrical or mechanical flow-meters, pressure and vacuum gauges and level meters. These instruments are available and can be selected according to the individual requirements.

The following types of electric or air operated controls are adopted :

(1) Two position, on-off ; high low.
(2) Proportioning ; adjustable sensitivity ; proportional position.
(3) Proportioning with automatic reset.

TWO POSITION, ON-OFF ; HIGH LOW

It includes all types of control equipment, electrical, pneumatic and hydraulic, in which high and low contacts around a given control point are made to open or close a valve or to move a valve to two positions which may or may not be fully opened or fully closed. These kinds of instruments do not respond to the rate or magnitude of load changes and work with satisfaction only if there is a large storage capacity, minimum process lags and low thermal potentials.

PROPORTIONING ; ADJUSTABLE SENSITIVITY ; PROPORTIONAL POSITION

This is also called throttle controller in as much as the valve does not travel fully immediately for small increases in temperature. It, on the other hand, adjusts itself with regard to control point.

PROPORTIONING WITH AUTOMATIC RESET

In the case of proportioning controller, it would be noted that there is no device to return the pen to the control point after a pen departure due to load change. When automatic reset is introduced in the controller, the pointer automatically comes back to the original control index. This device is available both in the case of pneumatically and electrically operated instruments but the former system is simple and easy in working. The most popular type of proportion control and automatic reset system is the Brown Air-O-Linc Controller.

The process control in the power alcohol distilleries can be regarded to involve the following operations :—

A. Dilution of the molasses and preparation of wort.
B. Sterilisation.
C. Fermentation.
D. Distillation and rectification.
E. Dehydration.

The power alcohol plants in India are being operated only on manual control. There is no data in regard to fuel consumption and heat balances. The relative efficiencies of the columns and their performance against standards have not been compared and need investigation. The plants were made during war period and several of them locally, using improper material for construction and employing inexperienced labour. They are, therefore, not accurate and have low efficiencies. Some of them already need replacement. It will, therefore, be only proper to step up the efficiencies and take recourse to instrumentation of the plants for automatic control and data collection.

DILUTION AND PREPARATION OF THE WORT

This operation involves obtaining a constant density of the solution having a more or less constant sugar concentration that is optimum for fermentation. The following two methods are indicated.

1. Manually operated injection type of continuous dilution and sterilisation by steam injection.
2. Control of water inlet for dilution, made automatic on the desired brix.

Fig. 1 shows the arrangement to be adopted.

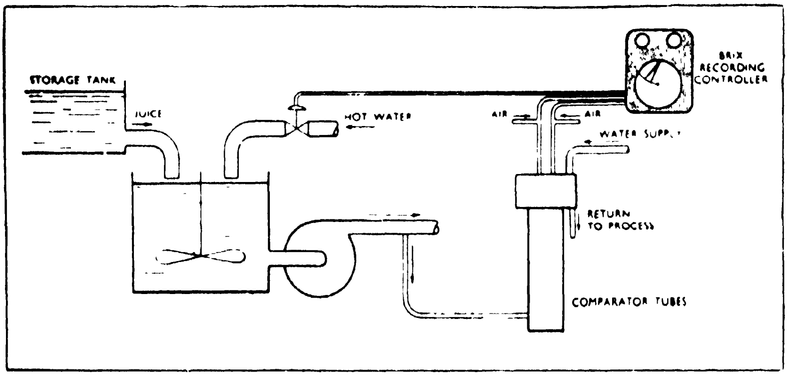

Figure 1.

PASTEURISATION OR STERILISATION

At present the main musts are not being sterilised nor is it considered essential for the industrial or power alcohol distilleries in view of abundent supply of molasses at cheap rates as are found in India. However, sterilization of musts for the production of industrial alcohol, rum, food yeast etc., has undisputed advantages. Tubular type of preheater and pasteurizer as shown in Fig. 2 will

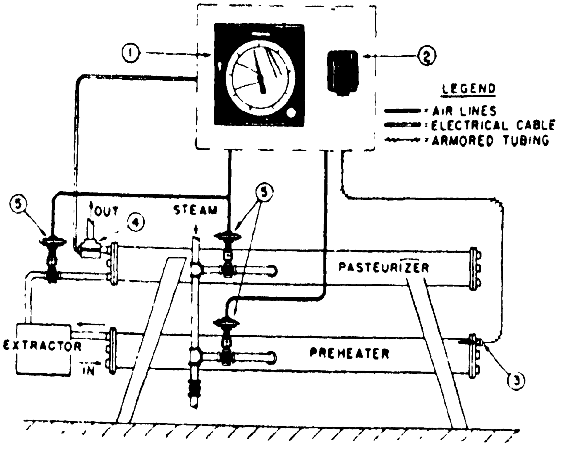

Figure 2.

be found to be useful. The continuous open cooker with temperature control as shown in Fig. 3 will be simpler and may be found to be less costly.

FERMENTATION

With a yeast population of 100 million cells per millilitre for rapid or high brix or continuous fermentation or 40-60 million cells per millilitre for batch type of fermentation where a wort is fed at controlled brix or sugar concentration, the efficiency can be improved by controlling the temperature of the wort and pH. In alcohol distilleries the limits of allowable variations are rather wide and molasses is richly buffered. It will, therefore, be found sufficient to instal the temperature recorders on the main fermenters, and yeast culture vessel to keep a check on the rise of the temperature of fermenting wort specially during summer months. A pH recorder located in the inlet line of the wort can also be installed to keep a seehow of diluted molasses with regard to its pH and acid addition but is not insisted upon.

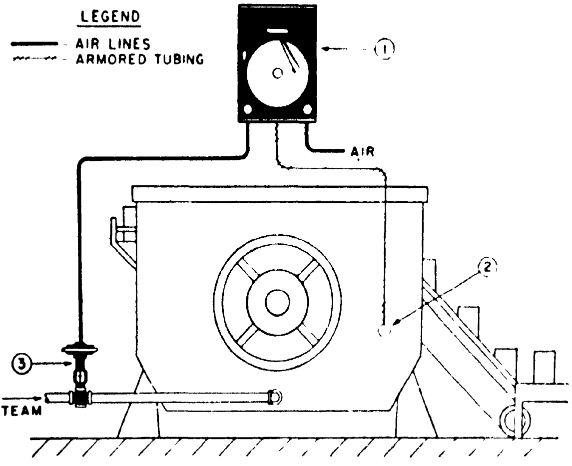

Figure 3.

DISTILLATION AND RECTIFICATION

For efficient operation of the distillation and rectification and obtaining high distillation efficiencies and heat economy correct instrumentation of the columns along with suitable automatic controls is absolutely essential. The following will be found useful for installation of the recording instruments.

1. Steam flow to the distillation house. The quantity of steam taken in the plant should be measured.
2. Total water taken for the condensers should be measured by water meters.
3. Air pressure supply to the control air operated instruments.
4. Temperature of the top and bottom of the analyser (beer column).

5. Temperature at the base and middle of the rectifying column.
6. Temperature of the feed entering the beer column or analyser.
7. Temperature of the condensers of the rectifying column.
8. Pressure at the base of the analysing column and the top.
9. Temperature at the base and top of the dehydration column and at the feed plate.
10. Temperature of the dehydration column condensers.
11. Temperature of the decanters.
12. Temperature at the top of the benzene recovery column.
13. To measure the rate of liquid flow and draw, rotameters are to be provided at different places as outlined below :
    (a) Rectified spirit draw from rectifier to the storage tank and feed of the same to the dehydration column.
    (b) Benzene feed and reflux benzene draw from the decanter.
    (c) Absolute alcohol draw to the storage.
    (d) Heads draw from the rectifier top.
    (e) Water fed to the benzene decanter.
    (f) Fusel oil draw and water for washing the fusel oil.

AUTOMATIC CONTROLS

The balancings of the column for purposes of the automatic controls is suggested as follows :—

1. The proof spirit at the top of wash column controls the feed (reflux) of the analyser column.
2. The proof, the absolute alcohol draw off, controls the rectified spirit feed to the dehydration column.
3. Reflux of the dehydration column controls the steam.
4. Condenser temperatures control the water inlet (with the flowmeters recording consumption).
5. Temperature of the top of dehydration column controls the benzene feed.
6. A sensitive steam regulator of the usual type should be installed and operated by pressure at the top of the analyser column to operate on the steam inlet in the beer column.

The instruments outlined above do not take into account the recording instruments to be used in the boiler or power portions of the plant and should be considered separately. As a minimum requirement a temperature recorder for the hot water inlet, and CO_2 recorder for the flue gases besides the usual temperature and pressure recorders for flue and steam must be installed. In the Indian distilleries this station is being neglected. The hot water from the condensers and the heat from the spent wash is being wasted, and the lagging of the steam pipe lines is not attended to.

It will be futile to expect results from the automatic controls and recording instruments if the basic steam supply is not having the normal efficiencies.

Fig. 4 gives the arrangement on the lines suggested in the text of the paper as a tentative measure. There are various alternatives which may be substituted and it is left to the individual distilleries to make selection of the installation, along with the instruments as are available from firms like M/s. George Kent Ltd., Luton and London or the Brown Instrument Coy. Philadelphia, Pennsylvania Division of the Minneapolis Honeywell Regulator Co. etc., who will be glad to supply further details.

The present note is oniy an attempt to emphasize the lines on which instrumentation of the distilleries is to be gone into.

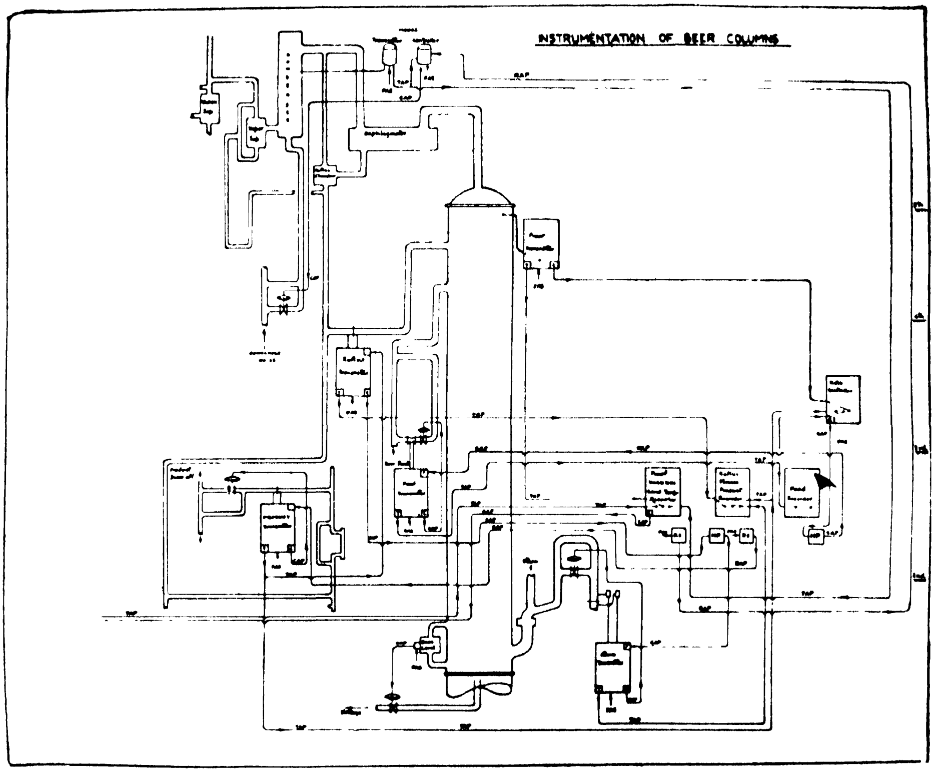

Figure 4.

ACKNOWLEDGEMENT

We wish to thank M/s. Brown Instrument Co., and M/s. George Kent Ltd. from whose technical literature we have drawn information. We are also thankful to Dr. K. S. G. Doss, Director, National Sugar Institute, Kanpur and the Excise Commissioner, U. P. for taking keen interest in the work.

Mr. Chaturvedi presented the following paper.

Paper

UTILIZATION OF BAGASSE FOR PAPER AND CATTLE FEED MANUFACTURE IN INDIA

V. Podder, K. Lenz and H. S. Chaturvedi

Rohtas Industries Ltd., Dalmianagar, India

Bagasse, the woody refuse of the sugar cane, after the extraction of the juice from it, has been known to be a very suitable raw material for the pulp and paper industry for a long time. However, until very recently all attempts to utilize this raw material for the Paper Industry failed on account of various reasons both economical and technical. Until the last couple of decades the importance of separating the pith (the residue of the sugar containing parenchyma cells of the cane) from the fibre for producing high quality pulp was not realised and this was perhaps one of the main reasons for the failure of the earlier attempts. It has now been established beyond doubt that for the manufacture of high quality pulp it is essential to remove a certain percentage of the pith from the bagasse before the chemical treatment.

Bagasse Pulp Mills have been started in various countries and reported to be doing well. In Formosa a hundred ton unit is reported to be operating using the neutral sulphite cooking process. In Peru (S. America) one plant is operating the ' Grace Process ' for pulping Bagasse and in the Philippines the 'Celdicor Pomilio Process' is in operation. In India also work was being done on the utilisation of bagasse for many years and M/S. Rohtas Industries Ltd., Dalmianagar took the initiative in establishing the first and the only Bagasse Pulp Mill in the country at present. The Cellulose Development Corporation of England was entrusted with the order for all the machinery and equipment. Thls plant went into production in 1951.

India is a major sugar producing country and over 14 million tons of cane, yielding about 2.2 million tons (bone-dry) of bagasse, are crushed annually in the sugar factories in the country. However, most of the bagasse is at present used as fuel for producing steam and generating power for the factories' own use. Only part of this bagasse could be released for the Pulp Industry as many of the factories are situated in places where alternative fuel is not cheaply available. However, even if one million tons of bagasse is made available to the Paper Industry it would suffice to produce 3,40,000 tons of paper based on 34% yield on the raw material. This is about double the production capacity of the existing Paper and Board Mills in India.

BAGASSE V. COAL

Under the present conditions the most suitable sites for establishing Bagasse Pulp Mills in India are East U. P. and Bihar. Coal, which is the only alternative fuel is cheaply available in this region. On a conservative estimate the steam consumption of a sugar factory working on the sulphitation process may be taken as 55% and for a carbonation factory 66% on cane. One lb. of bagasse with 48% moisture content will produce about 2.2 lbs. of steam in boiler of average efficiency. Thus the bagasse requirement in a sulphitation factory will be 55/2.2=25% on cane. In a carbonation factory it will be 66/2.2=30% on cane. In modern plants these figures can be reduced considerably. One lb. of coal with its calorific value as 12000 B.T.U. will produce 8 lbs. of steam in a modern boiler. Thus the coal consumption in a sulphitation factory, if all bagasse is to be saved, will be 55/8=6.9% on cane, while in a carbonation factory it will be 66/8=8.25 on cane.

Experimental : Bagasse is almost pure ligno-cellulose with a small amount of unextracted sugars, gums and waxes. The composition of an average sample of bagasse available in Bihar is as follows :—

1.	Lignin content	17%
2.	Cellulose	57%
3.	Pentosans	22%
4.	Ash	3%

The proper storage of bagasse is a very important factor in the successful operation of bagasse pulp plant. In our country it is essential to protect the bagasse bales from the rains during the monsoon. The amount of loss in improper storage can be visualised from the figures given in Table I, giving the results obtained with 100 bales stored in a packed stack with insufficient air circulation and examining at the end of one month and then after one year.

TABLE I

DETERIORATION OF BAGASSE DURING UNSATISFACTORY STORAGE

		After 1 month			After 1 year	
No. of bales	Gross weight	Moisture %	Bone-dry weight	Gross weight	Moisture %	Bone-dry weight
50	1850	12.4	1621	1340	10	1206
30	936	10.3	840	858	10.7	776
20	659	17.6	543	576	8.6	527
			3004			2509

$$\% \text{ loss} = \frac{3004-2509}{3004} \times 100 = 16\%$$

It is believed that this loss can be minimised if proper storing methods described above are followed. It is but natural to expect the best and most economical pulping results with mature bagasse free as far as possible, from fermentation and deterioration.

The fibre characteristics of bagasse pulp together with those of bamboo and other pulps are given below in Table II.

TABLE II

	Freeness SR.	Average length mm.	Av. width mm.	Ratio of L.W.	Below 1 mm.%	Above 1 mm.%
1. Bagasse bleached unbeaten	150	1.216	0.0186	64.4:1	54.00	46.40
2. Bamboo bleached unbeaten	13.75	1.7072	0.0129	132.3:1	28.30	71.70
3. Sulphite bleached unbeaten		2.416	0.03616	66·0:1	5.00	95.0

THE CELDICOR PROCESS AT DALMIANAGAR

The bagasse is baled to facilitate storage just as it leaves the sugar factory. The bales are stored for at least three months, during which period the moisture content of the bagasse falls to 10—15%. In the preparatory plant the binding wires are first removed from the bales manually and a belt conveyor then feeds the bales to the opening machine and the disintegrator. About 20-22% pith is separated from the fibre and screened out in a screening drum and a cyclonic dust-collector. The pith is collected in a pith collecting unit and used for packing purposes or destroyed. It is now proposed to make " Bago-Molasses " cattle feed out of this pith. The dusted bagasse falls into a Dosing Machine, from the cyclone, where it is soaked with a dilute caustic soda solution (2.5—3% strength) and subsequently fed to the continuous digestion tower. This is always kept full—the rate of extraction of the semi pulp controlling the feeding rate of the bagasse. The tower is steam jacketted and the temperature increases as the bagasse moves down the tower. An agitator at the bottom of the tower facilitates extraction and the pulp with the black liquor is pumped up to the wash filters for black liquor washing. There are two vacuum filters in series and in between the washing the pulp is given a mild disintegration treatment. After washing the pulp is dried to 30%consistency in a set of screw presses and the fibres opened out in an Opening machine for chlorination. There are three chlorination towers in which the pulp moves down from the top. Chlorine is forced in by a chlorine fan slightly more than half-way down the towers and the chlorinated pulp is extracted at the bottom by means of a specially designed extractor. The chlorinated pulp is diluted and washed over and acid pulp thickener and neutralised with caustic liquor in the Alkaline chest. The pulp is again washed over a vacuum filter and screened before the hypochlorite bleaching which is done in hollanders. The pulp is finally washed over another filter and pumped to the Beater House, for preparing the stock for the Paper Machines.

For the economical and successful operation of a high quality Bagasse Pulp Mill, it is necessary to

(1) have proper storage of bagasse,

(2) remove atleast twenty percent pith and

(3) utilize the pith removed as far as possible.

India today imports nearly 1,00,000 tons of papers and boards every year and the per capita consumption of paper is only 2 lbs. With the increasing living standard of the masses the consumption is bound to increase very appreciably. In view of the shortage of the existing raw materials, wood, bamboo and sabai grass in this country, bagasse appears to be the most promising raw material available to the Paper Industry in the years to come.

PITH

Considering that about 22% of pith is separated in the process described above, it is evident that proper use for this has to be found if the cost of paper making from bagasse has to be further reduced. M/s. Rohtas Industries Ltd., will be producing about 13 tons of pith per day. It is considered that the best use that can be made of this is for cattle feeding purposes. While no published data are available showing nutritive value of pith as cattle feed, it is generally assumed that it is similar to corn cobs which are considered in U.S.A. to have 60% of the feeding value of corn (Lathrop & Aronovsky-Sugar Journal, June 1951.)

In the U.S.A. 25 million tons of mixed feeds are consumed annually and it should be possible to develop a market for such feeds in our country. In Louisiana pith removed from coarse bagasse by dry screening is being used at present as molasses absorbent and extensively fed to cattle after mixing with other proteid feeds.

The following table will show the analysis of bagasse screenings along with other common roughages used in India at the present time :—

Roughage	Water	Ash	Crude Protein	Carbohydrate Fibre	Carbohydrate Nitrogen free extract	Fat
Bagasse screenings 49 mesh	6.8	5.2	1.4	42.2	43.5	0.8
Wheat straw	8.4	5.2	3.1	37.4	44.4	1.5
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4
Rice straw	7.5	14.5	3.9	33.5	39.2	1.4

M/s. Rohtas Industries have therefore put up a plant for the manufacture of Bago-molasses developed at the National Sugar Institute, Kanpur. This feed consists of one part of air-dry bagasse pith mixed with two parts of hot molasses and pressed into cakes for facility of transport, storage and handling.

The average composition of such feed is given below :—

	%
Crude protein	2.71
Crude fibre	16.09
Ether extract	0.37
Total ash	16.09
Nitrogen free extract	64.45
Lime (CaO)	1.45
Phosphate (P_2O_5)	0.22
Digestible nutrients (per 100 lbs. of dry matter)	
Crude protein	Nil
Starch equivalent	43.0

For the sake of comparison, the food values of other agricultural products are given below :—

	Digestible protein %	Starch equivalent %
Bago-molasses	Nil	43.0
Gram husk	,,	42.3
Wheat bhusa	,,	22.1
Rice straw	,,	18.6
Average mixed hay	0.5	25.0

It will be seen from the above that Bago-molasses is a rich carbohydrate feed and requires to be supplemented with other protein feeds to make the ration balanced, such as oil cakes, bran etc. For the present users of this feed will be advised to mix necessary proteid material to the Bago-molasses before feeding to the cattle. The company has projects for the erection of a Urea Plant as also for the Solvent Extraction Plant. When these projects take shape finally, it is intended to turn out from Rohtas Industries Ltd., a fully balanced feed for the cattle, which would no longer require the addition of any other proteid feed to the Bago-molasses.

The recent researches on the ability of the microorganisms present in the rumen of the cattle to utilise non-protein nitrogen into protein form for the cattle open up a vast field for solution of the nourishment problem of the half starved cattle population of our country.

It should be possible hereafter to ammoniate the molasses or add urea to it while manufacturing the balanced feeds containing bagasse pith, molasses and oil cake. Such feeds would then be supplied to dairies, concentration camps for cattle and Pinjra poles to be started in the Second Five Year Plan.

The animal husbandry wing of the I.C.A.R. which met at Ranchi in the first week of May 1955, rightly felt that the improvement achieved through cattle breeding and disease control measures could not be maintained unless the improved progeny was adequately fed. They have thus recommended that the Government should initiate a" Grow-more-fodder-Campaign" to keep the cattle in a proper state of health with the same vigour and enthusiasm as was shown in the case of " Grow-more-food-Campaign ".

The feeding value of Bago-molasses has already been determined at a number of animal nutrition centres in India by actual feeding trials extending over long periods under a scheme financed by the I.C.A.R. a few years back.

The feeding reports have shown clearly that the animals progress well and their general condition, health, milk-yield, as well as growth have been satisfactory. The feed was also reported to be quite palatable to the animals.

DISCUSSION

Mr. Duyf observed that quite a good amount of data had been brought forth and he knew experiments had been in progress on " Bago-molasses ' since long. The feed appeared to be good but the difficulty was that the animals were not attracted towards it.

Mr. Chaturvedi replied that they were manufacturing considerable quantities of "Bago-molasses" cattle feed on a commercial scale at the Dalmianagar Sugar Factory and the same was being purchased by the farmers. The cattle do take some time to have a liking for it but once they do so they like it very much. There appears to be a prejudice in this regard that the animals taking " Bago-molasses " develop a purging tendency. If, however, the animals were made to lick a lump of sodium chloride (common rock salt) the sodium balance of the animal body gets adjusted and the use of " Bago-molasses " then produces no harmful effects.

In the absence of the author the following paper was taken as read.

Paper

THE AMMONIATION OF MOLASSES

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INTRODUCTION

The patents of Millar (1) and Stiles (2) on the ammoniation of beet pulp and of molasses respectively focused attention on the technique of ammoniation as a means of fixation of nitrogen in a form suitable for use in animal feeding stuffs. In a protein hungry world any way by which it might be possible to augment natural protein supplies is worth serious study especially if it also uses unwanted or surplus by-products of other industries. Both beet pulp and molasses are already well known as cattle feeds but both are deficient in nitrogen and hence are essentially only producers of energy and cannot be considered as body building foods. Millar found that the nitrogen content of beet pulp could be substantially increased by treating it with ammonia. This idea did not meet with any great enthusiasm, probably because of technical difficulties in conducting the ammoniation, but more recently the idea is being looked at with more favour and ammoniated beet pulp will almost certainly become a useful ingredient in animal feeding stuffs. The ammonia in ammoniated beet pulp is probably found in the form of ammonium salts of the polyuronides which are present in beet pulp and possibly also as a compound with the lignin of the cellular constituents. Thus, there can be little doubt that nitrogen bound in this way is useful to ruminant animals which, through the rumen microflora, can convert simple compounds of nitrogen into the building bricks for protein synthesis. In the case of molasses, however, the situation is not quite so straightforward. It may be a little difficult, at first sight, to understand how molasses, consisting as it does of sucrose, reducing sugars and inorganic salts, can possibly fix ammonia. It certainly can not do so in such a simple manner as obtained in the case of beet pulp. The ammoniation procedure, according to Stiles, consisted of the heating of molasses with aqueous ammonia or with anhydrous ammonia. In the latter case the ammonia was passed through a sparger into the molasses. If ordinary molasses was used Stiles found that the maximum amount of nitrogen fixed in such a form that it was not removed on heating the product with dilute alkali, was 2.46%. If the molasses was pre-treated with agents such as invertase or acid so that all the sucrose therein was inverted then the maximum amount of fixed nitrogen was increased to 4.06%. Using the factor 6.25 the crude protein equivalents of these two types of ammoniated molasses are therefore 15.6% and 25.4% respectively and if the nitrogen can indeed be used as a source of protein these figures make it clear that ammoniated molasses may well become of great value as a new ingredient in animal feeding stuffs.

THE AMMONIATION TECHNIQUE AS DEVELOPED IN TRINIDAD(3)

The equipment used in our experiments consisted simply of a stainless steel reaction vessel fitted with a high speed (1120 r.p.m.) impeller type stirrer. A cylinder of anhydrous ammonia was linked to the vessel through a valve by a stainless steel tube. The ammonia is led to the top of the vessel and is not sparged through the molasses. The reaction vessel used is made to withstand 60 lbs. per square inch pressure and temperatures of 150°C.

A 120 lbs. charge of molasses was first inverted by adding 30% sulphuric acid (5 : 1) and heating the stirred mixture at 90-95°C. for one hour. Thereafter the mixture was allowed to cool to about 70°C. when the requisite amount of 35% caustic soda solution was added. After allowing the neutralized solution, now of about 70° Brix, to cool to 50-55°C., anhydrous ammonia was admitted to the gas space above the molasses and the mixture vigorously stirred. The ammonia is rapidly taken up and the temperature rises to 100-120°C. The ammonia feed rate is throttled down so that little or no positive pressure of ammonia builds up in the vessel. The jacket of the vessel is then steam heated so that the temperature of the charge is kept at 120°C. for about 2 hours. The amount of ammonia gas used, is of course weighed so that the desired degree of ammoniation of the molasses may be affected. In our experience it is possible to introduce between 6 and 7% of fixed nitrogen into the " invert " molasses. At the end of the reaction the product is blown off into an open vessel whilst still quite hot so that any surplus ammonia is removed. Prolonged aeration is necessary in order to remove excess ammonia from cold ammoniated molasses. Ammoniated " invert " molasses is a black liquid which has rather a burnt-bitter taste but no unpleasant odour. Its fixed nitrogen content is determined by the Kjeldahl method after having boiled the sample with dilute caustic soda to remove any occluded ammonia or ammonium salts.

THE NATURE OF AMMONIATED MOLASSES

When the chemical nature of ammoniated molasses comes to be examined, the first important point which emerges is that almost all the reducing sugars have been transformed into non-sugars. Chromatographic examination of ammoniated molasses revealed the presence of only traces of glucose. If non-inverted molasses is ammoniated then only the reducing sugars are transformed into non sugars and the sucrose contained in the molasses remains essentially intact. Paper chromatography also revealed the presence of eleven substances responding to the Pauly test (4) for imidazole derivatives.

Polarographic examination (5) of ammoniated invert molasses showed that it gave a strong reduction wave corresponding to the presence of considerable quantities of active material and this fact is being used to follow the course of the ammoniation reaction. Fig. 1 shows how the polarographic activity increases as the reaction progresses and indeed that the concentration of polarographically active material begins to increase rapidly when the temperature of the vessel reaches about 80°C.

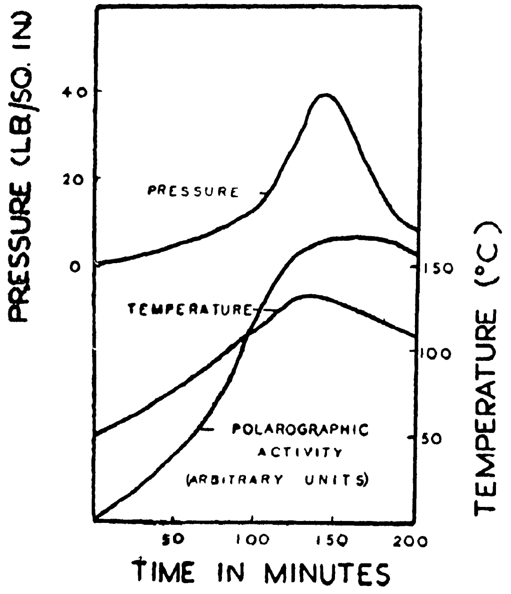

FIG. 1.

Solvent extraction of ammoniated molasses furnished a liquid containing both imidazole and pyrazine components and the compounds listed in Table I have actually been isolated from the mixture.

TABLE I(6)
SOME COMPONENTS OF AMMONIATED MOLASSES

Imidazole Derivatives	*Pyrazine Derivatives*
4 (5)-methylimidazole	2:6-dimethylpyrazine
	2-hydroxymethylpyrazine
	5-hydroxymethyl-2-methylpyrazine
	2-methyl-5-arabotetrahydroxybutylpyrazine
	2-methyl-6-arabotetrahydroxybutylpyrazine

Although only one imidazole derivative has been isolated, paper chromatography, as mentioned above, has revealed the presence of many substances of this type and it is highly likely that some of these will contain hydroxylated side chains.

Because of the fact that there are many different types of imidazole and pyrazine derivatives present in ammoniated molasses it is difficult to estimate those quantitatively. However, because many imidazole derivatives give rise to an intense red colour with diazosulphanilic acid in sodium bicarbonate solution it is possible to compare that obtained with pure imidazole with the colour derived from the mixture of imidazoles in ammoniated molasses and hence form a very rough estimate of the concentration of the latter. On this basis ammoniated invert molasses (6% N) contain about 10% by weight of imidazole derivatives.

The polarographic activity of pyrazine compounds can similarly be used to form an estimate of the amount of this type of compound present in ammoniated molasses. This appears to be quite large, about 20% by weight. It would therefore seem that most of the nitrogen content of ammoniated molasses can be accounted for in the form of imidazole and pyrazine derivatives.

AMMONIATED MOLASSES IN ANIMAL FEEDING

Although the preliminary reports (7, 8, 9) on the feeding of ammoniated molasses to ruminant animals were encouraging and revealed no serious problems either of palatability or of toxicity, ammoniated molasses has not yet been used for cattle feeds on a large scale. Attempts to do so were frustrated because it was found that some animals were affected by an intense hysteria. On the other hand, on many animals the ammoniated molasses had no harmful effect. A 180-day feeding trial carried out with water buffalo in Trinidad(10) was designed to examine whether it would be expedient to feed ammoniated molasses to farm animals and ½ lb. per head per day of the material was fed with chopped cane tops. No difficulties either from toxicity or palatability were encountered. However, a young Zebu calf, fed ammoniated invert molasses at the rate of ½ lb. per day mixed with ordinary concentrates, suffered a severe bout of hysteria. Furthermore, in Jamaica, two steers (Red Poll-Indian stock) were fed 1 lb. ammoniated invert molasses mixed with 3 lbs. citrus pulp. The animals took slowly to the feed but having become accustomed to it, over two days consumed the next batch which was offered in about six hours. During the next hour, however, one of the animals became quite mad and charged through two 5-strand barbed wire fences and a stout wooden fence before being caught. The other animal behaved quite normally. The National Institute for Research in Dairying at Shinfield in England has had a similar experience (11). Whilst the possibility of such toxic disorders exists, ammoniated molasses can have no chance of being used on a large scale. However, two methods of surmounting the trouble have been found (12). In one of these the heterocyclic compounds of small molecular weight which we believe to be the cause of the trouble are extracted with a solvent. The residue is then innocuous to animals fed on it. The extract itself is useful as a source of pyrazine and imidazole derivatives and may indeed be valuable if uses for these materials develop. The other method is simpler and consists of acidifying the ammoniated molasses with a non-toxic or food acid such as phosphoric, acetic or lactic acid. This gives products which are more palatable to sheep and cattle and have so far given no indication of causing toxic disorders. In trials with sheep the acidified ammoniated molasses was fed in gradually increasing amounts up to 2 lbs. per head per day over two 8-week periods separated by a 3-week rest period and the sheep remained normal and in excellent condition throughout the 19 weeks.

Thus it is believed, though of course further and more extensive trials are necessary, that the toxicity problem associated with the feeding of ammoniated molasses has been solved and if this is the case it may well be that this product will achieve considerable importance in the cattle feed industry and also provide a new outlet for a sugar factory by-product.

REFERENCES

1. Millar, H. C. 1942. U. S. P. 2,293,845.
2. Stiles, H. R. 1951. U. S. P. 2,603,567.
3. Joblin, A. D. H., Thomson, A. F. and Wiggins, L. F. 1955. *Proc. B. W. I. Sugar Tech. Conf.*
4. Pauly, H. 1904. Z. Physiol. Chem., 42, 508.
5. Wiggins, L. F. and Wise, W. S. 1955. *Chem. and Ind.*, No. 23, 656.
6. Wiggins, L. F. 1955. *Sugar J.*, in the press.
7. Magruder, N. D., Knodt, C. B. and Williams, J. B. 1953. *Agric. and Food Chem.*, **1, 944.**
8. Knodt, C. B., Williams, J. B. and Brumbaugh, J. 1951. *J. Dairy Sci.* 34, 1042.
9. Tillman, A. D. and Swift, R. W. 1953. *J. Anim. Sci.* 12, 201.
10. Howes, J. R. and Wiggins, L. F. 1955. *Proc. B. W. I. Sugar Tech. Conf.*
11. Wiggins, L. F. 1955. Private communication.
12. Wiggins, L. F. 1955. Brit. Pat. Application 11,509.

DISCUSSION

Shri Shukla observed that considerable amount of useful data had been collected in the paper. It was however mentioned in the paper that the horses and the mules fed on ammoniated molasses became hot and restless. This difficulty had to be got over. In his opinion another approach would be to fix the carbohydrate in molasses and the inorganic nitrogen in ammonium sulphate for the production of yeasts which could be used as a concentrated fodder. This feed would not only be free from the harmful effects of ammoniated molasses but also have all the advantages of being rich in growth promoting factors, assimilable nitrogen and nutrient rumen microflora and could probably compete in cost also where molasses was abundant and cheap.

SYMPOSIUM ON SUGAR ENGINEERING

SYMPOSIUM ON SUGAR ENGINEERING

Session—Wednesday, 1st February, 9-15 A.M.

RECENT DEVELOPMENTS IN SUGAR CANE MILLS

MR. K. S. ARNOLD, *Chairman*

INTRODUCTION

A number of advances have been made in the detailed design of mills over recent years, and some important developments have taken place, all of which are contributing to the higher crushing rates and improved efficiencies now being obtained. Some of the developments are radical in character, and give indication that certain items of plant—accepted as standard over a long period of years—are in process of being superseded by equipment of entirely different types. Apart from new developments, there are also some changing trends in the use of certain items of equipment associated with milling plants.

In this Symposium the more important of recent developments—apart from those already dealt with in the papers—are briefly described, and questions in relation to these are raised so as to stimulate discussion among delegates. It is hoped that both those responsible for the operation of mills and those engaged in their design and construction will contribute information gained from their various experiences and will also ventilate their problems.

The following aspects are dealt with :—

(a) Cane Shredders.
(b) Roller Grooving and Surface Speed.
(c) Mill Feeding Devices.
(d) Intermediate Carriers.
(e) Juice Strainers.
(f) Mill Roller Bearings.
(g) Hydraulic Pressure systems.

(a) CANE SHREDDERS

(Introduced by Mr. W. M. Livie, Australia)

Shredders for the disintegration of cane in the milling process have been employed for over 30 years but have never been universally adopted. In certain territories they have been largely employed, in others only occasional applications have been made, and in some none at all. In certain countries, where at first they were extensively installed, their popularity has waned, while in others there are indications of growing popularity.

At one time almost all the larger mills in Hawaii used the hammer-type shredder. Some factories subsequently removed the shredder permanently, while others—having removed them—have now re-installed them. Today 11 out of a total of 31 tandems, are equipped with shredders in that territory.

The hammer-type was also popular for a period on certain mills in the West Indies, but has now been discarded. They are still in favour on certain mills in South Africa and further installations are contemplated.

Formerly the National shredder was used extensively in Australia, but only a few are retained in service today. Around the year 1920 there were 3 mills in that country using the hammer-type shredder, about 8 more have since added shredders of this type, and there are indications that further installations may be made.

The hammer-type shredder does not appear to have been installed as yet in any factory in India. A number of Maxwell shredders were, however, formerly in operation but it is believed that these have all now been discarded.

As adjuncts to cane mills, shredders do not appear at any time to have been adopted on the majority of mills in any cane sugar country, and have experienced a varying degree of popularity. While they are undoubtedly well suited to deal with certain specific conditions—such as the preparation of extremely hard canes like Uba—their essential value on a milling plant still remains undecided. The almost universal adoption of cane knives—with in some cases two sets to a tandem—doubtless reduces considerably the advantages to be derived by the use of a shredder.

From the general experience in the use of shredders in many countries the following questions naturally arise :—

(a) Will the addition of a shredder to a milling plant always be justified by the improved results obtained—either by way of increased crushing rate, higher extraction, or a combination of both ?

(b) If not always justified, what are the factors which should decide a particular application ?

DISCUSSION

Mr. Livie stated that of the 12 Colonial Sugar Refining Company's Mills in Australia, 6 employed hammer-type shredders, and 4 National shredders. Good preparation of cane can be ensured either by knives or shredders. In one factory this shredder has been removed and two sets of high speed knives installed, resulting in an increase in crushing rate of 15 tons per hour.

Mr. J. H. Nicklin stated that in about 25 other factories in Queensland 10 shredders were in use.

Mr. O. M. Henzell said that he knew of only two hammer-type shredders operating in the West Indies, and these were placed after two-roller crushers. He considered that with adequate preparation by knives and with a feeder cane carrier placed at right-angles to the main carrier, a shredder was not necessary.

Mr. J. O. Sason said that of 30 tandems operating in the Philippines 8 were provided with shredders. In some cases the direction of rotation of the shredders had been reversed.

Mr. D. K. Brahma said that in India 3 Maxwell shredders were discarded as the resulting fine bagasse had given trouble in the furnaces. He considered, however, that shredders allowed higher imbibition being applied, resulting in increased extraction.

Mr. R. Lagesse considered that two sets of knives gave adequate preparation for satisfactory crushing rates and high extraction and preferred these to shredders.

Chairman's Conclusion. The discussion showed a wide variation in opinion on the usefulness of shredders. Good preparatory work by cane knives appeared to render additional disintegration by shredders unnecessary for satisfactory mill performance. There were indications that when the cane preparation was carried out intensively by shredders, the finely divided bagasse gave trouble in the furnaces.

(b) ROLLER GROOVING AND SURFACE SPEED

(Introduced by Mr. Hari Chand, India)

In order to achieve higher crushing rates there has recently been a marked increase in the surface speeds of mill rollers, these speeds being increased up to the highest amounts consistent with the rollers gripping the cane and maintaining the feed without slipping. An important factor in this trend is the type and dimensions of the surface grooving of the rollers, and practice in this connection varies considerably. The general practice is to employ coarse pitched deep V-grooving in the earlier units of a milling train, and gradually to decrease the pitch in succeeding mills. In the latter mills of a train, some operators prefer grooving of relatively coarse pitch, whereas others consider that fine pitch grooving is essential for maintaining good extraction.

While the advantage of Messchaert drainage grooves is full recognised, some operators consider that these are only beneficial on the feed rollers of mills and should not be employed on the discharge rollers. Chevron and other types of transverse grooving is also extensively employed on the earlier mills of a train to assist feeding in some cases on top rollers only. and in others also on the feed rollers.

The difference in grooving practice for achieving high crushing rates are appreciable, and delegates are asked to contribute views on the type and size of mill roller grooving for giving the best over all results under present-day conditions.

DISCUSSION

Mr. Hari Chand described a case in which by increasing the surface speed from 20/22 ft. per minute to 35/38 ft. per min. on a 14-roller 24″×48″ plant, and by adding an additional mill, the crushing rate was progressively increased from 400 tons per day to 1200 tons per day. He considered that speeds above 40 ft. per min. would sacrifice extraction efficiency.

He considered that grooving of 3/4″ pitch in the last mill, properly maintained, resulted in improved extraction, as more imbibition could be applied due to improved juice drainage compared with finer pitch grooving.

Mr. G. Mazery considered that a satisfactory mill grooving was 2″ pitch for the first two mills, and either 3/4″ or 1/2″ for the subsequent mills. He considered that ample capacity was assured with surface speeds up to 35 ft. per min. and that troubles experienced at higher speeds, and lowering of extraction, did not justify operating faster.

Mr. O. M. Henzell spoke in favour of having wider pitched grooving on feed rollers—generally double that on the top and back rollers.

Mr. B. M. Sawhney considered that the wider pitched grooving was preferred, as with fine pitch roller surfaces were liable to wear flat during a long crushing season.

Mr. J. P. Mukherji preferred differential angle grooving in the top and bottom rollers, with 60° angle for the top and 35/40° angle for the bottom rollers. He preferred using small angle grooves in the bottom rollers to assist juice drainage and to avoid the use of Messchaert grooves. Wear on Messchaert grooves allowed considerable dropping of cush-cush, and the roller surface is liable to break away at the edges of these grooves.

Mr. W. M. Livie preferred the angle of grooving to be 55°.

Chairman's Conclusion. Whereas emphasis is often placed on the crushing of fibre—and crushing rates are commonly compared on a tons fibre per hour basis—increased crushing rates have brought the juice drainage problem into prominence, thus stressing that it is not fibre which we are crushing, but cane. This drainage problem has led to coarse grooving being favoured, particularly on front rollers, with a tendency also to make the angle of groove deeper. Coarse grooving also doubtless affords a better grip on the cane and helps to prevent slipping.

(c) MILL FEEDING DEVICES

(Introduced by Dr. W. R. Crawford, Australia)

With rollers of suitable coarse cast-iron which remains rough in service, appropriate roller grooving, adequate juice drainage arrangements, and correctly adjusted settings, mills can be made to feed satisfactorily without the aid of mechanical feeding devices. For a long period mills have been so operated, special feeding equipment being employed in local instances only as, for instance, in Australia where pusher feeders and two-roller feeders have found favour.

Under the most propitious conditions there is naturally a limit beyond which a mill will not be self feeding and, with the present demand for higher crushing rates, operators are turning to the assistance which can be given by mechanical feeding devices. Most manufacturers of mills now supply single-roller feeders as standard on their plants. The single roller was formerly located on top of the cane blanket where this enters the mill, but is now more usually placed below the discharge end of the carrier, so that feeding is assisted by engagement on the underside of the cane blanket.

In Australia—due largely to the use of maceration bath system—feeders appear to be essential on mills. The feeding equipment employed is, however, more elaborate than the single-roller feeder now generally used in other countries. A two-roller feeder has been developed and is extensively employed. In arrangement this is similar to a two-roller crusher and incorporates an enclosed tapered discharge chute. This device expresses the main volume of juice from the sodden bagasss and introduces it in a compacted form under pressure to the following three-roller crushing unit. Reciprocating pusher feeders are also still in use in Australia—both the horizontal and vertical types, and often a combination of both. Neither the two-roller feeder nor the pusher types have, however, so far been adopted in other countries.

The following questions naturally arise in regard to the use of feeding devices:—

(a) Are feeders essential, or can this additional mechanical equipment be omitted from a mill provided all contributory features are properly adjusted to provide satisfactory self-feeding?

(b) When single-roller feeders are provided should these be fitted on top of the bagasse blanket or below?

(c) Do the advantages to be gained by the installation of two-roller feeders and chute justify the additional mechanical equipment employed?

(d) If the use of the maceration bath system makes it essential to provide special feeding devices, would it be more economical to discard the bath system and to use instead slat-type carriers with applied imbibition?

DISCUSSION

Dr. Crawford explained that Australia had more experience than other countries in dealing with saturated bagasse, as a result of the maceration bath system employed. In these circumstances it is necessary to have forced-feeding of a mill in order to avoid slip. He considered that the self-feeding mill was restricted in surface speed, and therefore limited in capacity. The 2-roller feeder invented in Australia presented to the mill a compact thickness of feed of uniform density and exercised a steady pushing action. The 2-roller feeder was run 10% faster than the following mill. In particular cases this feeder had enabled 66″ mills to crush up to 130 tons per hour.

Mr. F. L. Stewart asked for information on the power requirement and cost of the 2-roller feeder as compared with a 3-roller mill.

Mr. W. M. Livie replied that for a 72″ mill 50 B. H. P. was required, and the installation normally provided an increase in crushing rate of around 12%, and lowered the moisture content of the bagasse emerging from the mill.

Mr. J. P. Mukherji enquired about the increased centre distances necessary between mills for accommodating 2-roller feeders.

Dr. Crawford replied that the centre distance required was around 29 ft.

Chairman's Conclusion. With the higher crushing rates now required the discussion showed that some form of mill-feeding device was necessary, and new mills were now normally provided with such equipment. He described the application of the single-roller feeder placed below the apron delivery and of a slat-type intermediate carrier, which was now becoming popular, and could be readily installed on existing mills.

(d) INTERMEDIATE CARRIERS

(Introduced by Mr. O. M. Henzell, British West Indies)

Intermediate carriers of two types have been in general use—the slat and the scraper types. At different periods one or other type has gained favour, and at the present time the slat type is in more general use.

Each type possesses certain advantages over the other. The slat-type presents a continuous bagasse blanket to the mill, and the action of the slats at the delivery end of the carrier assists in the feeding of the mill. On the other hand, this type is liable to be dirty and to allow excess imbibition liquid to drain through below. It is also not so readily cleaned and sterilised as the scraper-type. Replacement costs of slats and chains are high due to rapid wear and corrosion resulting from the action of juice and grit.

Efforts to overcome the maintenance problem of the slat-type are constantly being made, some of these being the provision of hardened bushes in the chains, stainless steel link pins, and galvanised slats. A recent development entirely discards the metallic slat and chain apron, and replaces this by an endless rubber belt. A large new milling plant recently installed in Cuba has been fitted with rubber belt intermediate carriers.

Having regard to the contribution which intermediate carriers make towards the satisfactory operation of a milling plant, the following questions arise in connection with modern practice :—

(a) Does the slat-type meet present-day requirements better than the scraper type ?

(b) On account of the facility now offered by the use of steam turbine drive to shorten the distance between mills, is it desirable to introduce the shortest possible intermediate carrier, or will this be detrimental to imbibition efficiency ?

(c) What are the results of experience in the use of rubber belt intermediate carriers and are there any other possible types of apron suitable as substitutes for the metallic slat and chain arrangement ?

DISCUSSION

Mr. Henzell said that for high tonnage rates on mills the slat type of carrier was essential, and that the drag type only had an application on small mills with short centre distances. He preferred relatively short carriers, and considered that, with cane properly prepared by knives, satisfactory imbibition efficiency could be obtained without employing long and complicated carrier arrangements.

He emphasised that all current forms of intermediate carriers were unsatisfactory, and that there was ample scope for improvement. The rubber belt apron gave promise of being a valuable development.

Dr. W. R. Crawford considered that for the best milling results the feed blanket should be continuous. The scraper type carrier broke the feed into sections and was thus deterimental.

Mr. Heggie gave his experiences on Meniche chute carriers, and concluded that they were unsatisfactory.

Mr. C. McNicol stated that Meniche carriers were designed for a particular crushing rate, but when operators appreciably exceeded these rates trouble followed.

Mr. G. H. Jenkins said that in Australia the wide spacing of mills did not allow the use of Meniche carriers. He also considered that this type did not naturally allow of efficient imbibition.

Mr. W. M. Livie explained the arrangement of maceration bath and intermediate carrier as employed in Australia, and stated that improved extraction was obtained by increasing the length of bath and carrier. He referred to cases of between 60 and 90 ft. long.

Chairman's Conclusion. Under present day crushing conditions the slat type of intermediate carrier appeared to be preferred. It was not, however, considered a satisfactory piece of equipment, and was open to considerable improvement in materials, design and construction. Wide variation existed regarding the most appropriate length of carrier, ranging from short, around 12 ft., to the Australian view that lengths up to even 90 ft. are justified by the resulting improvement in extraction.

(e) JUICE STRAINERS

(Introduced by Mr. C. McNicol, India)

For a long number of years the conventional cush-cush strainer and elevator remained standard equipment on all milling plants. This consisted of stationary straining screen to which the expressed juices from the individual mills flowed through gutters. Scrapers attached to endless chains driven from the mill removed the cush-cush from the screens, and elevated this to a cross conveyor which distributed it over the bagasse on the appropriate intermediate carrier.

This form of strainer is now being largely superseded by other types for straining the extracted juice passing to process, and by the pumping of imbibition juice directly back on to the mills in its unstrained state by means of chokeless pumps. Strainers for the process juice are either of the rotary screen type, or the mechanical or magnetic vibrating types. They may be located in any convenient situation either over the mill or on a platform alongside.

It appears that the conventional combined cush-cush strainer and elevator is destined to be displaced entirely by these newer straining and pumping arrangements. In the transition period opinions are being formed on the merits of the various new types of equipment, and delegates are asked to give the results of their experiences, and to discuss trends of further development.

DISCUSSION

Mr. McNicol stated that for high crushing rates now employed the slat and chain type cush-cush strainer and elevator was an unsatisfactory arrangement. He pointed out that rotating or vibrating types of strainer were more sanitary and occupied less space, apart from being much more efficient in straining action.

Mr. J.P. Mukherji stated that 10 years ago he had discarded the conventional cush-cush strainer and replaced this with a vibrating type with beneficial results. With the old type of strainer there was a purity drop between primary and last mill juice of 3.5, but this had been reduced to 1.5 with the new arrangements.

Chairman's Conclusion. It would appear from comments that the former conventional type of strainer was now being largely discarded. The opinion had been expressed that more attention should be paid by manufacturers to the particular application of the new types of strainer to the straining of cane juices as a number of problems still existed.

(f) MILL ROLLER BEARINGS

(Introduced by Dr. Langen, West Germany)

The use of journal type bearings for the rollers of sugarcane mills has until the present been almost universal. There have been occasional applications of roller bearings in the past—one noteworthy instance occuring in India 25 years ago when two 14-roller 18″×36″ plants were designed and manufactured by a Calcutta engineering firm for Indian factories. There has, however, been no general adoption of roller bearings in any country. In the past few years, however, greater attention has been directed to the subject, and certain machinery firms are now manufacturing mills with the crushing rollers carried in roller bearings, and some mills so fitted are now being erected in India.

The main advantage claimed for the use of roller bearings is the reduction in friction and corresponding lower horse-power demand for driving the mills. On the other hand, the large-diameter roller bearings required are appreciably more expensive than the equivalent journal bearings. Furthermore, roller bearings require to be carefully lubricated and maintained, as otherwise deterioration will result and be accompanied by heavy replacement costs.

The main problem of applying roller bearings to mills is to exclude the entrance of juice, so as to prevent the consequent corrosion and damage to the finely finished surface of the rollers and races. Forms of sealing device have now been developed whereby the bearings can, with reasonable assurance, be safeguarded against risk of juice entry. Here again, however, the seals must be maintained in a satisfactory state if they are properly to perform their function, and it is obvious that with roller bearings a much stricter standard of maintenance must be enforced than with the journal type.

The following are some questions which arise in connection with the application of roller bearings.

(a) What is the proportional saving in power effected by the use of roller bearings in place of journal bearings ?

(b) Are the sealing arrangements for preventing entry of juice into the roller bearings absolutely effective ?

DISCUSSION

Dr. Langen described the application of roller bearings to heavy machinery and the recent development in the case of sugar cane mills. He stated that, as the relative outside diameter was larger than in the case of journal bearings,it was not possible to fit roller bearings into existing headstocks. A new design of headstock had therefore been involved. He stated that there was a saving in power of 20/25% by the use of roller bearings and that some of the advantages to be obtained were the absence of a cooling water system, no lubrication attention necessary during operation, improved cleanliness of the mill, and lower maintenance costs. If properly maintained he considered that the life of roller bearings on sugar mills should be at least 10 years.

Mr. W. M. Livie asked how many years had roller bearings been in service on any particular mill.

Dr. Langen replied that experience covered 4 years.

Dr. W. R. Crawford asked what was the maximum size of mill on which roller bearings had been fitted.

Dr. Langen replied that the largest size so far was 32″ × 60″.

Mr. H. E. B. Scriven considered that during the off season the static condition of the bearings might result in corrugated etching of the races by the rollers.

Mr. Atma Singh considered that unless the sealing arrangements were perfect, even a little juice entering into roller bearings would cause considerable damage. He also asked how long would it take to change a roller bearing should one break in service, particularly with regard to the race having to be forced off the shaft.

Dr. Langen replied that about 2 hours was required for changing a bearing.

Mr. J. R. Leclezio considered that the claim of 25% saving in power was unduly high as the major proportion of the power in a mill was demanded by the crushing of the cane, and was not due to bearing friction.

Chairman's Conclusion. As a recent development the application of roller bearings to mills was obviously exciting considerable interest, and engineers had many questions to ask regarding performance. It appeared a little early to judge the position and more experience would doubtless require to be gained. Opinion on the amount of power saved by the use of roller bearings varied considerably and no authoritative information appeared to be available on this important aspect. Some experimental work was obviously necessary in order to establish comparative data on the difference in power effected by the use of roller bearings.

(g) HYDRAULIC PRESSURE SYSTEMS

(Introduced by Mr. J. P. Mukherji, India)

From the time hydraulic pressure regulation was first applied to the rollers of sugar cane mills seventy years ago, the weight loaded accumulator—with no change in general design—has continued until recent years to be the standard pressure arrangement employed.

Nearly 20 years ago the air-hydraulic accumulator was introduced in which air at a pressure of 200/300 p. s. i. g. is employed in an intensifier to provide hydraulic pressures up to 4,500 p. s. i. g. for direct application to the top cap cylinders on mills. This type of accumulator represents a marked advance over the conventional pattern, as it dispensed with weights and can be placed conveniently in an elevated position close to the mills from which point pressure adjustment can be readily made.

More recently the gas-oil accumulator has been introduced for duty on sugar mills, this consisting of a steel pressure cylinder inside which gas at high-pressure is contained within a rubber bag. Due to its simplicity, small size, and absence of moving parts, this type of accumulator is now being extensively adopted on new mills, and is also replacing weight loaded accumulator on many existing plants.

While in the majority of cane-sugar countries hydraulic pressure regulation on mill top rollers is regarded as essential and is applied on all plants, an exception exists in the case of Australia where a large number of mills operate without pressure regulation of any type, the top rollers being fixed in position.

Questions which might be considered in regard to hydraulic pressure regulation are :—

(a) Is it necessary to have the top roller of a mill " floating " on the bagasse blanket under the control of a uniform pressure, or is it preferable to operate with the top roller fixed in position thereby maintaining constant openings between rollers and trashplate ?

(b) Is the gas/oil rubber bag accumulator the most satisfactory form of pressure equipment so far evolved ? If so, is it likely that this may in turn be superseded by other improved types ?

DISCUSSION

Mr. J. P. Mukherji considered that the recent rapid development in the use of the gas/oil accumulator on mills was evidence of its superiority over the weight-loaded type. He stated, however, that some operators expected the accumulator to increase capacity and extraction, whereas these aspects depended equally on the maintenance of the hydraulic cylinders in good condition and the proper setting of the mills to ensure even floating of the top rollers. He referred to the quick response of the gas/oil accumulator relative to the inertia effect experienced with the weight-loaded type.

Mr. W. M. Livie spoke in favour of the Australian practice of fixed top rollers without hydraulic loading. He considered that hydraulic loading was only necessary in cases where more than one mill is driven by one engine. With properly adjusted settings and even feed he contended that the fixed top gave a better performance, and would enable the moisture content in bagasse to be kept at least 2% lower than when hydraulic pressure equipment was employed.

Dr. W. R. Crawford stated that in Australia opinion was evenly divided on the question of fixed or hydraulically loaded top rollers.

Mr. O. M. Henzell said that in certain cases where recording devices have been fitted on the top rollers bearings of mills, it has been found that the top rollers were not floating, but were in effect operating as fixed rollers. In such unsatisfactory circumstances hydraulic loading could play little part in the mill performance.

Chairman's Conclusion. It was obvious that the newer forms of hydraulic pressure equipment were rapidly gaining favour, and that the weight-loaded accumulator was now obsolete. Apart from being more convenient, however, the new type of accumulator could not in itself ensure improved extraction as this depended largely on the proper adjustment of mills in respect to grooving, settings, etc. Also the design of hydraulic top-cap cylinder was important as, if this did not function correctly, the pressure would not be applied properly to the top roller.

SYMPOSIUM ON CANE JUICE CLARIFICATION

SYMPOSIUM ON CANE JUICE CLARIFICATION

Session—Monday, 30th January, 9-15 A.M.

Dr. DOUWES DEKKER, *Chairman*

The *Chairman* delivered the following opening address.

Gentlemen,

The fact that you find me in the chair of the session in which we will discuss the papers grouped together in this symposium on clarification is due to the absence of Dr. Pieter Honig. As we all know Dr. Honig has taken much trouble in organising this symposium and he should have been here. I am sure that he much regrets not to be able to lead the discussions and I am also sure that all of us much regret his absence.

By sincerely attempting to make the discussions of the present session a success, we should be able to show our gratitude for his work done in bringing together the papers which shortly will be presented.

In the first place I want to extend to you a very hearty word of welcome. From our various countries we have come together to discuss the subjects in which we are professionally interested in the firm belief that such discussions are a necessary step forward in the direction of an improved manufacturing technique. It is not enough to carry out research in laboratories and factories when the results are not available to all and available for an open discussion. I know that the tendency for secrecy has turned up from time to time in nearly all sugar producing countries and in isolated cases such a secrecy may be justifiable.

But the great danger for countries in which such a tendency becomes a system is a state which sometimes is symbolised by a dog biting its own tail, going round in circles. When an industry has reached this condition further technological progress is dubious and the vicious circle has to be opened.

There is no better method for opening the vicious circle than publication of the results of our work and inviting a free discussion, for the man, who often learns most of such a discussion, is the author of the paper.

The subject of the symposium of which we are going to discuss the papers now is Clarification. Eleven papers have been presented, but unfortunately not all the authors of the papers are present. Fortunately other Technologists have agreed to introduce the papers. This will enable us to discuss them intelligently.

I have pleasure in declaring this session open and we shall now proceed to our business.

In the absence of the author the Chairman read out the paper.

Paper

INTRODUCTION TO THE SYMPOSIUM ON CLARIFICATION

DR. PIETER HONIG

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The literature on clarification, clarifier construction and clarifier performance is over whelming. It has, however, to be stated that the multitude of publications, including the pamphlets of manufacturers, have not resulted in a clear understanding of the fundamental problems involved in cane juice clarification.

This state of confusion is caused partly by the fact that in many cases only a detail, and in many cases a minor detail of the technological design of clarifier constructions has been emphasized without due recognition of the main factors. It is for this reason that according to our opinion there is no exaggeration in the statement that 90% of the publications on clarification and clarifiers is unscientific, very subjective and of doubtful value.

The object of conferences as held by the International Society of Sugar Cane Technologists is to promote the scientific progress of sugar manufacture. It is necessary that we understand each other well what has to be understood by the scientific treatment or approach of the different phases of sugar production. It has to be the co-ordination of our experiences and to bring these experiences into a logical pattern. What we are trying is to discover together the general rules that can be applied to the different phases of sugar manufacture and we are only slightly interested at our international conferences in individual observations that do not fit in the experience we have in common, or that are not based on or related to the logic of the natural laws as applicable to the progresses involved in sugar manufacture.

We are not enthusiastic towards new gadgets or theories that have not a solid support in generally recognized reactions, facts and natural laws; it is considered to be a waste of time and energy to accept as a scientific approach the introduction of a new hypothesis which is not based solidly on our experience and the state of natural science as it is today.

We have tried in this Symposium to bring together the views of a number of leading authorities in the field of sugar cane technology with the request that they present their views in general terms but related to actual observations that we are able in our discussions to come to a logical comparison of the experience of technologists in different countries and to find out where we are of opinion that gaps exist in our knowledge, because Mr. Davies has stated in his paper : "real advances in the field of clarification can not be made till these gaps in our knowledge are filled ".

A number of these studies to be made on clarification will be difficult and time consuming, and in many cases negative in the obtained results. It has also to be recognized that in many cases the experimental technique has to be developed as in many cases the existing analytical procedures are not accurate enough to arrive at reliable conclusions.

Our present state of technology and experience is briefly stated as follows :

The mixed juice as resulting from the extraction process, depending on the quality of the cane and the method of extraction, contains a certain amount of suspended impurities that have to be removed to obtain a juice that can be concentrated as raw material for the crystallization process. A part of these suspended impurities adheres to the harvested cane as a result of the harvesting technique and they are described under the general term of " soil " or " soil particles ". The modern technology tries to eliminate this kind of impurities via cyclone separators (see the paper by Dr. John H. Payne, Hawaii).

Another group of suspended impurities is described as cush cush or bagacillo, resulting from the disintegration of plant tissue in the milling process. These particles have to be removed via a screening process (see the paper by Mr. Marsh, New York). These pretreated juices are subjected to the liming process and the heating process, resulting in a precipitation and coagulation, and a flocculation of the insoluble non-sugars.

The chemistry of this precipitation is commonly stated in a very simple way that the lime combines with the inorganic phosphates in the mixed juice to an insoluble calcium phosphate. This calcium phosphate assists in the elimination of insoluble non-sugars as a kind of adsorbent for non-sugars, described as lipids, colloidal silicic acid etc. At the same time by the change in reaction and the heating process coagulation of nitrogen containing non-sugars usually described as proteins and a change in the solubility of the sesquioxides occurs.

A number of these reactions have been studied and we know something about the equilibria and kinetics, the solubilities of certain types of non-sugars and the instability of certain groups of colloidal non-sugars. But we have to admit that a tremendous amount of fundamental investigations have to be made before we may state that we understand all the reactions involved in the liming of cane juices. We know for certain that the flocculation process of precipitated non-sugar is affected by intensive stirring as occurs in the passage of juices through pumps and heaters.

The sedimentation of the limed juice is commonly done in two stages. All modern clarifier constructions have settling compartments for a first settling and a lower or secondary compartment for a second settling. How are the settling characteristics of the precipitate affected when after a presettling for one or two hours the settled impurities are mixed up homogeneously for resettling?

In factories before the introduction of continuous clarifiers it was customary with intermittent settling tanks that the mud from the first settling was relimed and reheated before it was subjected to the second settling to obtain the same pH of the mud juices for the second clarification as for the first settling. This practice as a rule does not exist in continuous subsiders. It is not a part of the technological design of clarifiers and if a certain amount of soda ash is added to readjust the pH in the bottom compartment, it is done primarily with the idea that it will reduce the inversion losses but it is not done to obtain an maximum, removal of non-sugars nor to improve the settling rate.

The fundamental investigations in clarification are to a certain extent not of a character that the leaders of our industry are willing to finance such fundamental investigations, as the calculated profits resulting from an improved knowledge are considered to be a minor importance. By controlling the conditions in the clarification as to pH the inversion losses can under extreme conditions be reduced to 1% of the sucrose present in mixed juice, but as an average it will not surpass 0.2 to 0.3%.

The clarity of the juice has up till now been impossible to study in an exact way, as the optical quality described as turbidity is very difficult to correlate with certain types of non-sugars. The conception that the turbidity was caused in many cases by the presence of the loose term "cane wax" is certainly incorrect.

It has been stated several times, and it was even an argument for clarifier manufacturers, that the introduction of new cane varieties as, for instance, the POJ-varieties required the introduction of larger clarifier capacities and they have even applied the disreputable term "refractory" or unmanageable juices.

For sugar technologists it is necessary that they have a clear understanding what is understood by this word. Does it mean juices that under no conditions of processing produce a clear clarified juice free of turbidity, or does it mean that the percentage of mud juice in proportion to the percentage of clarified juice is increased, or does this term include both ? We have to realize that there are certain cane juices that are always forming a small amount of precipitate on prolonged heating. This is, for instance, the case with juices of immature cane, high in organic phosphates and high in silicic acid.

If a clarified juice separated from its sediment is subjected to a prolonged heating at 100°C. for 2 or 3 hours, it will be observed that such juices become turbid and that the cause of the turbidity is the formation of calcium phosphate, resulting from the hydrolysis of organic phosphates and the co-precipitation with a certain amount of colloidal or soluble silicic acid always present to a certain extent in clarified cane juices.

The percentage of organic phosphates can be fairly high in immature cane. If a sugar industry has to harvest cane fields consisting of stalks of different ages, it is unavoidable that such canes produce juices which give always an exceptional behaviour and undoubtedly an undesirable complication in clarification. The cause of this is not a property of the cane variety as such, but it is the result of agricultural practices resulting in a continuous tillering and the formation of new shoots in the cane fields. The vigorous growth of these varieties results in the harvesting of a certain percentage of immature cane stalks which are difficult to handle by a simple liming and settling process.

Active co-operation between the field department and the factory staff becomes essential for the general management if a sugar factory is receiving an excessive amount of immature cane stalks. It is not only reducing the overall yield of the cane, but it is also introducing a complication in the clarification process for which we have not found up till now a simple solution.

There are other phenomena in clarification which are not well understood by the average technologist. One of this is the change in the pH of juices subjected to settling. It has been assumed by many technologists that we are dealing with a micro-biological action and operating on this assumption they have introduced the application of disinfectants as chlorination, formaldehyde and other disinfecting chemicals to suppress this change in pH.

The change in pH, however, is not the result of micro-biological action. It is partly the result of a decomposition of certain types of non-sugars among others the hydrolysis of hexose-phosphates, partly the result of the transformations of the complex reaction product between lime and phosphate. Also the formation of gas, mainly CO_2, in hot juices is a chemical reaction.

If a sugar mill has decompositions in its clarifiers as a result of micro-biological action, for instance, as a result of accumulation of suspended non-sugars on the bottom trays, cooled down to such a temperature that micro-biological action can start, which is a temperature under 70°C., we are certain that such an accumulated pile of dirt will never be disinfected by the introduction in the juices of a small amount of a disinfectant. It has to be stated that when this occurs there is something fundamentally wrong in the construction or the method of operation of the clarifier. Each clarifier, even in the cleanest state, will show a certain change in the reaction of the juices to be handled. Also a certain amount of CO_2 formation is unavoidable.

We have to ask ourselves the question how we can reduce these undesirable reactions to a minimum but the complete answer to this can only be given if we know the exact nature of the reactions.

A difficulty in progress in clarification is that the more mechanically inclined designer of a clarifier is not always familiar with the chemical reactions taking place in hot limed juice subjected to a settling process. On the other hand the pure chemist stands aloof when a discussion takes place on the advantages and disadvantages of certain types of mechnical design.

The opportunity is given at the meeting of the I.S.S.C.T. to bring the different groups co-operating in sugar manufacture together and to have a frank discussion on the different problems that each of these groups tries to solve. This will result in a better understanding of each others problems and each group has to admit that much hard work has to be done before we can be satisfied with this part of our technology. Much will be gained if we are willing to acknowledge that there are many things we do not know accurately at this moment. Such a discussion will be a stimulant for those among us who have the inclination for systematic investigation to make these fundamental studies and to present them periodically at the meetings of the I.S.S.C.T.

The presentation of this Symposium has not to be that we are proud of all the knowledge we have already collected, but it has to be the recognition of the lack of knowledge of the many reactions involved in the liming and settling of cane juice.

In the absence of the authors Dr. H.W. Kerr presented the following paper.

Paper

REMOVAL OF SUSPENDED MATTER FROM JUICES BEFORE CLARIFICATION AND THE TREATMENT OF JUICES AFTER HEATING

JOHN H. PAYNE AND GEORGE E. SLOANE*

REMOVAL OF SUSPENDED MATTER FROM JUICES BEFORE CLARIFICATION

Juices from mechanically harvested cane, inspite of cane cleaning operations, contain relatively large amounts of insoluble solids. In some factories the average is 2.5%, and under wet-weather harvesting conditions 6 and 7% are not uncommon figures. This material, which is present in a wide range of particle sizes, is mostly inorganic in nature and is usually classed as soil, sand and ground rock.

This type of insoluble matter is troublesome. It increases wear on pipelines, pumps and heater tubes. Likewise, it collects in the bottom of mixed juice tanks, vacuum filter supply tanks and in the filter troughs. This furnishes dead spaces for the growth of micro-organisms as well as increasing costs due to periodic cleaning operations.

Vacuum filter operation is affected by the larger quantity of material to be handled. Increased supply of bagasse fines for filter aid is necessary and more pol is lost in filter cake.

Solids removal devices of various types have been tried in the industry and several papers on these have appeared in the Reports of the Hawaiian Sugar

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Technologists (1,2,3,4). Operations represented have been screening, centrifuging, settling and cycloning.

Screening : Screening of mixed juice is standard procedure in sugar factories. Of the various types of screens employed, none is very effective in removing large quantities of soil and fine sand, so their value lies primarily in the removal of bagacillo.

Centrifuging : Screening in conventional sugar centrifugals with several types of screens has been tried many times. The method, like any kind of screening, is not effective for soil removal. Furthermore, capacity is low and discharge of the solids is difficult.

Solid-bowl centrifugals are effective in removing all sizes of solids. A batch-type machine similar to a non-perforated sugar centrifugal was used in connection with ion exchange experimentation at Clewiston, Florida, in 1947. Problems of low capacity, washing and discharging, as well as high labour costs, make the method unsatisfactory in routine operation.

The development of countinuous-discharging solid-bowl machines offered promise of solving some of these problems. A Merco machine of this type tested at Grove Farm Company is shown in Figure 1. These machines operate at 6000 r.p.m. and solids are continuously discharged through small ports (around 0.1 inch diameter) around the periphery of the bowl. Tests showed that a machine had a capacity of 1500-1800 gallons per hour and affected a suspended solids removal of 50-75% depending upon the feed rate. Due to high velocities in the machines, abrasion is rapid, however, and the life of the separation and discharge members is short. This high maintenance requirement, coupled with high initial cost, makes the use of these machines uneconomical for routine factory use.

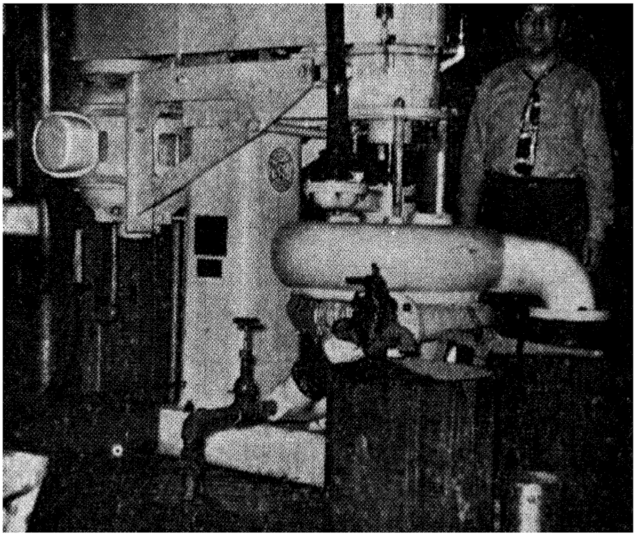


Figure 1. Merco continuous discharging centrifugal
Grove Farm Company, Koloa Factory.

Settling : Continuous type settling devices are in use in several factories in Hawaii for the removal of sand and coarser particles of soil. They are not effective in removing clays and fine soils.

The unit developed by Montgomery (1) at Paauhau Sugar Plantation Company has a primary separator similar in construction to a Smith limer. Juice is introduced at one end of the separator and the velocity is reduced by baffling so that the sand drops to the bottom toward the other end where revolving buckets remove it. The buckets are shallow so that the sand can be discharged by water jets into a smaller unit of similar design. Overflow from this unit goes to the last mill juice receiving tank and the washed sand is flumed away.

A similar principle is used at Kohala Sugar Company. In this unit the sand is moved toward the buckets by means of a ribbon scroll (Figure 2).

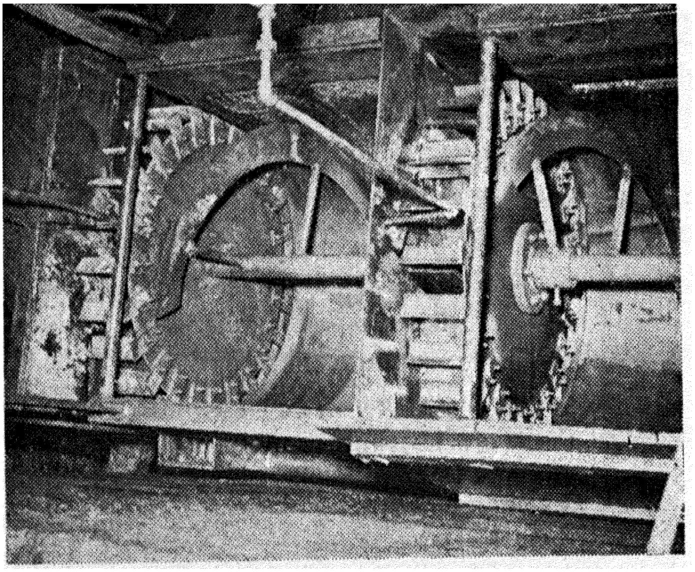


Figure 2. Kohala Sand Separator (Plan view).

Cycloning : Although sand removal is effective in decreasing erosion of pipes and pumps and in improving rotary filter operation, relatively large quantities of soil remain a problem for the clarification station. In the removal of this material the cyclone appears to offer the most promising solution. Various types of cyclones have been tried in Hawaii.

The simplest type is installed at Hilo Sugar Plantation Company (Figure 3). It consists of a four-foot diameter dust collector-type cone adapted to use on cane juice. The unit has removed up to 160 pounds of suspended matter per hour. The underflow, as shown in the photograph, runs into a bucket-type washer similar to the one previously described. Only relatively large-size particles are removed, however, so the unit is essentially a sand separator.

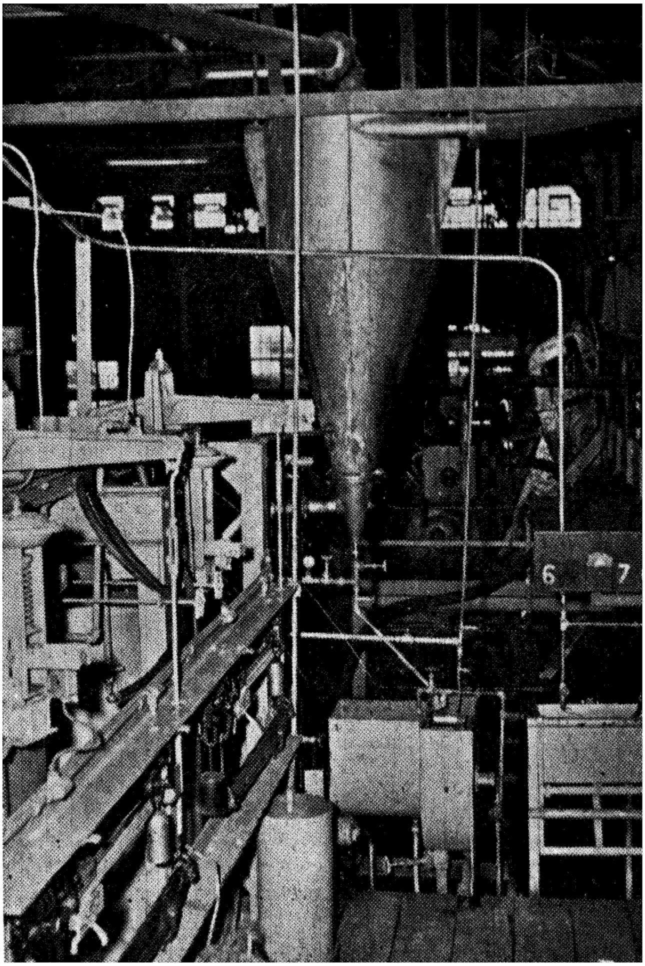


Figure 3. Cyclone separator and " Smith Limer " type sand washer Hilo Sugar Plantation Company.

Since the separating force in a cyclone is inversely proportional to the radius of curvature of the liquid in the cyclone, the smaller the diameter the smaller the particles that may be removed. Webb(3), at Olokele Sugar Company, designed a multiple unit consisting of four graduated cones capable of removing particles down to 100 microns in size. Incidentally, commercial units are available which are made up of banks of small diameter cones which are capable of removing particles down to 2 microns. In Webb's installation the four cyclones are operated in series, with the underflow from one serving as feed for the next. The last three cyclones serve as wash units. The first cyclone was 2 feet in diameter and was designed to handle 275 gallons of mixed juice per minute. Final underflow from the last cyclone averaged only 3.2 gallons per minute. Removal of over 95% of the solid particles larger than 100 mesh was obtained.

A serious problem with cyclone operation is erosion. This can be lessened to a considerable degree by the use of rubber-lined equipment. A commercial unit called the Dorrclone employes this construction. Such an installation consisting of two cyclones as installed at the Grove Farm Comapny is shown in Figure 4. A line drawing is shown in Figure 5.

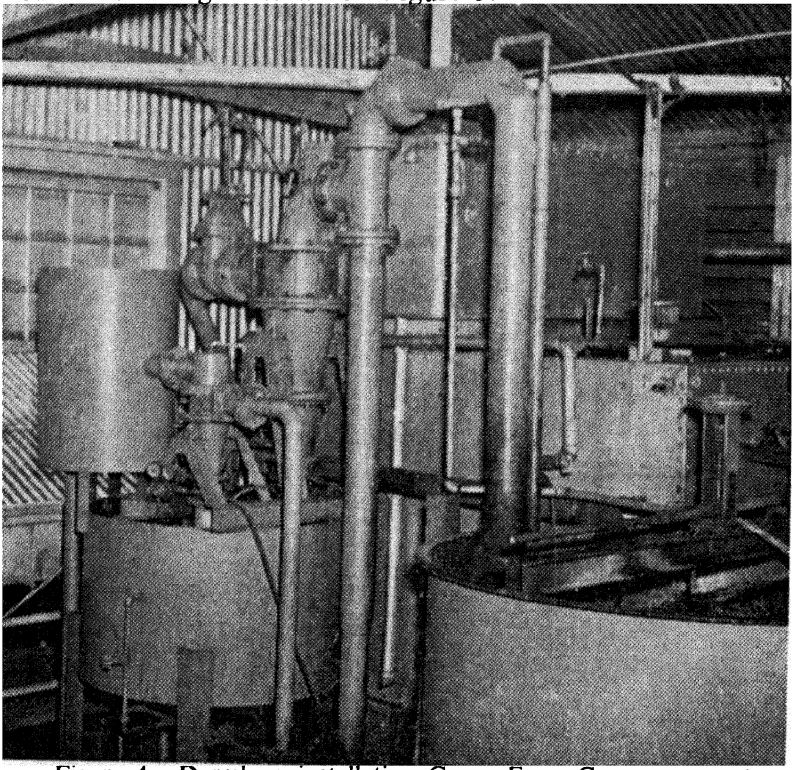


Figure 4. Dorrclone installation Grove Farm Company.

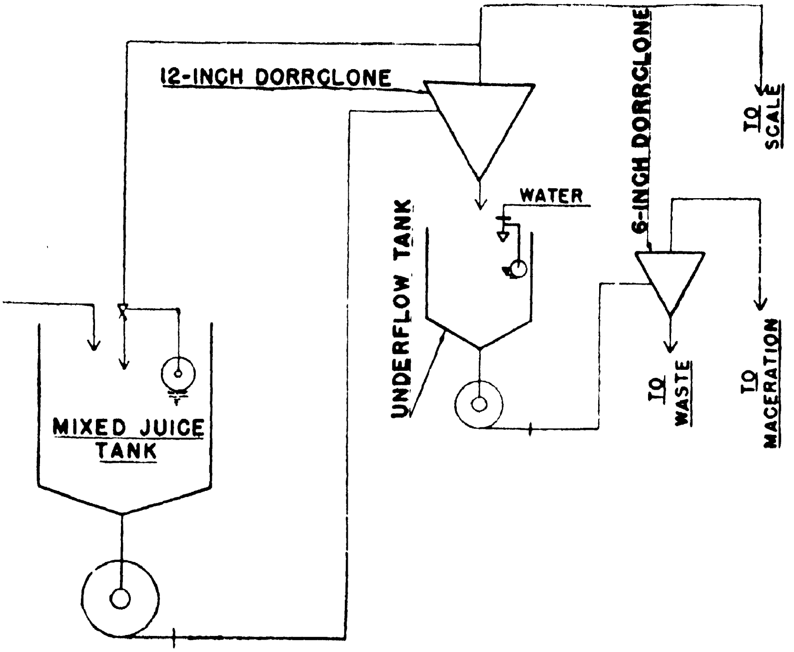


Figure 5. Flow diagram of Dorrclone installation.

The first cyclone is 12 inches in diameter and was designed to handle up to 280 gallons mixed juice per minute. (Insoluble solids range was 0.3 to 6.0%). The underflow from this unit goes to a 6-inch diameter wash cyclone as shown in Figure 5. Underflow from this is discarded and the overflow goes back to maceration.

In routine operation this equipment has removed from one to ten tons of solids per 24 hours.

As illustrative of the type of material removed in one 24-hour period, 2.48 tons were obtained. Particle size ranges were as follows:

Size	% of total
Larger than 20 mesh	0.5
Between 20 and 35 mesh	4.4
,, 35 and 65 ,,	8.6
,, 65 and 100 ,,	6.0
,, 100 and 150 ,,	8.1
,, 150 and 200 ,,	11.2
,, 200 and 325 ,,	26.6
Finer than 325 ,,	34.6

The overflow was free of any material larger than 200 mesh.

CONCLUSIONS

In summarising, experience in Hawaii has shown that with mechanical harvesting, solids removal equipment of the sand-separator type is economically sound. Simple devices involving settling with bucket discharge and washing are satisfactory. For removal of finely divided soil, cyclone treatment is the most effective. The economics of this operation remain to be established.

THE TREATMENT OF JUICES AFTER HEATING

In the modern lime clarification process, the limed juice passes from the heater into a flash tank and then into continuous clarifiers. Supernatant juice from these units goes directly to the evaporator station and settlings are screened on rotary vacuum filters. The so-called filtrate is customarily returned to the mixed juice, limed, passed through the cycle again and the cake is discarded.

This type of operation is about as simple as it is possible to conceive, therefore, any change must almost inevitably involve an increased expenditure for chemicals, labour or equipment. It is not strange, therefore, that almost all of the "improvements" are short-lived. They rarely pay off. This means that in general the standard procedure works well and the indisputable advantage of cheapness dominates.

Average juices, properly limed and heated, settle well in a commercial clarifier and enable the continuous draw-off of fairly clear supernatant juice. The settlings filter moderately well on a rotary vacuum filter and losses in cake can be kept to a modest figure. The filtrate, which may range from 10 to 20% of the total juice, contains a considerable amount of suspended matter, but this returns to mixed juice and "clear" juice continues, under normal conditions to flow from the clarifier.

A large share of the objections to the system arises from this return of filtrate. The major effect of this is to decrease the capacity of the clarification station. Secondary deleterious effects on the settling rates and quality of clarification have not been firmly established. Certainly the return load of insoluble solids places a burden on the clarifiers and filters. Whether there is an effect over and above this on the "new" juice is problematical.

Looking at the situation entirely from the capacity stand point, one can say "put in more clarifier and filter capacity". Actually it is not so simple. With mechanical harvesting, Hawaii has been faced with major problems at the clarification station from many years. High capacities are required to handle the heavy load of insoluble solids, but there are times when capacity is definitely not the answer.

There are areas on several plantations which are low-lying and consist of hydromorphic clay soils which give slow-settling, difficult-clarifying juices. It is impossible to draw off "clear" juice at the normal rate. Slow settling also means a larger volume of settlings, hence the return filtrate volume increases. Operating conditions at the clarification station rapidly deteriorate until a shut-down of the crushing plant is inevitable.

All sorts of reagents and procedures have been tried, but about the only low-cost means of operation in these areas has been to mix cane from the poor areas with cane from good areas—usually higher elevation—in such proportion that the factory could be kept operating. Recently, however, certain polyelectrolytes have been found useful in speeding up the rate of settling in some instances and one of these is the first material which consistently yields a smaller volume of settlings.

POLYELECTROLYTES

Polyelectrolytes are synthetic water-soluble polymers with the characteristics of electrolytes. Certain of these possess the ability of aggregate suspended solids in water, but little information is available on the mechanism of their behaviour. Since in most suspensions of this type the particles bear a negative charge, as in cane juice, cationic polymers (those with positive active groups) would be expected to be the most effective. Only a very few cationic polyelectrolytes are available, however, but laboratory testing in Hawaii has indicated that these offer considerable promise in cane juice treatment.

Of the anionic, polymers, one known commercially as Lytron X-886 has been subject to several trials in cane juice processing (6,7,8,9,10). It is the partial calcium salt of an acrylic co-polymer. The use of this material has been subject to extensive testing in Hawaii. Another material with the trade name Separan 2610 has been investigated initially in Hawaii and has proved the most effective substance yet found in decreasing the volume of settlings.

Laboratory Tests : A large number of tests made on juices from various factories have led to the conclusions presented below :

1. Lytron and Separan often aid clarification sufficiently to be of economic interest, but the effectiveness varies widely, depending upon the nature of the juice.

2. Lytron usually improves juice clarity where as Separan often does not.

3. Separan usually gives faster settling and a smaller volume of settlings, where as Lytron often does not.

4. By chemical modification, Separan can be converted into a form equally as effective as Lytron in improving clarity.

5. Neither of these materials are of appreciable effectiveness in the treatment of juices from the high-rainfall non-irrigated areas of the Island of Hawaii.

6. No satisfactory explanation for the varied behaviour of the polyelectrolytes has been developed.

Factory Tests : Factory-scale tests on various islands confirmed the laboratory results. In addition they pointed out the following :

1. Polyelectrolytes in concentrations of 5 to 20 p.p.m. in limed juice can increase the settling rate as much as 80-fold and reduce the volume of settling as much as 50%. Action of this sort is limited to juices from cane grown in particular areas. However, with other juices the effect of even much larger dosages may be negligible.

2. In instances where the polyelectrolytes are effective, they may be used to maintain normal grinding rates when poor settling juices are encountered. Cost of the treatment is small in comparison to the costs imposed by a slow-down in production.

3. Secondary treatment of filtrate with polyelectrolytes is feasible but it has not been shown to be of over-all value. This is particularly true during periods of poor settling, where it remains necessary to treat all incoming juice in order to provide effective relief.

4. The method of addition of the polyelectrolyte is important. Experience has shown that the best results are obtained by addition to the limed juice after heating. The flash tank of the clarifier offers the most convenient location. Addition to the pipeline leading to the flash tank is less satisfactory. This is probably due to breaking up of the flocs by the high velocity inside the pipe. The material must be added in dilute solution (0.05 to 0.10%).

In Figure 6 is shown a flow diagram for a polyelectrolyte addition system. Figure 7 shows the addition tank atop the clarifier at Grove Farm Campany.

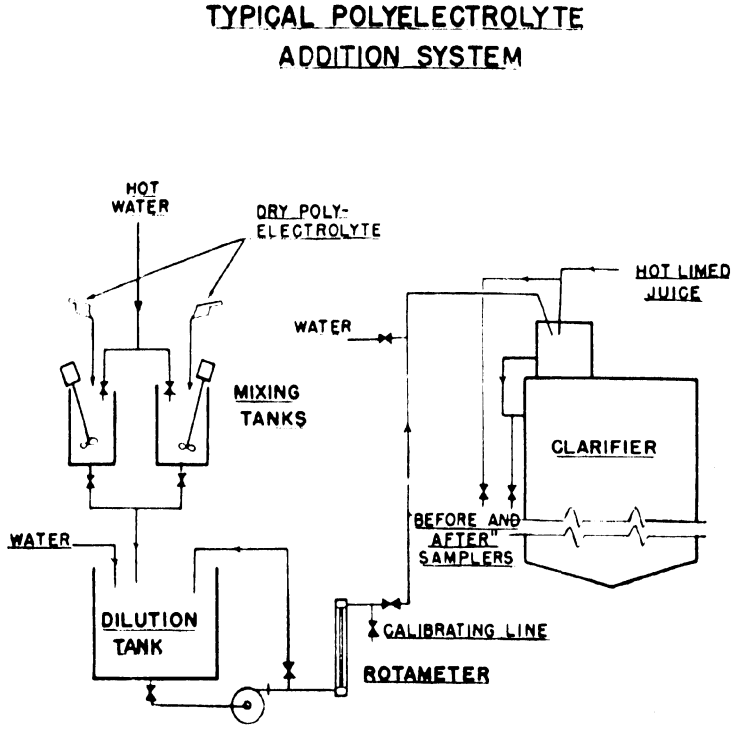


Fig. 6. Flow diagram of polyelectrolyte addition system.

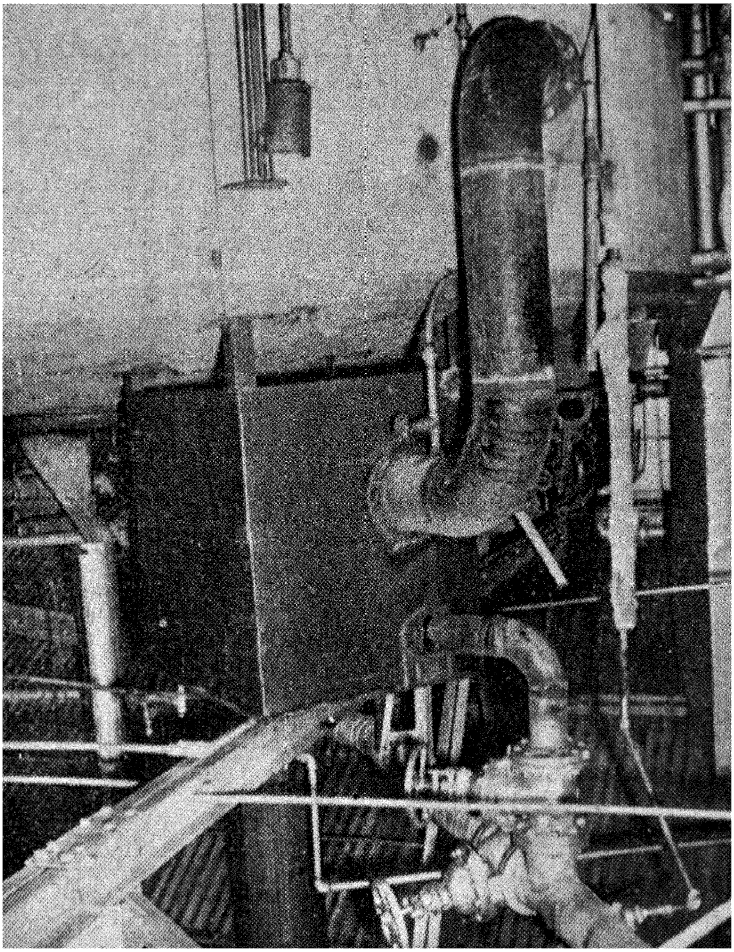


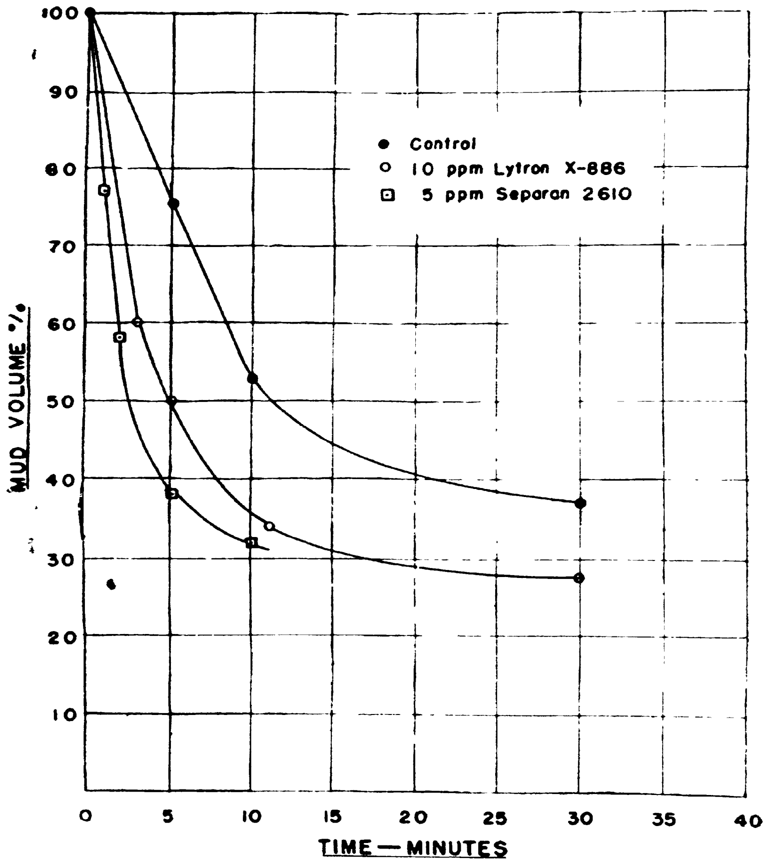
Fig. 7. Polyelectrolyte addition tank at Grove Farm Company. Hot limed juice enters through small elbow, polyelectrolyte from small line atop right.

Typical Data : Graphs of data from several tests are given in Figures 8, 9, 10 and 11. These serve to show the wide variation in behaviour of juices.

CONCLUSIONS

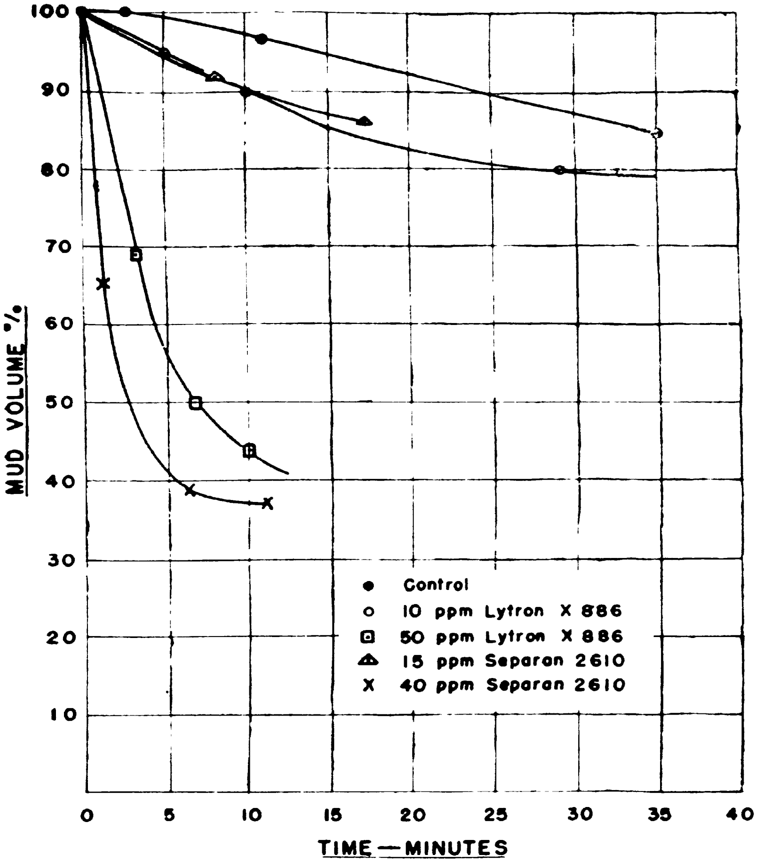
In the treatment of juices after heating, polyelectrolytes offer promise of economic utility in cases where poor settling is encountered. The mechanism of the varied behaviour of juices is not understood. It would appear, however, that polyelectrolytes of the cationic type would be more effective than the anionic type now commercially available,

Fig. 8.



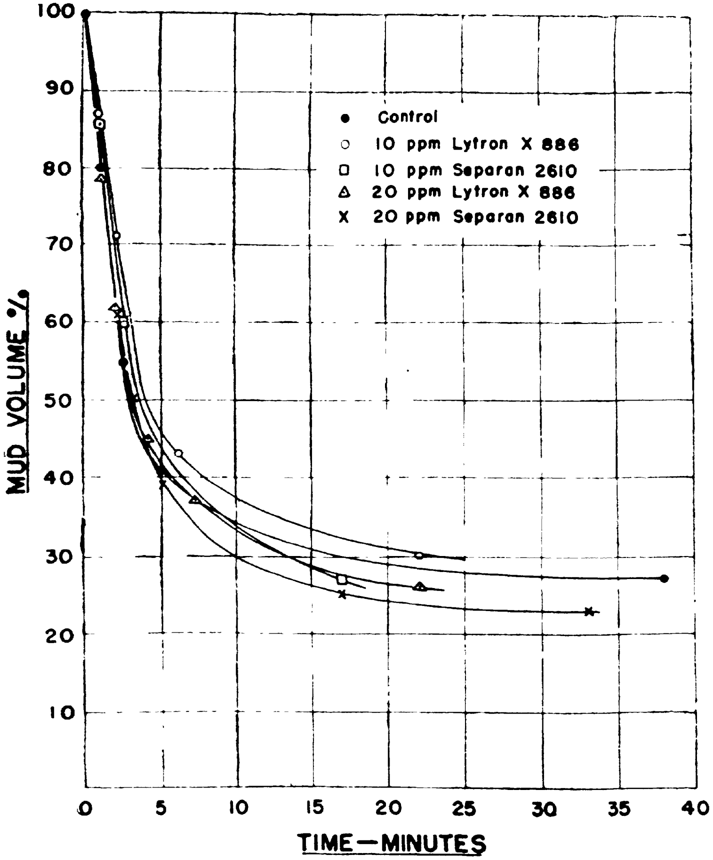
Polyelectrolyte treatment of limed mixed juice from Grove Farm Company. Turbidity of all juices after 30 minutes settling was zero. This is representative of a juice that gives good clarity and fairly rapid settling without polyelectrolytes.

Fig. 9.



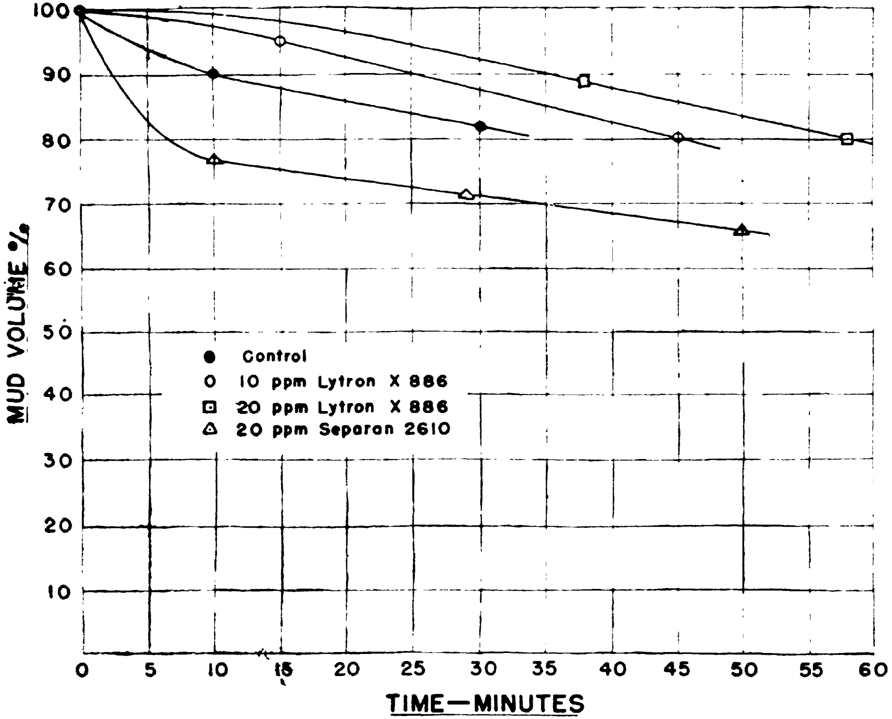
Polyelectrolyte treatment of limed mixed juice from Grove Farm Company. Turbidity of all juices after 30 minutes settling was zero. This is representative of a juice giving good clarity but very slow settling in normal clarification. Relatively large amounts of polyelectrolytes are necessary.

Fig. 10.



Polyelectrolyte clarification of filtrate from Pioneer Mill Company. This illustrates a good settling juice on which polyelectrolytes have little effect. Turbidities after 30 minutes : Control 46, 10 p. p. m. Lytron 21, 20 p. p. m. Lytron 0, 10 p. p. m. Separan 52, 20 p. p. m. Separan 25.

Fig. 11.



Polyelectrolyte clarification of filtrate from Olaa Sugar Company. A very poor settling juice which is adversely affected by Lytron and which Separan improves only to a limited degree. Turbidities after 30 minutes : Control 48, 10 p.p.m. Lytron 8, 20 p.p.m. Lytron 6, 20 p.p.m. Separan 44.

REFERENCES

1. Montgomery, J. W. 1950. Reports of the Hawaiian Sugar Technologists, 98.
2. Culver, E. C. 1951. ibid. 86.
3. Webb, R. T. 1952. ibid. 88.
4. Kenda, W. 1953. ibid. 54.
5. Michaela, A. S. 1954. Industrial and Engineering Chemistry, 46, 1485.
6. Bonneville, A. B. 1953. Sugar. 48, 36.
7. Thibaut, J. H. 1954. Sugar Bull., Louisiana, 32, 232.
8. Ghosh, S. K., Rao, P J. M. and Sanyasiraju, K. R. 1954. Indian Sugar. 4, 637.
9. Lee, C. A. 1954. Taiwan Sugar. 1, 20.
10. Clayton, J. L. 1954. Queensland Bureau of Sugar Experiment Stations, 54th Report, 83.

DISCUSSION

Mr. N· C. Varma observed that working with Geolgum, a polyelectrolyte though faster settling was realized, there was stickiness of the mud.

Dr. K. S. G. Doss ascribed the differences in the behaviour of polyelectrolytes to the conditions of use. By adjusting the condition in a manner that some small residual charge is present, the aggregation of flocs would continue and the mud would become more compact. Sedimentation volume and thickness of mud are of greater importance when using rotary filters. A perfectly reliable method is needed to achieve better correlation as between laboratory results and factory results.

Dr. Kerr ascribed the differences in the behaviour of polyelectrolytes to the nature of soils accompaying the juices.

Mr. Foster observed that final mud volume was never found to be appreciably smaller with polyelectrolytes. If it is impossible to filter when solids in mud are less than 4% irrespective of bagacillo, retention will be low with dilute muds, while with good muds retention can be as much as 80%.

Mr. F. H. C. Kelly referred to the experiments carried out in Tasmania and stated that for effective separation of soil particles from the juice in a liquid cyclone, it is necessary to have smaller diameter cyclones, with length considerably larger than the body diameter and pressure drops from 16 to 25 lbs. The required capacity could be obtained by having separators of the multicyclone type. He referred to the hydrophilic and hydrophobic colloids and said that the hydrophilic types are more troublesome.

Dr. S. Mukherji mentioned the work done by him on the naturally occurring polyelectrolytes, the Indian gum which has galacturonic acid as the chief constituent. The results obtained were similar to lytron.

Dr. Doss considered that in cane juices considerable proportion of even hydrophobic colloids would behave like hydrophilic due to the coating by proteins. Dr. Douwes Dekker stated that cyclones had not found to be quite successful in Java possibly due to the suspended matter being of a different nature as occuring in Hawaii.

Concluding the Chairman observed that the application of polyelectrolytes to the clarification of cane juices is yet in the development stage and considerable work has to be done to understand their application for best results.

In the absence of the author the Chairman Dr. Douwes Dekker presented the following paper.

Paper

LIMING OF CANE JUICES

J. MARCHES

Tiedeman and Van Kerchem, Surabaia, (Indonesia)

INTRODUCTION

In the liming of cane juices for the manufacture of raw sugar the amount of milk of lime added to the mixed juice results in a weakly alkaline reaction (in Java from pH 7.3 to pH 7.8). The result of this liming process is a purification of the juice ; the resulting clarified juice can be used without any difficulties for the manufacture of standard raw sugar. This purification is cheap. The amount of lime used as an average by the Java sugar industry is 0.75 kg. CaO per metric ton of cane, corresponding with 5 liters of milk of lime of 15°Be′ per m^3 of mixed juice.

For a good understanding of the liming process it is necessary to know exactly the reactions taking place in the liming. When a certain amount of milk of lime is added slowly to cold or heated mixed juice, the formation of a precipitate can be observed, in the beginning a small quantity but very voluminous. With an increased addition of lime the formation of flocks can be observed, settling easily. If this liming is demonstrated in a glass vessel, we observe that after a certain time of settling the precipitate sinks to the bottom of the vessel and the juice is practically clear, having a yellow to reddish brown colour. The turbidity and suspended impurities have all been concentrated in the settled flocculated precipitate.

These changes in mixed juice as a result of the addition of lime and the application of heat are partly physical and partly chemical. In the precipitate are eliminated the suspended non-sugars in mixed juice but together with a certain amount of organic and inorganic non-sugars present in solution in the mixed juice. The removal of the different types of non-sugars in clarification is incomplete, but it is satisfactory for the manufacture of raw sugar. The number of studies on the chemisty and the physical chemistry of clarification is extremely great and we know at this moment in how far it is possible to remove certain types of inorganic and organic non-sugars by the liming process. But what is lacking is the predetermination of the maximum conditions for non-sugar removal, if a mixed juice has to be processed of which we know nothing as to its composition. The criteria used commonly by sugar technologists to judge the results of the clarification are : rapid settling of the formed precipitate, light coloured clarified juice of a pH of approximately 7.0, free of turbidity and a maximum concentration of the settled muds.

It is a common experience that the behaviour of cane juices in the clarification shows tremendous fluctuations. It is for this reason that it is recommended to cane sugar mills, practising simple liming, to equip the factory with apparatus, enabling the application of different modifications of the liming process.

FACTORS INFLUENCING THE RESULTS OF THE CLARIFICATION

The main factors determining the results of the clarification are : the composition of the mixed juice, the temperature to which the juice is heated before and after liming, the pH traject and pH levels used in liming, the time the juice is subjected to certain temperatures and pH values, the regularlity in processing and the quality of the milk of lime. To prevent decomposition of reducing sugars and inversion of sucrose the processing of cane juice sets certain limitations to the acceptable combinations of time, pH level and temperature. But even with these limitations a great variation is possible in the liming technique.

COMPOSITION OF THE MIXED JUICE

One of the greatest difficulties to determine the maximum conditions for clarification is the variable composition of the mixed juice. This composition depends on cane variety and age, the soil and the system of the application of fertilizers, irrigation, rainfall and the maturity of the cane. Further on the time elapsing between harvesting and milling, the milling technique, the quality of imbibition water and in some cases eventually microbiological reactions in the mill tandem and the handling of the juice between mill and liming station. Extremely important is the quality of the cane. Green cane tops and trash, but particularly the tops, have as a rule a bad influence on the results of the clarification. Mechanical harvesting and particularly if the fields to be harvested have had rain a short time before the harvest, results in the introduction of a considerable amount of clay and soil particles in the mixed juice. It is essential for the clarification that the following points is always given careful consideration :

(1) The cane to be milled has to be clean and free of green tops.

(2) Cleanliness in the mill station and in the handling of the mixed juice is important to reduce microbiological action to a minimum.

(3) Suspended impurities particularly soil particles have to be removed before the juice is subjected to clarification by sand catchers or by modern cyclone separators. The disintegrated cane present in the form as fine bagasse particles has to be removed by a screening process.

(4) If the amount of inorganic phosphates in mixed juice is very low, it may be advantageous to increase the phosphate content by the addition of soluble phosphate.

Temperature :

The increase of the temperature of the mixed juice to be limed accelerates the different reactions and particularly the realization of certain reaction equilibria. The old practice was cold liming, after which limed juice was heated to a temperature slightly above 100° C. and boiled in a defecator to eliminate air in the hot limed juice before it was transferred to the settling tanks. This method of liming makes it practically impossible to obtain a constant pH of the clarified juice. This was partly the result of the fluctuating pH differences between limed juice and clarified juice. Hot liming has resulted in a tremendous progress to have a constant pH difference between the limed mixed juice and the clarified juice. Hot liming resulted in an improved control of the pH of the clarified juice. A secondary effect is that hot liming, under practically all conditions, results in an improvement in the non-sugar elimination particularly of proteins and the precipitation of the inorganic phosphates.

The present technique is liming at high temperatures either at boiling temperature or somewhat lower, as for as 70°C. The heating of the mixed juice has as advantage that microbiological reactions are completely suppressed. A disadvantage mentioned occasionally in the literature is that the heating of acid mixed juice would cause some sucrose losses by inversion. But a calculation shows that with modern juice heaters the time during which the juice has been subjected to a high temperature at a pH between 5 and 7 is so short that the sucrose losses by inversion are negligible (see the paper by Dr. P. Honig in this Symposium "Chemical Reactions in the Settling of Limed Cane Juices"). If factories wish to compromise on this point, there is no objection to lime the juices at 90°C.

pH :

To obtain the maximum removal of non-sugars and to prevent a non-admissible destruction of reducing sugars it is necessary that the amount of milk of lime to be added to the mixed juice should be such that it results in a clarified juice to be sent to the evaporators with a pH of 7.0 or slightly over it. Between 1934 and 1940 the average pH of the clarified juice of the Java raw sugar mills was 7.0 to 7.2. The limed mixed juice had an average pH of 7.3 to 7.5. Considering this final pH of limed mixed juice and clarified juice it is evident that the mixed juice can go through a large pH traject. We assume that 1 m^3 of mixed juice with a pH of 5.5 has to be mixed with 5 litres of milk of lime of 15° Be' to obtain a pH in the limed juice of 7.5. The mixing of juice and milk of lime can be done in the two following extreme ways :

(1) Gradual addition of juice to the milk of lime.

(2) Gradual addition of milk of lime to the juice.

If homogeneous mixing of the two components is assumed, we will have in case no. 1 : the first added juice will reach a pH of 12.5, decreasing with the addition of juice to a pH of 7.5. In case no. 2 the juice will go gradually from a pH of 5.5 to 7.5, therefore, no high alkaline reactions will occur in this liming process. It has, however, to be understood that homogeneous mixing is a technological problem in itself and even in case no. 2 it will be unavoidable that some of the juice particles will be exposed to a high alkalinity.

Another system of liming is by the use of saccharate. In this method 10% of the cold mixed juice is mixed with all the lime to be used in the clarification, the lime will dissolve in the juice to saccharate and this saccharate solution is applied for the akalination of 90% of the heated mixed juice. In this case a part of the juice will reach a high alkalinity at a low temperature which alkalinity decreases to a pH of 7.5. In the main part of the juice the pH increases from 5.5 to 7.5 in the liming process. This pH increase is instantaneous if the liming with saccharate is done continuously under perfect conditions of mixing.

Time :

The holding times of the juice in the different steps of the purification process are determined by the juice volume of the reaction vessels and crushing rate. This holding time will be determined by the variation in the grinding rate. It is still an unanswered question which holding times have to be considered as maximum. In liming tanks we can observe that the different factories go to very great extremes. The smallest liming tank we have ever seen in operation had a juice content of only 200 litres, or a holding time of only 15 seconds. At another factory we have seen a liming tank of 15,000 litres juice volume for a juice capacity of 16 litres per second, or with a holding time of 938 seconds.

The experience has shown that for the preparation of saccharate a holding time of 5 minutes is sufficient to dissolve milk of lime of good quality quantitatively in cold mixed juice.

Quality of the milk of lime :

It is essential in the liming of juices that the milk of lime is of the highest quality and has a uniform composition. We have to understand under these characteristics the purity of the lime, the density of the milk of lime, the degree of dispersion of $Ca(OH)_2$ and the reactivity of the lime. The best results are usually obtained with a milk of lime of 5 to 7°Be′.

In using saccharate as alkalising agent it is customary to mix cold mixed juice with milk of lime in a ratio of 9 volumes of mixed juice with 1 volume of milk of lime of 15° Be′. The exact and accurate dosage of saccharate is easier than the use of milk of lime of 5° Be′.

Regularity of the processing of juice :

Maximum results can only be obtained when the different phases of the clarification are completely controlled. It is necessary that this point is realized by the engineering and fabrication staff and that the size of the equipment is dimensioned in such a way that this ideal is approached as closely as possible.

EXECUTION OF THE LIMING PROCESS

Discontinuous or batch liming is considered in Java to be an old fashioned and unsatisfactory technique. The same opinion exists as to cold liming. We will discuss only the continuous hot liming process. In Fig. 1 the principle of this system of liming is given in the form of a diagram. If a juice is limed at boiling point temperature, the juice from the liming tank can overflow directly to the de-aerating vessel. It is possible in this case to eliminate the pump for limed juice going to the last juice heater. It has been found in practice that the settling quality of the precipitate formed in hot liming can be altered substantially when it is going through a centrifugal pump breaking up the flock structure and causing a much lower settling :

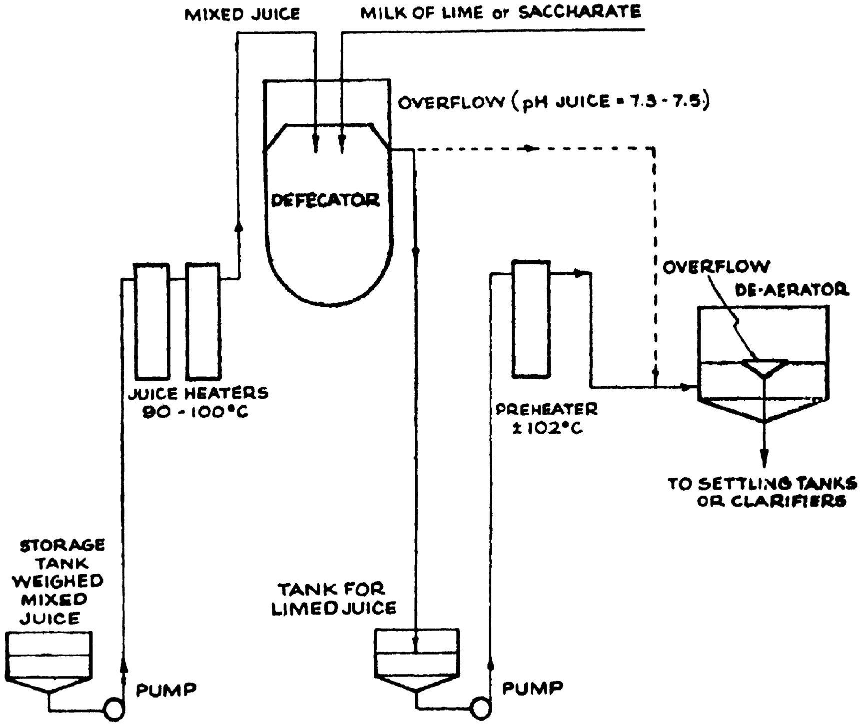


Fig. 1. Principle of continuous hot liming of mixed juice.

Holding time in liming tank :

The optimum times for liming juices are determined to a great extent by the regularity of the flow of mixed juice. The flow of mixed juice coming from the mill station is far from uniform. We have to include in the equipment a number of holding tanks or equalizing tanks resulting in a levelling of the juice flow. Usually the receiving tank for mixed juice at the mills has a capacity of 3000 to 5000 litres. The juice from this tank is pumped to the scales under which is constructed the receiving tank. This receiving tank under the scales has to be dimensioned in such a way that a uniform flow of juice is going to the juice heaters. It is customary in Java to dimension the receiving tank under the scales 2½ times the volume of one weighing of the scales. For instance with Boulogne scales with a capacity of 2400 litres per weighing the receiving tank should be at least 6000 litres.

Accurate technological studies on the establishment of uniform conditions in the liming of juices as affected by the type of installed equipment have been done only sporadically, but it has to be stated that the regular flow of juice going to the liming tank is one of the fundamental technological factors to obtain maximum results in clarification. Irregularities in milling are one of the main causes of unsatisfactory results in the clarification.

Juice temperatures :

The adjustment and maintenance of constant juice temperatures, assuming that a uniform juice flow has been realized, is simple. The irregularities in juice temperatures are primarily the result of the irregularities in milling and of bad adjustment of the mixed juice pump. Constant pressure of the vapours or steam used for heating the juice heaters can easily be realized in modern mills. The simplest solution is to maintain a constant pressure of the exhaust steam via an automatic overflow from the high pressure steam or via a coupling where vapours from the first bodies of the evaporators are used to have an overflow from the exhaust vapour line to the juice vapour lines.

In juice heaters it is essential that the off flow of condensate is uniform and that there is a satisfactory removal of uncondensable gases, as the quantity of uncondensable gas in using juice vapours can be quite considerable. The use of recording thermometers to control the juice temperatures is absolutely necessary in modern mills. Which deviations are permissible in the heating juices to be subjected to hot liming is a subject for further investigations. Furtheron we refer for the heating of juices to the paper presented by Mr. Chs. G. M. Perk " Systems of heating juices ".

Liming tanks :

The addition of milk of lime or saccharate of lime to the heated mixed juice is usually done in defecators. To maintain a uniform pH in the out flowing limed juice, a good mixing of the defecator contents is required. The mixing is done in different ways. As a rule the equipment is considered to be satisfactory when the limed juices show a good settling and the clarified juices are clear. However, well defined specifications as to the mixing of juice and lime, leading to optimum clarification, are not known.

In Figures 2-6, we give a number of installations as used in Java for the liming of mixed juice.

(a) In Fig. 2, a small tank of 200 litres juice content for a juice capacity of 13 litres per sec., is used as liming tank. The mixing is achieved via the energy of the flowing juice. It is possible with this kind of arrangement to get a good mixing of lime and juice, but it is occasionally very difficult to maintain a uniform pH of the outflowing limed juice. Therefore, a buffer tank of 5000 litres was put before the liming tank. Furtheron an indicating pH meter was used. Nevertheless, the operator had to give his full attention, as the system is rather sensitive. A small change in lime addition causes a rapid change in pH of the limed juice.

(b) In Figure 3 we have given a liming tank of a larger dimension. If the mixing in this kind of tank is insufficient, there is always a certain lag in the pH of the outflowing limed juice. This system is preferred where the operator is a little bit slowly acting and lazy. The liming tank given in Fig. 3 is an old pan used for a capacity of 33 litres of mixed juice per second. This system is used for hot liming. The juice is kept at boiling point temperature by the admission of steam to the calandria. The evaporation by the calandria results in a satisfactory mixing of mixed juice and milk of lime. The pH control and the attendance of the dosage of milk of lime have to be located on the same spot. But this last principle has to be applied in all liming installations.

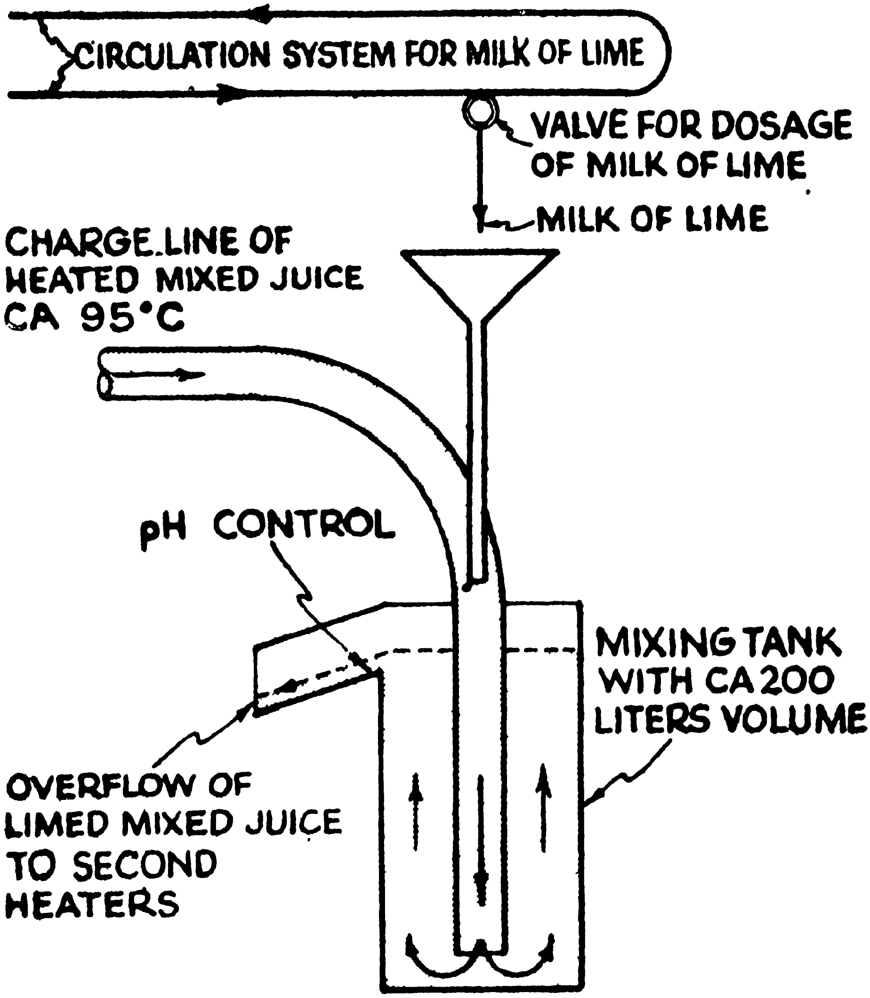


Fig. 2. Hot liming of mixed juice.

(c) A good mixing of mixed juice and milk of lime can be realized by forced circulation. This can be done via the mixed juice pump or via a special circulation pump. The juice delivered via these pumps is introduced at high velocity via nozzles or spray pipes into the diffuser. This results in a juice circulation as indicated in Fig. 4. The capacity of this installation is 16 litres of juice per second. The circulation pump has a capacity of 19 litres per second. The juice volume of the liming tank is 15,000 litres, being according to our opinion very large.

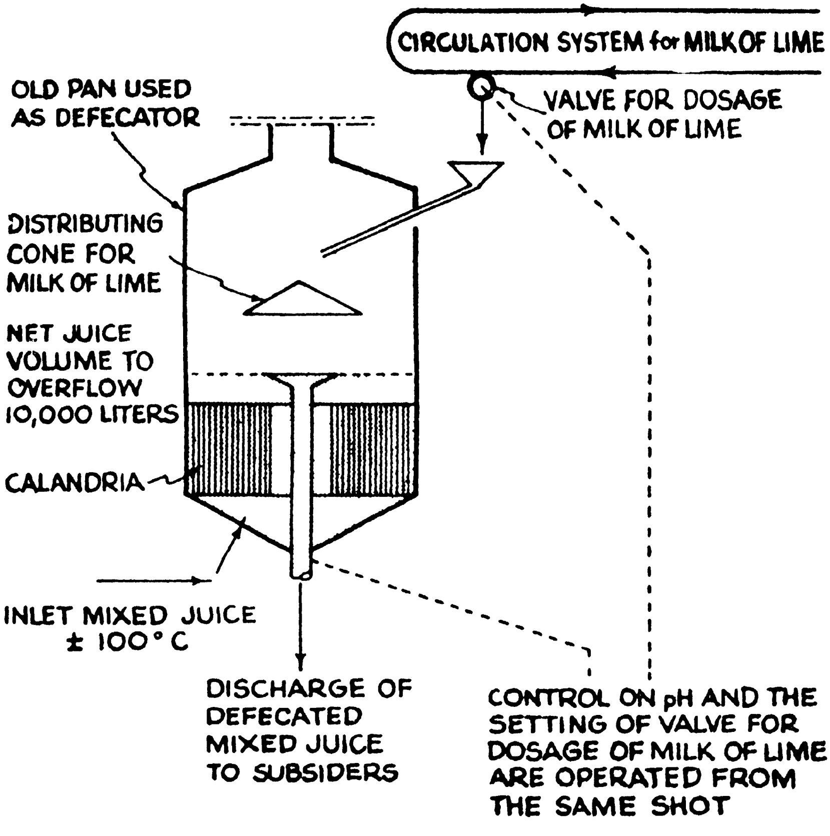


Fig. 3. Hot liming of mixed juice at boiling point temperature.

The original construction was to use only a special installed circulation pump to maintain a satisfactory mixing. This kind of mixing has been investigated by filling the liming tank with water and determining the time necessary that a certain amount of added milk of lime was mixed homogeneously with the liquid. The pH of the water taken from different places was determined at fixed intervals. We added in this experiment 4 litres of milk of lime of 11° Be'. Sampling was done at 7 different places as indicated in Figure 5. The sampling valves were fully opened during the experiment. The results were as follows. After the liming tank was filled with water and the circulation pump had been functioning for sometime, at a time = 0, all the milk of lime was added at once. At the same time the sampling was started. The results of this experiment are given in Fig. 5. After 3 minutes the lime was mixed homogeneously through the whole water volume in the liming tank. We considered that a mixing time of 3 minutes was a fairly long time. Therefore, later on the inlet of mixed juice was used as an additional source of energy to promote the circulation.

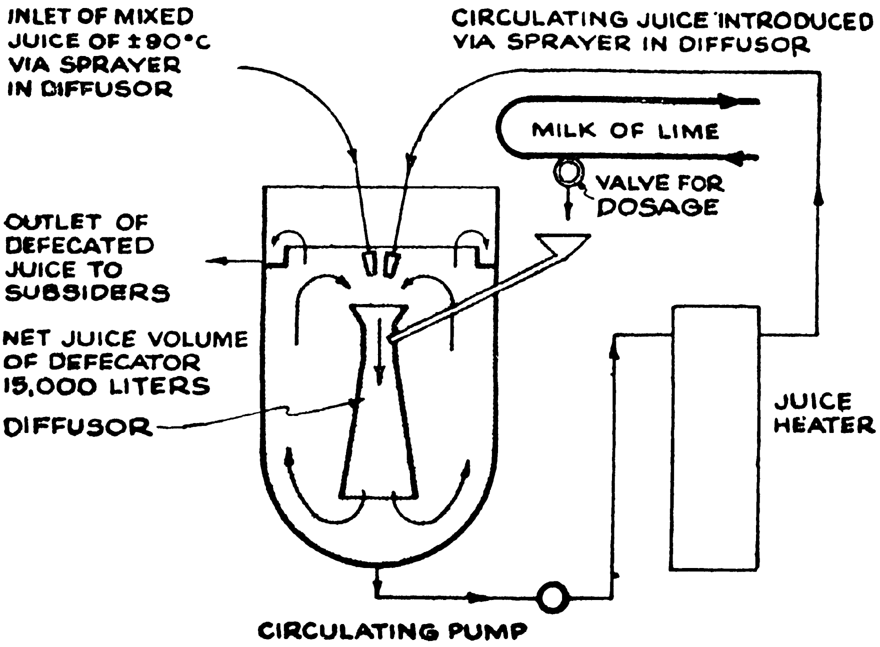


Fig. 4. Hot liming of mixed juice with forced circulation.

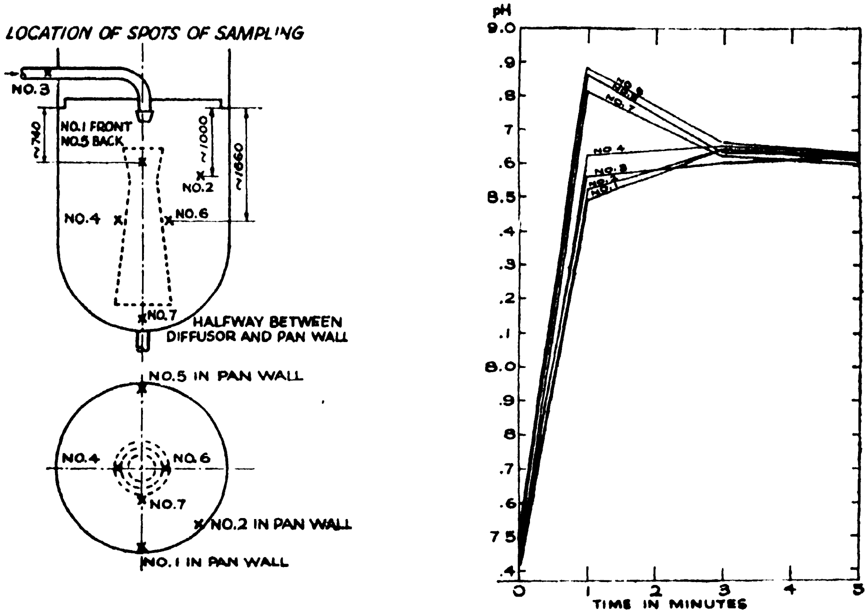


Fig. 5. Position of sampling and relationship between pH and time interval.

(d) In Figure 6 we give a circulation system with a propellor mounted in the vertical tube. This system gives a really good circulation and mixing and results in a very constant pH of the limed juice.

Mixing, circulation and circulation number:

The principle of mixing in liming tanks is that each juice particle has to pass one or more centres of intensive turbulance. In the mixing centres prevail turbulent currents determining proper mixing. It is necessary for good mixing that each juice particle passes several times these mixing centres. Outside the mixing centres the juice flow has to be smooth or mainly of laminar character. This part of the flow way therefore has to get smooth surfaces and no obstacles in it. The milk of lime or saccharate of lime has to be introduced in such a way that it never can go directly to the outflow. Preferably it has to be introduced short before or in the mixing centre.

Assuming that a liming tank has been constructed in such a way that there are no dead spots, meaning that the whole juice content takes part in the circulation, we can use as an indicator for the circulation intensity the circulation number. This is the number of times the juice content circulates per minute. We have found that good mixing performance is obtained if the circulation number is 2.5 to 4.

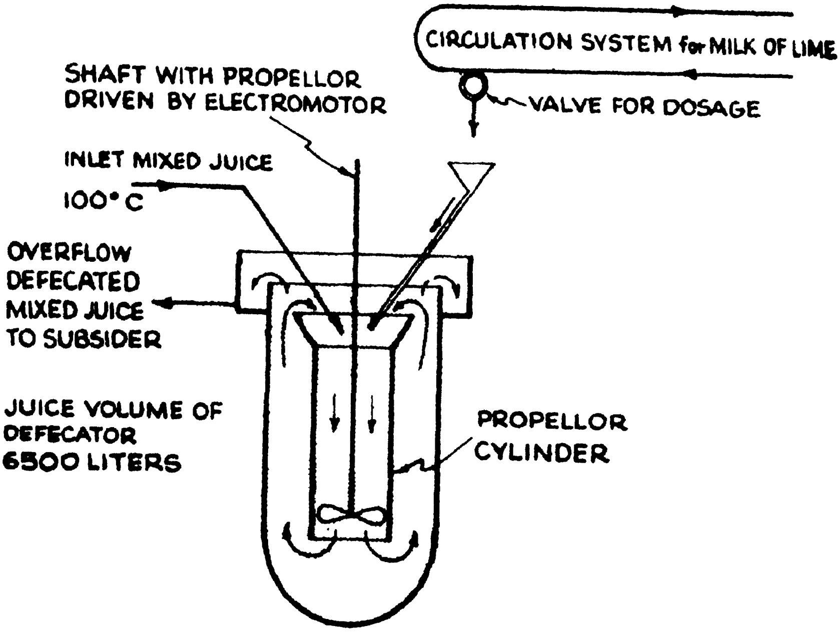


Fig. 6. Liming tank with propeller as mixing device.

A liming tank as given in Fig.6, juice volume 3000 litres, was used with good results for a capacity of 16 litres/sec. Fig. 7 gives the main dimensions of such a liming tank. The propellor velocity was found empirically. To reach this end the tank was filled with water, the propellor set in action and then a bucket full of $KMnO_4$ solution was emptied at once (time=0) into the concentrical tube. By means of a stopwatch was found how many seconds were needed until the $KMnO_4$ colour became visible after one complete circulation of the tank content. Now the velocity of the propellor was adjusted until one circulation lasted 15 to 20 seconds, giving a circulation number of 4 to 3. This means the capacity of the circulating liquid is 4 to 3 times the tank content. Assuming the latter as 3000 litres, they circulate in the tank 12000 to 9000 litres/min.

The use of circulation pumps mounted outside the reaction vessels has not always been an engineering success in Java in prewar time, especially if bearings came into contact with alkaline juices. If a mixing device is installed as given in Fig. 6, it is advisable to mount the propellor similar to a suspended centrifugal.

It can be stated that the maintenance of a constant pH in the limed juice is better if a more perfect circulation exists. It is also certain that a number of conclusions on the destruction of reducing sugars has been influenced by imperfect mixture of mixed juice and milk of lime. The better the mixing in the liming tank, the less is the possibility for locally high alkalinities and a destruction of reducing sugars. It is a logical conclusion that with perfect mixing in liming tanks higher temperatures can be applied in the liming of juices without danger for nonpermissible destruction of reducing sugars.

Dosage of milk of lime and saccharate.

The purpose of the dosage of milk of lime or saccharate is to add so much reagent to the mixed juice that the mixed limed juice has a pH between 7.3 and 7.8. The amount of milk of lime necessary to obtain this final pH varies with the composition of the mixed juice. In Java this variation is between 2 and 6 litres milk of lime of 15° Be′ per 1000 litres of mixed juice. It is impossible to realize a constant pH of the limed juice with a constant and prefixed addition of milk of lime. Automatization of the dosage of milk of lime is only possible by using the pH fluctuations of the limed juice as impuls for the adjustment of the dosage mechanism for the milk of lime. It is possible to use a constant amount of milk of lime per 1000 litres of mixed juice but only as a preliming or first liming, to be followed by a second liming adjusted to the lime requirements of the juice processed.

The common system in Java is to add the milk of lime hand operated. For the dosage are in use ; common plug cocks, y-shaped valves Nielsen plug cocks or nozzles with regulator pins. The pH of the limed juice (determined colorimetrically or electrometrically) is an indication for the operator how the regulating mechanism for the addition of milk of lime has to be adjusted. The regulation mechanism for the addition of milk of lime has to be sufficiently sensitive but not oversensitive. Furtheron it must be possible to correct a too

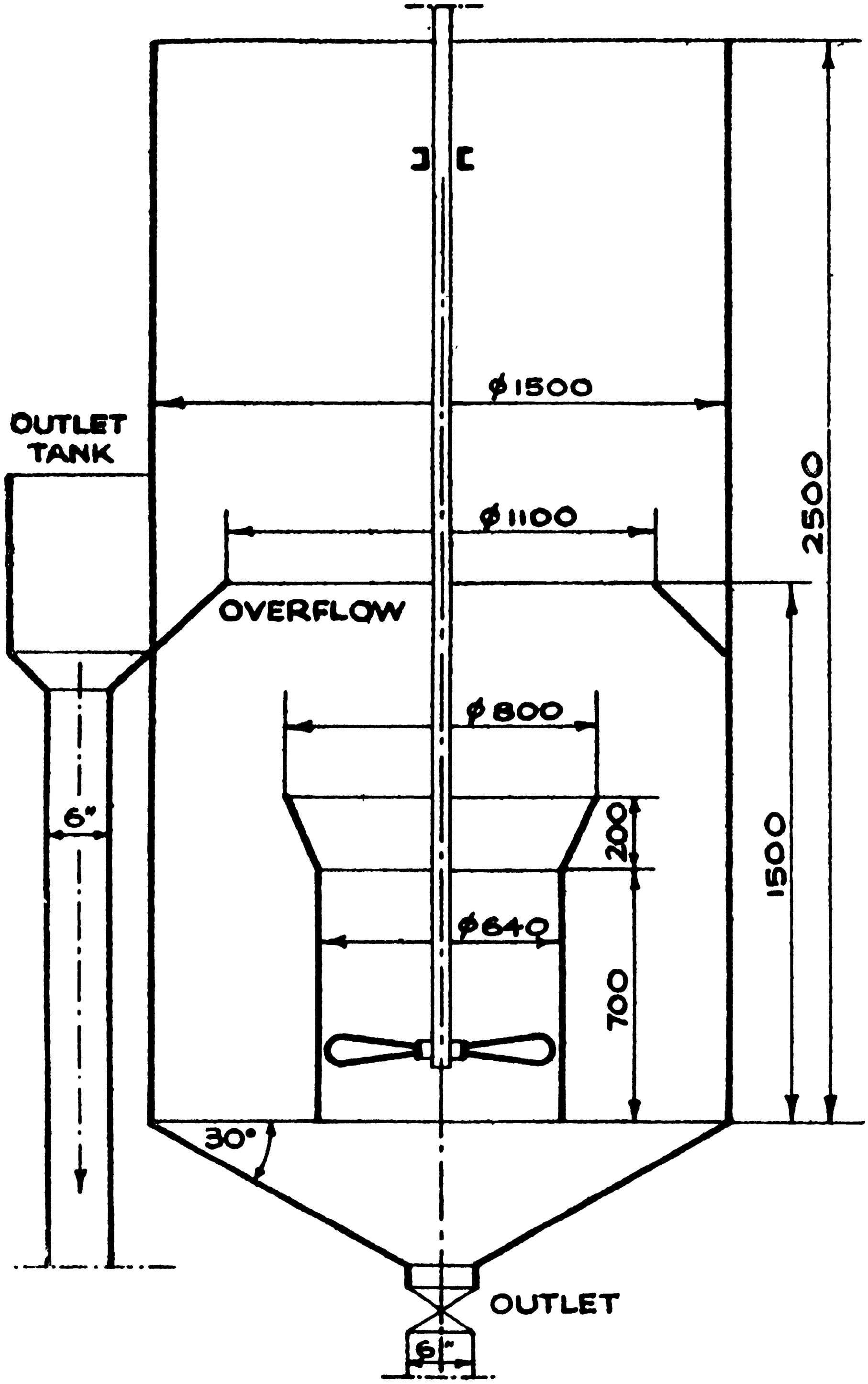


Fig. 7. Liming tank.

low pH rapidly by opening the dosage mechanism to the full extent. Is the pH value too high, it is necessary to shutoff or to reduce the flow of milk of lime and to wait that a sufficient amount of mixed juice has entered the liming tank to obtain the correct pH. It is, of course, understandable that the regulating mechanism for the milk of lime has to be adjusted to the juice volume of the liming tank. A regulating mechanism has to operate under all circumstances in such a way that in the same position the same amount of milk of lime is delivered per unit of time. For this it is necessary that the milk of lime has a constant composition and also that the pressure of the milk of lime before the regulating mechanism is constant. A simple solution to realize this is to use a small reservoir (net volume 150 to 250 litres) with a continuous overflow as given in Fig. 9. It is posssible to use with such a reservoir a small pressure height for the milk of lime, enabling us to apply a larger outflow opening in the regulating mechanism. The opening of the outflow is reciprocal with the velocity of outflow or reciprocal with the root of the pressure height : $V = c\sqrt{2gh}$*).

This means that if the pressure height of the milk of lime is 9 cm., the outflow opening can be twice as large as at 36 cm. and three times as large as at 81 cm. The outflow co-efficient c for milk of lime increases with increased pressure heights. For circular outflow openings and milk of lime of 11° Be' this co-efficient increases for pressure heights from 10 to 50 cm. from 0.90 to 0.95. As a rule we use the co-efficient of 0.90.

Besides by the application of small pressure heights of the milk of lime, a larger outflow opening can be obtained by the use of more diluted milk of lime. An example may illustrate this point :

A factory with a capacity of 1500 tons of cane per day produces an amount of mixed juice of approximately 15 litres per second. The average lime addition is equivalent to 5 litres of milk of lime of 15° Be' per m^3 of juice. We have to add the following amounts of milk of lime per unit of time :

$15 \times 5 = 75$ ml. milk of lime *of* 15° Be' per second

or : $75 \times \frac{148}{94} = 118$ „ „ „ of 10° Be' „ „

or : $75 \times \frac{148}{46} = 241$ „ „ „ *of* 15° Be, „ „

or : 750 ml. saccharate 1 : 10 per second.

Manual dosage of milk of lime.

Assume we want to calculate the dimensions of a nozzle with an adjustable pin regulator as given in Fig. 8 for a factory with a capacity of 1500 tons of cane per 24 hr., with a liming tank of 3000 liters the use of milk of lime of 5°Be' and a pressure height of the milk of lime of 20 cm., the calculated velocity of outflow of milk of lime is :

$$V = c\sqrt{2gh} = 0.9\sqrt{2 \times 9.78 \times 0.2} = 1.78 \text{ m./sec.}$$

---

* V = velocity of outflow in m./sec.
c = outflow co-efficient
g = acceleration of gravity (9.78 m./sec.^{2})
h = height in metres of the column of milk of lime above the outflow opening

The cross section F of the outflow opening is derived from :

$$178 \times F = 241$$
$$F = 1.35 \text{ cm}^2.$$

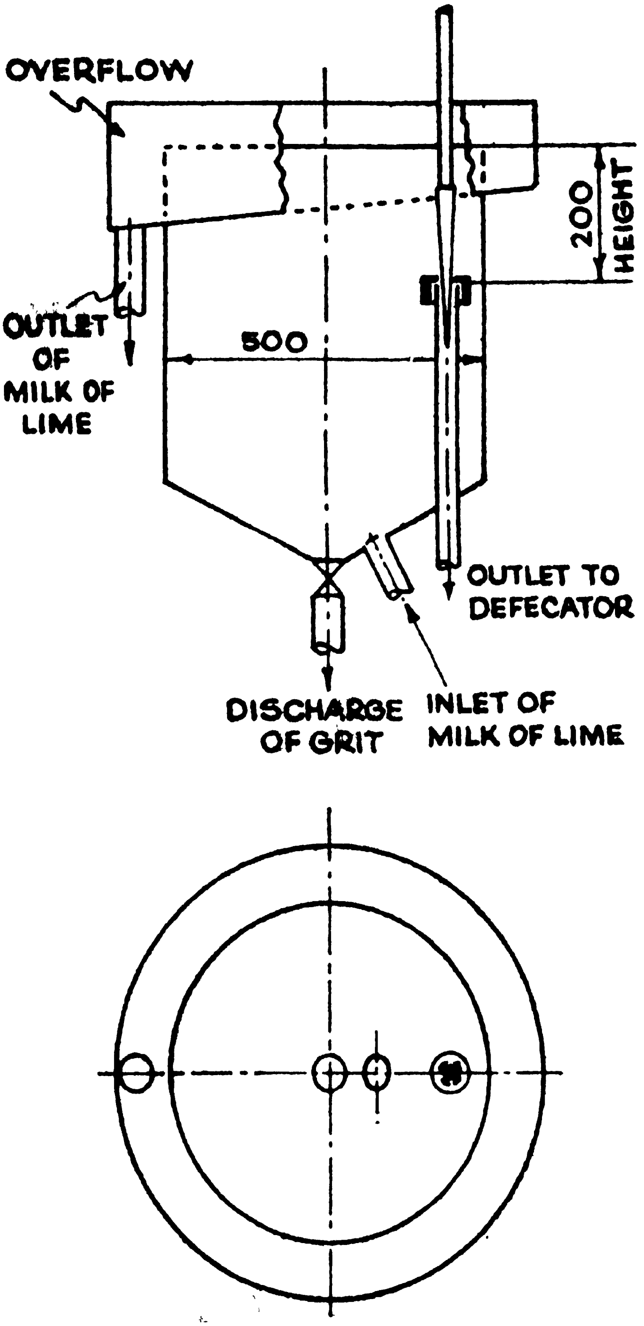


Fig. 8. Tank for milk of lime with nozzle and regulator pin.

We want to calculate also the desired maximum outflow area when the full opening of the nozzle is applied. For this calculation we suppose that the juice in the liming tank has to be brought from 6 to 7.5 pH in one minute, The lime requirement of the juice can be taken from titration curves. For this example we use the following data :

Required to adjust the pH of the juice from 6.0 to 7.5	max. 700 mg. CaO/litre
Required to adjust the pH of mixed juice to 7.5	max. 900 mg. ,, ,,

Assuming a perfect mixing it is (roughly calculated) necessary to add in the liming tank in one minute the following amounts of CaO :

To adjust the pH at 7.5 in the liming tank	3,000 × 700 = 21,00,000 mg. CaO
To adjust the pH of mixed juice to pH 7.5	60 × 15 × 900 = 8,10,000 ,, ,,
Total	29,10,000 mg. CaO

This quantity of CaO corresponds with $\frac{29,10,000}{60 \times 46} = 1,054$ ml.

milk of lime of 5° Be′ per second. At the calculated velocity of outflow of 178 cm. per second the opening of the nozzle has to be :

$$Ft = \frac{1,054}{178} = 5.92 \text{cm}^2.$$

A nozzle diameter of 2.75 cm. corresponds to this area. For the practical construction of the nozzle we take as the diameter 30 mm. The adjustable pin, a smooth cone, has to be made of such dimensions that if a length of 150 mm. is put into the nozzle, the opening is completely closed, as shown in Fig. 9. The mechanism for moving the regulating pin upwards and downwards has to go smooth, so that the pin cone can easily be brought to a known position. It is important that the pin position is indicated to the operator in a clear way. This can be done by a vertical or horizontal scale, depending on the means of transmission between the hand operated lever or hand wheel and the regulator pin. The extreme positions of the pin, full open and closed, should be easily reached without too much turning of the lever or wheel.

The normal (average) position of the adjustable pin in the nozzle corresponds to a ring-shaped opening of 1.35 cm^2. In the normal position the pin has to close a cross section O, to be calculated from :--

$$\pi/4 \times 3^2 - O = 1.35$$

$$O = 5.72 \text{ cm.}^2$$

This area belongs to a diameter of 2.7 cm. In the normal position of the pin therefore the opening between nozzle and pin cone is 1.5 mm. clogging of this opening is exceptional if well screened milk of lime of 5°Be′ is used. However, it is recommendable to let the milk of lime from the nozzle flow

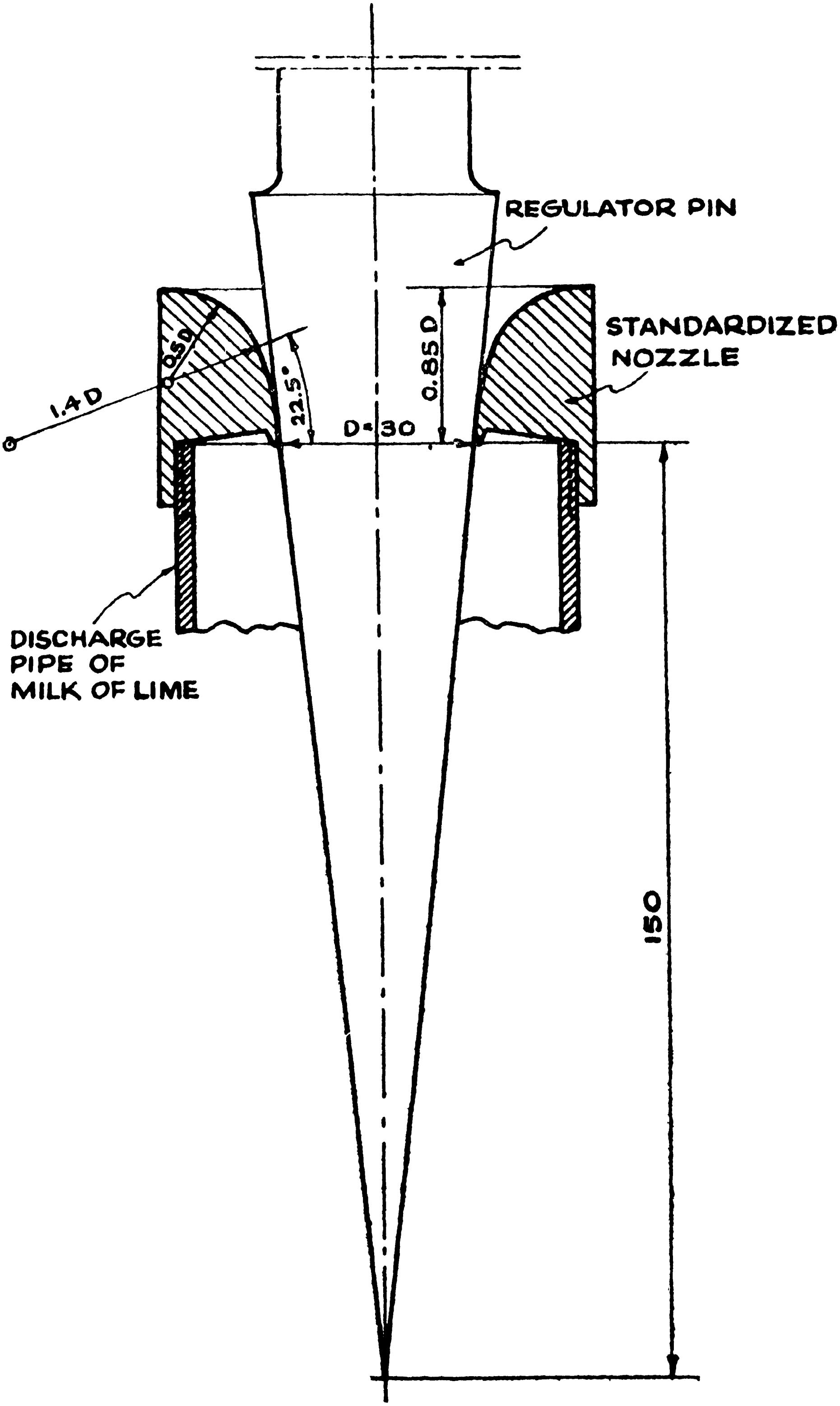


Fig. 9. Nozzle with regulator pin.

out into an open funnel visible for the operator, thus enabling him to inspect the function of this piece of equipment.

Different other forms of regulating mechanism for milk of lime are possible. I am referring to page 816 of "Principles of Sugar Technology" by P. Honig. The calculation of the openings in a Nielsen valve can be made in a similar way as has been described for nozzles.

Partial automatization of the addition of milk of lime.

With the equipment as described on page 618/620 of "Principles of Sugar Technology" by P. Honig, it is possible to add continuously a constant and predetermined volume of milk of lime to a given volume of mixed juice. The lime addition is here independent of fluctuation in the flows of the mixed juice. It is, however, necessary to combine this lime addition with a second piece of equipment, in order to meet the differences in the lime requirements of the juice. This second piece of equipment can be a Nielsen plug cock mounted on the outside of the automatic liming device, or a nozzle with an adjustable pin. In Fig. 10 is given the principle of this system of liming.

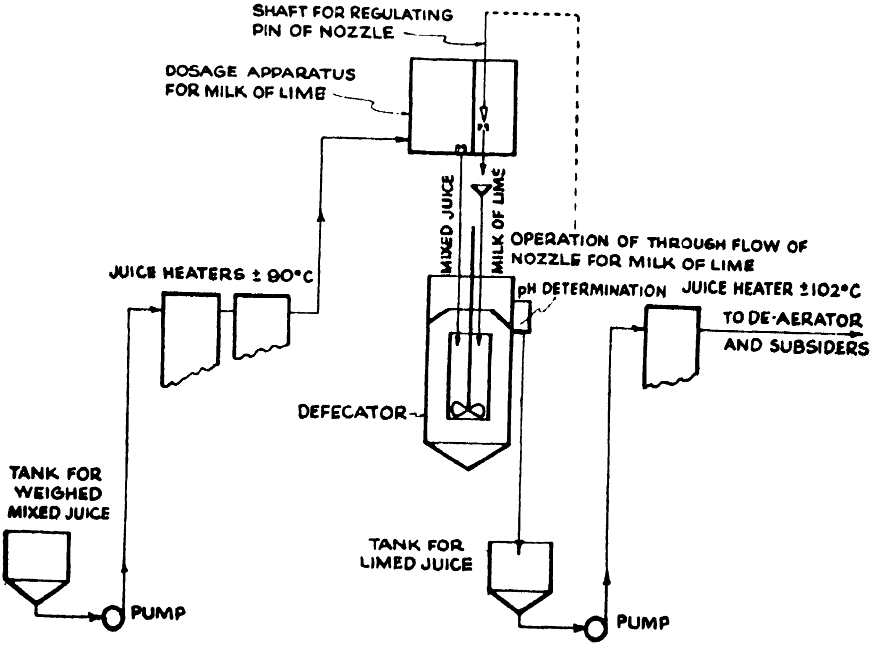


Fig. 10. Partial automatization of the addition of milk of lime to mixed juice.

Partial automatization of the addition of saccharate of lime only.

Liming exclusively with saccharate is possible, if every moment only the needed amount of saccharate can be prepared. The liming equipment as given on page 618/620 of Honig's "Principles of Sugar Technology" can prepare saccharate of a constant volume ratio : mixed juice to milk of lime. To prevent destruction of reducing sugars the temperature of the saccharate should never exceed 55°C. For sake of simplicity the mixed juice is pumped unheated (30°C.) to the automatic liming device. In Fig. 11 the principle of the liming is shown.

For the preparation of saccharate the nozzle B in the mixed juice compartment and the nozzle C in the milk of lime compartment are both equipped with a regulating pin. The two regulating pins, of equal cone length, are coupled with each other in such a manner, that both nozzles at the same time are either fully closed or fully opened. This guarantees a constant ratio of the outflow areas. Hence the ratio : outflown mixed juice to outflown milk of lime remains constant, meaning that the mixture of both (=saccharate) has a constant composition. Moving the coupled pins upwards or downwards results in the outflow of more or less saccharate. The small tank for saccharate shown in Fig. 11 is necessary to dissolve the Ca $(OH)_2$ completely in the mixed juice. This saccharate tank (volume 500 litres) is always filled to the brim. For every inflowing volume mixed juice plus milk of lime the same volume saccharate flows over to the liming tank.

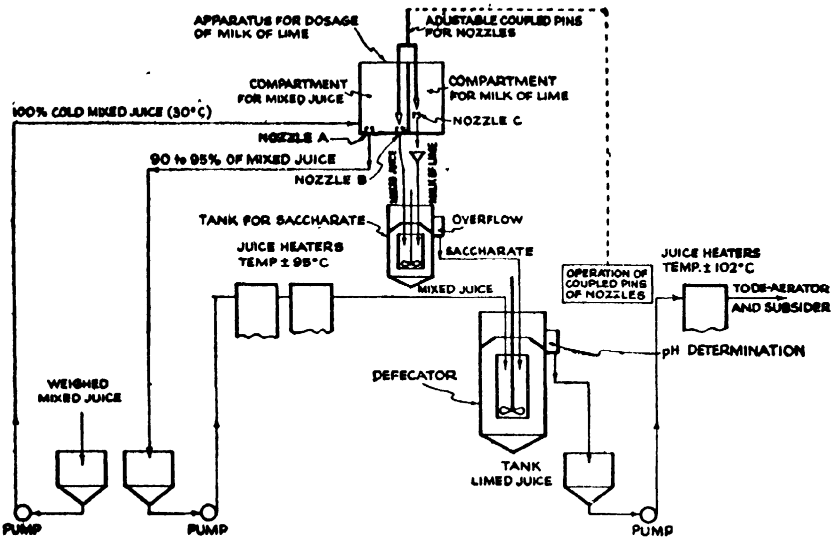


Fig. 11. Partial automatization of the addition of saccharate in the liming process.

The mixed juice not used in the preparation of saccharate flows via nozzle A, tank, pump and heaters (100°C.) into the liming tank. If nozzle A is given a large diameter and is provided with a regulating pin, this pin can be used to adjust for considerable changes in milling capacity.

The ratio mixed juice to milk of lime for the preparation of saccharate can be chosen and fixed as desired, using for instance 5, 10, 20 or 30% of the mixed juice for saccharate making. It has to be kept in mind that with high percentages of mixed juices, used for saccharate, the temperature in the liming tank decreases. Then heating of the contents of the liming tank may be needed. This can be done by a system as given in Fig. 4.

DISCUSSION

Mr. S. N. Gundu Rao referred to the present day availability of proportioning pumps for automatic liming of cane juices which where necessary can also be linked to the juice flow.

Dr. H. W. Kerr referred to the variation in the quality of juices in Queensland and said that it is the pH controlled unit that takes care of such variations.

Mr. Clayton referred to the several factors working to the detriment of the defecation system and in particular to staleness which also affects the bufferring capacity of the juice. Experiments have indicated the desirability of adding some stronger alkali in addition to lime. With the adoption of hot liming the problem of adding lime to hot solutions under pressure introduces further difficulties. The relative importance of proportional addition and fixed addition needs study.

Dr. Doss stated that while using partly strong alkali may have advantages, the possible contribution of alkali to molasses formation should be kept in mind.

Mr. Gundu Rao pointed out that in the sulphitation system of clarification proportioning is of great importance.

Mr. Kelly posed the question what is clarified juice and considered that the chief objects of controlling pH are prevention of inversion and of destruction of reducing sugars.

In the absence of the author, Mr. S.N. Gundu Rao presented the following paper.

Paper

CHEMICAL REACTIONS IN THE SETTLING OF LIMED CANE JUICES

Pieter Honig

West Indies Sugar Corporation, 60 *East*, 42*nd Street*,
New York, 17, *N.Y.*

> "Repeated generalities without quantitative foundations are employed frequently in technical discussions, but sweeping statements never assist in technological progress".
>
> From the Lessons of an Old Professor.

INTRODUCTION

A number of important reactions occur in the settling of cane juices. These reactions become of greater importance with the introduction of continuous clarifiers compared to the old system of intermittent subsiders.

The reactions can be distinguished into the following groups:

I. The effect of the clarification on sucrose.
II. The effect of clarification on reducing sugars.
III. The effect of clarification on suspended non-sugars.
IV. The effect of clarification on the soluble non-sugars.

INVERSION OF SUCROSE

The most important reaction in connection with sucrose is inversion. Sucrose is hydrolyzed in solution in acid medium and this reaction is called inversion. A large number of fundamental studies on the rate of inversion has demonstrated that the main factors in the inversion reaction are the concentration of the H-ions and the temperature. The inversion rate is proportional to the H-ion concentration at the same temperature and the inversion rate increases with the increase in temperature.

It is possible to calculate the magnitude of the sucrose losses in the clarification process when we know the pH of the juice subjected to clarification and the temperature. For technical calculations in the manufacturing process certain assumptions have to be made :

(a) An assumption has to be made as to the average temperature to which the juices have been subjected in the settling process. It is possible to take the average of the temperature of the ingoing juice and the temperature of the outgoing juice. It is also possible to base our calculations on the average temperature of the outgoing juice.

(b) It is possible to calculate the inversion losses based on the average pH of the hot limed juice entering the clarifier and the pH of the outgoing clarified uice.

(c) It is possible to take the most unfavourable assumption, namely, that all the juice in the clarifiers has been subjected during the settling process to a pH equal to the average pH of the clarified juice. This assumption is undoubtedly incorrect. There is always a certain change in the pH of the juice during the settling process as a result of transformations of the precipitated non-sugars and the dissolved non-sugars. This change in pH cannot be predicted but it has to be determined by actual determinations. This drop in pH may be 0.2 of a pH unit or it may be 1.5 to 2 units. It depends on the liming technique, the composition of the non-sugars, the rate of disintegration of decomposition products of reducing sugars, the amounts of organic phosphates hydrolyzed in clarification, and still a few other circumstances.

It is a fair assumption to calculate inversion losses using as the temperature the average temperature of the outgoing clarified juice and the average pH of the clarified juice of all the compartments. The actual average pH in the clarifier will be higher than this determined value of the pH of the clarified juice but, on the other hand, the juice temperature during the settling process will be higher than the determined temperature of the outgoing juice.

As the inversion rate is proportional to the H-ion concentration, we have to know exactly what the inversion rate is at carefully determined pH values. The best available data show that the inversion rate at 100°C. and a pH of 7.0 is equivalent to 0.021 % sucrose inverted per hour. This value has been determined several times by investigators and it is at the present moment the best basis for the calculation of inversion losses.

In Table I we give the percentage of sucrose inverted per hour at 100°C. at different pH values, calculated with the assumption that the H-ion concentration and inversion rate are strictly proportional.

The temperature co-efficient of the inversion is extremely high. Also the relationship between inversion rate and temperature has been determined with great accuracy. If the inversion rate at 100°C.=100, the rate of inversion at other temperatures relative to the velocity of inversion at 100°C. is as given in table II.

TABLE I

%OF SUCROSE INVERTED PER HOUR AT 100°C. AT DIFFERENT pH

pH	% inversion	pH	% inversion	pH	% inverison
4.6	5.32	5.9	0. 27	7.1	0.017
4.7	4.24	6.0	0. 21	7.2	0.013
4.8	3.37	6.1	0. 17	7.3	0.011
4.9	2.70	6.2	0. 13	7.4	0.008
5.0	2.12	6.3	0.117	7.5	0.007
5.1	1.68	6.4	0.084	7.6	0.005
5.2	1.34	6.5	0.067	7.7	0.004
5.4	0.84	6.6	0.053	7.8	0.003
5.5	0.67	6.7	0.042	7.9	0.003
5.6	0.53	6.8	0.034	8.0	0.002
5.7	0.42	6.9	0.027		
5.8	0.34	7.0	0.021		

It is possible by a graphical method to determine for any given condition in the clarifier the inversion losses, if the pH and the temperature of the juice are known. In Fig. 1 we have given this relationship and this figure can be used by sugar technologists to estimate the inversion losses in clarification. A direct determination of the inversion losses by the change in the amount of reducing sugars or by the ratio of reducing sugars/sucrose is never as accurate as a direct calculation with determined pH values and temperatures.

TABLE II

Temperature in °C.	Relative velocity of inversion (rate of inversion at 100°C. = 100)	Temperature in °C.	Relative velocity of inversion (rate of inversion at 100°C. = 100)
120	523	100	100
110	257	99	92.1
107	200	98	85.0
105	167	97	78.3
100	100	96	72.0
95	66	95	66.0
90	41.5	94	60.5
85	24.5	93	55.4
80	15.7	92	50.6
75	8.5	91	45.9
70	4.9	90	41.5
65	2.9		
60	1.7		
55	1.0		
50	0.47		
45	0.25		
40	0.13		
25	0.018		

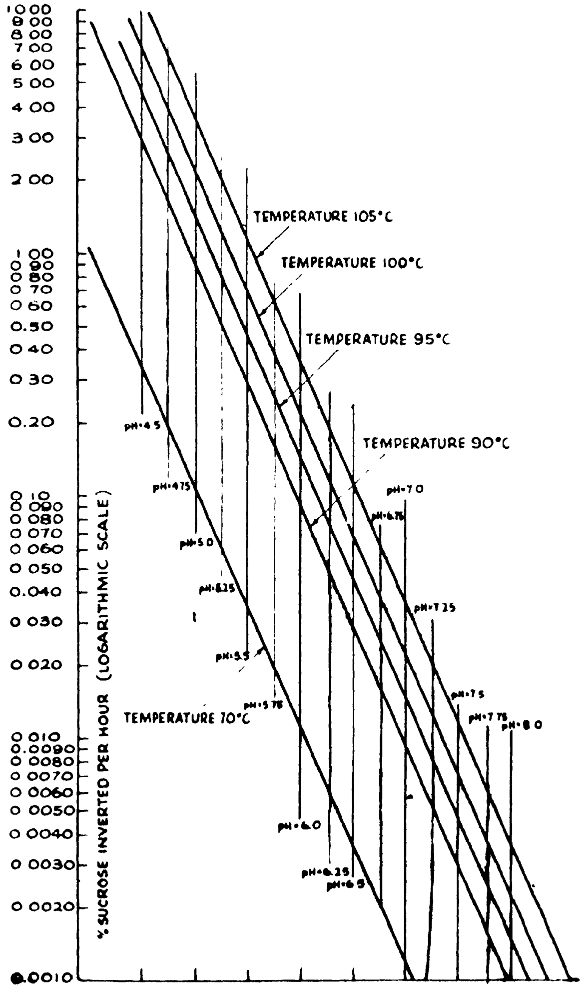


Fig. 1. Representing the relation between pH and inversion per sucrose per hour in

The sucrose inversion is calculated as folows :

1. Take the determined pH of the juice (syrup or liquor) and read this pH value on the abscissa.
2. Determine where this pH value crosses the temperature line (the temperature to which the juice has been subjected).
3. Read on the ordinate the corresponding value for the percentual inversion per hour.
4. Multiply this inversion value with the number of hours the juice has been kept at the determined pH and temperature.

DECOMPOSITION OF REDUCING SUGARS

In the settling process there is also a change in the reducing sugars. If a clarified juice is subjected to higher temperatures at a sufficiently high pH (pH over 7), it can be observed that there is a loss in the concentration of reducing sugars as determined with Fehling solution.

The explanations for these reactions are several, but there is a good reason to assume that at high temperatures and at higher pH values the reducing sugars react with amino acids, which reaction results in a loss of the reducing power of the reacting reducing sugars.

The magnitude of this change is not exceptionally great, but it has been found that clarified juice heated at 100°C. for 3 hours can show a loss in reducing power of about 4% of the reducing power originally present. This change in reducing power in reducing sugars is greater at a high pH value. If we are working under abnormal conditions as for instance clarified juices of a pH of 8 to 8.5, the loss in reducing power can be as high as 3 to 4% per hour.

ACID FORMATION IN CLARIFIERS

One of the most important reactions in clarification is the change in the pH of juice when it is heated for a longer time. This drop in pH in the settling process is well-known to all sugar technologists. This reaction results occasionally in a pH value of the clarified juice from the bottom compartments of continuous subsiders as low as 5.0.

An opinion expressed by technologists not only in discussions but also mentioned in the literature is that the change in reaction would be the result of a kind of microbiological action of the mud and a fermentation process, but this assumption is undoubtedly wrong. Experiments show that the change in pH value increases with an increase in temperature. The higher the temperature to which juice with suspended non-sugars is subjected, the greater is the drop in pH value. This change in pH is a chemical reaction. The reactions causing a change in pH of juices subjected to settling are of a different nature.

The following reactions in the development of acidity respectively and the formation of acids have to be distinguished :

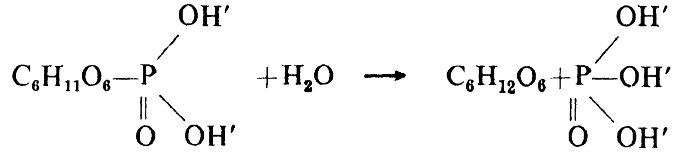
(a) The transformation of $CaHPO_4$ into $Ca_3(PO_4)_2$

$$2\ CaHPO_4 + Ca'' \rightarrow Ca_3(PO_4)_2 + 2H'$$

This acid formation can be considerable. In particular if juices have been limed to a too low pH value (under 7.0) the original precipitate consists to a great extent of $CaHPO_4$. This reaction in juices that have been limed to an unsatisfactory level can cause a severe drop in the pH during settling.

Assuming that the amount of precipitable P_2O_5 in average mixed juices lies between 150 to 250 mg. per litre, the acid formation per litre of mixed juice may be equivalent as a maximum to 15 to 30 ml. 0.1 normal. This is an extremely high quantity of acid. If a juice has been limed to a pH of 7.6 to 7.8, it has been found that after bringing this juice to the boiling point approximately 70 to 80% of the P_2O_5 has been precipitated as $Ca_3(PO_4)_2$ and $Mg_3\ (PO_4)_2$. It is in particular the time of heating and the temperature to which the juices have been subjected in the juice heaters, combined with the pH of the juice, which will determine the amount of phosphates precipitated as tertiary calcium phoshate, which does not show any change in composition in the settling process.

(b) Among the phosphates showing a change in composition with the formation of H-ions the hexose-phosphates have to be mentioned. The hexosephosphates are unstable at high temperatures and dissociate according to the general equation :



$$C_6H_{11}O_6{-}\underset{\underset{O}{\|}}{P}{\diagdown}^{OH'}_{OH'} + H_2O \longrightarrow C_6H_{12}O_6 + \underset{\underset{O}{\|}}{P}{-}OH'{\diagdown}^{OH'}_{OH'}$$

The amounts of hexose-phosphates in mixed juice expressed as organically bound P_2O_5 is approximately 20 to 60 mg. per litre. In juices from young cane (Primavera cane of 10 months age) larger quantities of oragnic phosphates have been found.

It has been observed that only a part of these hexose-phosphates are hydrolyzed in the clarification. The hydrolysis is greatest at low pH values. The maximum acidity, if all the hexose-phosphates would be hydrolyzed, which can develop by the decomposition of these organic phosphates, is as an average equaivalent to 2 to 5 ml. 0.1 normal acid per litre of juice.

(c) A well known reaction is the decomposition of the reaction products of reducing sugars formed in alkaline medium. It has been found that in normal mixed juice 1 to 5% of the amount of reducing sugars present can be destroyed, depending on the pH and the temperature to which the sugar juice has been subjected in the purification process. This destruction of reducing sugars is an extremely complex reaction. It can be expressed as the decrease in the reducing power of Fehling solution ; it has been found that in a mixed sugar juice the destruction of 1% of the reducing sugars corresponds with an acid formation of 2 to 10 ml. 0.1 normal acid per litre of juice. These acids are primarily very weak acids. They are present in sugar solutions as complex calcium organates or alkali organates, but it is known that if these decomposition products are subjected for several hours to a temperature of 100 °C. that the decomposition goes on even in neutral and acid medium and that acids are formed with a lower molecular weight and greater strength. It is for this reason that it has to be the endeavour to prevent high alkalinities (pH values over 8.5 at temperatures over 60—65°C.) as any excessive liming will finally result in the formation of organic acids and a change in the pH value.

(d) As acid forming components have also to be mentioned—the proteins in mixed juice. A considerable percentage of the proteins is coagulated in the purification, especially in the heating process, but the proteins as such cannot be qualified as stable, inert, precipitated non-sugars. They are subject to decomposition and hydrolysis with the formation of amino acids.

The amounts of proteins precipitated in the clarification vary with normal cane between 300 and 1000 mg. per litre of mixed juice. If these proteins are subjected in a juice to a temperature of 100°C. for 3 to 5 hours, it has been found that at average pH values as met in practical sugar manufacture, the formed amino acids are equivalent to 0.5 to 2 ml. 0.1 normal acid per litre of juice. These are extremely weak acids and their presence can only be demonstrated by a potentiometric titration; the amino acids show their acid character respectively alkali binding power at a pH between 8.0 and 10.0.

(e) An extremely complicated reaction is the reaction between hexoses and amino acids. The reaction product has the tendency to polymerize under the formation of dark coloured substances, with the development of CO_2*.

(f) In the clarification of cane juices we are also confronted with a small amount of plant mucilage, what is usually described in the sugar literature as gums and pectins. Also this group of non-sugars is not stable at a temperature of 100°C. and at the pH values as met in the clarification. This group of non-sugars which is described in the biochemical literature under the general name of poly-uronides can be decomposed with the formation of complex organic acid commonly called uronic acids or hexuronic acids or specifically galacturonic acid, etc., having the general formula $CHO.\ (CHOH)_4.\ COOH$. This decomposition may be quantitatively small, but under certain conditions, especially if there is an accumulation of precipitate in the clarifiers or if the clarifiers are not completely emptied, it may be the cause of a difference in the pH between the clarified juice and the juice resulting from the filtration of the cachaza, respectively the clarified juice from the bottom compartment.

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* The reaction between hexoses and amino acids does not only manifest itself by the formation of acid reaction products, but also by the formation of coloured substances. [See : M.L. Wolfrom, W.W. Binkley and J.N. Schumacher, Ind. Eng. Chem. *47*, 1416 (1955)]

When a cane juice has been sujected to a high alkalinity ($pH > 8.5$) at higher temperature (temperature > 75°C.) the reaction products are unstable at high temperature and are transformed into products of greater acidity. Overliming is one of the main causes of abnormal acid formation in subsiders.

(g) As a factor influencing changes in the pH has also to be mentioned—the use of partly unslaked or nonhydrated lime. These lime particles will be included in the precipitate and may dissolve slowly in the hot juice, not causing an acidification but locally high alkalinities affecting the average pH of the filtered juices. Eventually, if a considerable quantity of unslaked lime particles are present in the used milk of lime, it may result in an increase in the decomposition of reducing sugars, with a corresponding increase in the decomposition of reducing sugars, with a corresponding increase of the lime salt content of the juices, respectively an increase of decomposition products, which are subjected to further decomposition during the processing of the juices.

(h) A reaction not related with the milk of lime but which may cause an increase in the lime content respectively an alkalination of the mud juice is the decomposition of calcium silicate by reacting with sesquioxides according to the equation :

$$n\ CaSiO_3 + m\ Fe_2O_3 \longrightarrow (SiO)_n(Fe_2O_3)_m + n\ CaO$$

These eight reactions* are known to occur in the clarification of limed mixed juices ; the combination of these reactions is responsible for the changes in pH we can observe in our sugar mills.

It is possible to reduce the quantity of decomposition products by selecting suitable operating conditions. This is a matter of proper equipment for mixing, heating and adjusting the pH with reliable control equipment to regulate the pH of the juices to be limed, to be heated and to be settled as uniform as possible.

HOW TO LIMIT ACID FORMATION TO A MINIMUM

The following general rules have to be laid down to obtain maximum results :

1. In the liming process is, regularity of the pH, a point that can never be overemphasized. It is necessary that all the juices entering the juice heaters have a pH of at least 7.3 to 7.6. The change in the pH in the heating process is unpredictable. The endeavour has to be that the juice entering the clarifier has a pH of 7.1 to 7.3. The drop in the pH in the clarification, if the juice has been properly limed and heated, is usually less than 0.3 pH unit.

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* There are undoubtedly still a number of other reactions in hot cane juice, leading to the formaion of acids, respectively of CO_2. CO_2 is formed in cane juices as a decomposition product of organic non-sugars. In acid medium (pH 4.4—5.3) the decarboxylation of aconitic acid as one of the sources of CO_2 formation has been put forward by R. C. Henry and L. A. Clifcorn, Ind. Eng. Chem. *41*, 1427 (1949). It appears that mineral non-sugars have a catalytic effect on this reaction. It is, however, certain that also other reactions are taking place producing carbondioxide.

A large drop in pH in the clarifiers can be caused by different conditions. Important in this connection are insufficient heating of the limed juice and insufficient liming of the juice. If a juice has only been limed to a pH of 7.0, the drop in pH in the clarifier may be large and going down to 6.2 in the clarified juice. We have to avoid as well overliming as underliming.

2. Overliming, meaning a lime addition to such an extent that the juice leaving the juice heaters has a pH over 7.6, has to be avoided. The heated juice with a pH of 7.5 has usually been subjected to a pH over 8.5 before liming and although the formation of acids as a result of the decomposition of reducing sugars will not show by the presence of weak organic acids in the juices directly after heating, it is an undisputable fact that the decomposition products that have been formed are liable to further disintegration at high temperatures and that they have to be qualified as one of the main causes of the continuous and creeping acidification of juices in process.

3. The precipitated non-sugars have to be liquidated continuously from the clarifiers. Any stagnation and accumulation of the precipitate will result in an acidification of the clarified juice from the lower compartments.

The acid formation is an extremely complicated reaction. The result of it is that especially in the lower compartments of the clarifier the pH value can drop to such a level that we have the decomposition of the carbonates present in the juices. The carbonates in cane juices are stable at a pH=8 and higher, but below a pH=8 we have the formation of bicarbonates and we have also the formation of carbonic acid.

THE FORMATION OF CO_2 IN CLARIFIERS

The equilibria between carbonic acid, bicarbonate and carbonate at different pH values have been determined accurately at 25°C. Determinations at higher temperatures are lacking but it is certain that similar equilibria exist at higher temperatures. In Table III we give the equilibria between CO_2, bicarbonate and carbonate :

TABLE III

PERCENTUAL FRACTION OF CO_2 PRESENT AS H_2CO_3, HCO_3' AND CO_3'' AT DIFFERENT pH VALUES AT 25°C.

pH	H_2CO_3	HCO_3'	CO_3''
5.0	95.9	4.1	—
5.5	88.0	12.0	—
6.0	69.9	30.1	—
6.5	42.3	57.7	—
7.0	18.8	81.1	0.0
7.5	6.8	93.0	0.1
8.0	2.3	97.3	0.5
8.5	0.7	97.8	1.4
9.0	0.2	95.3	4.5

The solubility of CO_2 at higher temperatures is much less than it is at lower temperatures as shown in Table IV.

TABLE IV

SOLUBILITY OF CO_2 IN GM. PER LITRE OF WATER* AT ATMOSPHERIC PRESSURE AT DIFFERENT TEMPERATURES

Temperaure in °C.	At atmospheric pressure	At a pressure of 1.05 kg./cm.^{2}
20	1.69	—
25	1.48	—
30	1.26	—
40	0.97	5.79
50	0.76	—
60	0.58	3.99
70	0.39	3.38
80	0.21	2.85
90	0.09	2.51

It can be observed occasionally in sugar mills that the clarified juice on the bottom compartments, when the hydrostatic pressure is released, liberates a certain amount of CO_2, giving to the juice a milky character. This is especially the case with juices of low pH's. It has also been found that if the air in the overflow tanks of continuous subsiders is analyzed on the CO_2 content, that CO_2 precentages over 10% are not abnormal at all. A continuous subsider is a continuous producer of CO_2. Whether all the CO_2 is actually the result of the decomposition of carbonates by a change in the equilibria between bicarbonate and CO_2 is not certain. It is possible that also a certain amount of CO_2 is formed at the same time as a result of decomposition reactions. It has been shown the sugar solutions subjected to

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*Sucrose decreases the solubility of CO_2. The number of accurate determinations of the CO_2 solubility in sucrose solutions mentioned in the literature is limited. Findlay and Shen (J. Chem. Soc., London, *101*, 1459 (1912)) give the following data :

Solubility of CO_2 at 25°C.

Sucrose concentration in %	g. CO_2/100 ml.
2.6	0.813
5.2	0.798
9.7	0.767
12.3	0.744

The effect of the temperature on the dissociation constants of CO_2, HCO_3' and CO_3'' is as follows :

	pK at different temperatures in °C. 30°	50°	70°
First apparent dissociation constant $K_{CO_2+H_2CO_3}=\frac{(HCO_3')\,(H^+)}{(CO_2+H_2O)}$	6.32	6.26	6.18
Second dissociation constant $K_{HCO_3'}=\frac{(CO_3'')\,(H^+)}{(HCO_3')}$	9.95	10.05	10.15

The presence of sucrose has the tendency to increase the strength of carbonic acid as a dibasic acid, but it is doubtful whether the same occurs with CO_2 as a monobasic acid.

higher temperatures develop a certain amount of CO_2. This can be as high as 1 to 5 mg. CO_2 per hour per 100 g. brix at 110°C.

A surprising reaction is always that the rate of acid formation increases with an increase in H-ion concentration. The acid formation is accelerated as the pH is dropping off. This reaction can be studied in a very simple way by filling closed bottles with limed juice and heating them in a thermostat at 100°C. It will be found that there is a continuous increase in pressure by the formation of CO_2, which reaction is always combined with a drop in pH.

It is also found that this drop in pH is greater when a limed juice is heated together with its precipitate. The drop in pH of clarified juice subjected to heating is less. If we like to give an explanation for this difference in behaviour, .we have to refer to the different types of reactions that are causing an acidification of limed juices as given above.

Fundamental studies on the reaction rate of the different decomposition and transformation reactions occurring in the handling of technical cane juices have been done only in a few cases.

There are a number of methods to suppress acidification, which according to my opinion are of no benefit and for which there is no foundation whatsoever. One is the introduction of formalin in clarifiers. Another one is the chlorination of sugar juices or other kind of disinfectants.

To prevent the undesirable effect of a low pH, as to the rate of inversion, by the introduction of soda ash in the bottom compartments of clarifiers results usually in an increased CO_2 formation which occasionally can result in an accumulation of such a great amount of CO_2 in the bottom compartments that when the CO_2 is released it upsets the whole performance of the clarifier. To counteract this it is recommended to release the clarified juice, saturated with CO_2, from the bottom compartments periodically to have an undisturbed settling process.

But the principle to introduce carbonates,considering the equilibria between CO_2 and bicarbonates as given in Table III, is a practice that cannot be recommended as the best panacea. If we wish to counteract the acid formation, we should introduce an alkaline substance not leading to the formation of CO_2. But we can use just as well milk of lime, or, if we are afraid of secondary precipitation reactions as a result of the introduction of the precipitating cation Ca^{++}, use a diluted solution of caustic soda diluted to a very low concentration.

DISCUSSION

Mr. Foster stated that in the preliminary experiments carried out by him on the liming of cane juices at temperaturers of 100°F., 140°F. and at boiling temperature, for 5 minutes, 10 minutes and 20 minutes, and determining P_2O_5 content CaO, content of the clarified juice suggested that the reaction is a rapid one and not a slow one. He also observed that Polyuronides are unstable in the region of 7.0 pH.

Mr. Parashar referring to the development of acidity due to phosphates mentioned about the variations from compartment to compartment. It was highest in the bottom most compartment. As against the good effect of phosphates on clarification, the adverse effects of mud volume and acidity development existed. One has to strike a proper balance.

Mr. F. H. C. Kelly posing the question what is pH, considered that the author had overstepped the mark by claculating the inversion at pH 7.0. The pH at 100°C. would be different. The effect of buffering has not been considered. It is dangerous to say without proper qualification that the rate of inversion is proportional to H^+ ion concentration. Such over simplification on which Table I is based is not correct.

Dr. Douwes Dekker considered that Mr. Kelley's fears are exaggerated and referred to the publications of the results of the Java Sugar Industry and the experiments at the Berlin Sugar Research Institute, on which basis he believed Dr. Honig has prepared the tables.

Dr. K. S. G. Doss pointed to the nature of the graphs and observed that the graphs must have been from actual data and interpolation.

Mr. Gundu Rao stated that it has not been possible to measure the pH of the juices at the high temperature of the settler, without cooling.

Dr. Douwes Dekker referred in this connection to the work of Dr. Gross, who had measured pH values at very high temperatures.

In the absence of the author, Mr. Nicklin presented the following paper.

Paper

SYSTEMS OF HEATING JUICES-PART III

CHS. G. M. PERK

INTRODUCTION

Juices have to be heated on their way from the milling train to the clarifiers and sometimes the juices are reheated before entering the first vessel of the evaporator. These heating operations are carried out with the aid of juice heaters.

The operational principle of juice heaters, and hence their design is markedly similar to those of surface condensers. Surface condenser design is based on the flow rate of the cooling water, a high flow rate being required for efficient heat transmission. Although the higher the water velocity, the better the heat transmission, such is limited by the high pumping power so necessitated to overcome the consequent rise in frictional resistance and a velocity must, therefore, be chosen suitable for both.

The same problem is encountered when designing juice heaters. Here too the velocity must be high, not only for efficient heat transmission, but also with a view to reduction of deposition of scale on the tubes. The limiting factor is here less the increased pumping power* than the increased pressure on the heater, when the juice velocity is raised.

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*N.B. The total power consumption of a cane sugar factory is equivalent with 8.5% of the total heat in steam or with 5½% of the heat in bagasse burnt, approximate.

In the case of surface condensers condensing of the steam is the purpose, but in the case of juice heaters it is only the means to achieve our purpose, i.e., the heating of the juice. This difference in purpose causes difference in design.

HEATER CONSTRUCTION

The shell of the juice heater is generally cylindrical in shape, placed either horizontally or vertically. The shell is closed up between two headers and tubes are running between the headers, supported by tubeplates. The heating medium, either exhaust steam or vapour bled from the effect (in exceptional cases live steam) is admitted to the space enclosed by the shell and the tubeplates, outside the the tubes. The juice is admitted into one of the headers and passes through the tubes from one header to the other several times; leaving the heater finally through the same header as entered. In order to achieve that the juice passes several times, to and fro, the tubes are divided in several nests or passes and the headers in compartments. In addition to connections for juice and steam, the heater is provided with outlet branches for condensate and uncondensable gases, with gauges for pressure of juice and steam and with thermometers to gauge the temperature of the in-and out-going juice.

The Shell. In earlier days the shell was constructed from steel plate by rivetting. The present practice is a competely welded construction.

Headers and Tubeplates. It has been general practice before 1915 to provide heaters with separate tubeplates. English manufacturers following surface condenser design provided horizontal heaters with rolled brass tubeplates (62% copper ; 37% zinc and 1% tin) and Continental manufacturers following beet sugar practice provided vertical heaters with steel plate tubeplates. The separate tubeplate had two big drawbacks. Firstly, it necessitated two packed joints between header and shell. Secondly the separate tubeplate had joints between the plate surface and the division walls of the compartments of the header. In particular where there was a large difference in juice pressure across the heater, it was difficult to prevent leakage of juice from one compartment to the other. A leak across a division wall cuts the tubeplate face and will rapidly reach serious proportions, necessitating shutting down the heater for a time consuming repair.

Gradually the cast iron headers and separate tubeplates were replaced by headers and tubeplates integrally cast. At the same time cast iron was replaced by cast steel as construction material so that the headers could be rivetted to the shells and the seams caulked or the headers could be welded to the shells. Modern design is, however, the completely welded heater, i.e., the tubeplates welded to the shell and the division ribs of the compartments welded together and to tubeplate and to extended shell.

The headers are closed by hinged covers or doors in order to assure a quick access to the tubes for inspection or cleaning. The doors (balanced by counterweights for easy manipulation in the case of vertical heaters) are tightened by hinged bolts of sufficient strength to counteract the pressure of the juice on the door and to exert in addition sufficient pressure on the joint faces to prevent short-circuiting and leaking of juice. In order that the pressure exerted by the bolts will be uniformly distributed not only over the annular joint face at the periphery of the door, but also over all joint faces of the partition walls, the door has to be of a rugged (reinforced) construction.

To avoid leakage, sheet lead jointing is employed between door and header face or asbestos metallic jointing. Sometimes dovetail grooves are machined in the door face in which case a made-to-measure hard rubber packing is used. (In the latter case the grooves ought to be in the door and not in the header, so that the packing moves away when the door is opened and the packing does not get damaged during cleaning operations).

No matter what type of packing is used, it always remains the weak point of the construction and limits the permissible pressure across the heaters. Hence, in order to prevent short-circuiting and leakage, it is recommended not to exceed a pressure of 4 kg./cm.^{2} (g.), measured at the inlet branch of the first heater of a series. This maximum allowable pressure limits : the number of heaters in series, the number of passes and the juice velocity.

Tubes : Different metals conduct heat at different rates. For example, the thermal conductivity (measured at 100°C.) of (pure) copper is 320 ; of Monel 265; of red brass 132 ; of Admiralty 97 ; of yellow brass 94 and of mild steel 40 kcal./m.^{2}/h./°C./m*. Under normal operational conditions, i.e., the tubes more or less scaled, the tube metal offers only a minor portion of the total resistance to the flow of heat from heating medium to juice. It is therefore, that the chemical and mechanical resistance of the tube metal is of more importance than its thermal conductivity.

Where tubes have to be cleaned often and mechanically, a tube metal should be chosen suitable for this operation. The tube may not rust because rust scale retards heat transfer. In this respect steel tubes cannot be recommended because they are susceptible to corrode during the off-season. Moreover, since their surface is not smooth or does not stay smooth long, oil and dirt adhere more easily to steel tubes than to copper and brass tubes.

In some countries it has been routine to specify brass tube-plates and copper tubes. Copper tubes as cupro-nickel tubes are more resistant against fatigue cracking and against acids than brass tubes. Continental manufacturers, affected more by the requirements of the beet sugar industry (where copper cannot be used because of the presence of ammonia in juice vapours), supplied brass tubes and steel tubeplates. The question of brass or steel tubeplates was automatically solved when separate tubeplates became obsolete, but copper and brass tubes are both still used.

From a point of view of good resistance against mechanical cleaning there are two copper alloys suitable for tubes, i.e., 70/30 and 60/40 brass. The latter

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*N.B. For conversion factors see Appendix.

though harder is more susceptible to dezincification and cracking than the former. It is therefore that Admiralty brass tubes (70% copper ; 29% zinc and 1% tin) have found a more widespread use. In particular, tubes tinned at the outside are to be recommended because of their longer smooth staying surface ; a smooth outer surface being of importance because a smooth surface fouls less easily and maintains therefore drop condensation longer.

Though the tube manufacturer has annealed the tubes between drawing operations, it is good practice to anneal (only)the tube ends before expanding when fitting new tubes ; a suitable annealing temperature for brasses upward of 63% copper being 600-700 °C.

Season-cracking occurs when brass tubes are drawn too cold. It is therefore good practice to immerse tube samples in a solution of mercurous nitrate, containing a little free acid before starting to fit the tubes. Susceptibility to season-cracking is revealed by the samples cracking within thirty minutes due to high internal stresses.

Though for the sake of economic design the diameter of the tubes ought to be small, with a view to mechanical cleaning, the bore should not be smaller than 30 mm. Hence, the inner diameters of juice heater tubes range between 30 and 40 mm. The thickness of the tube walls ranges between 1½ to 3½ mm.

The tube length is limited to about 3.60 m. since otherwise an expansion joint has to be fitted in the body of the shell with a view to the difference in expansion by heat of the shell and the tube metal.

Steam and Juice Connections and other Fittings. Differentation has to be made between horizontal and vertical juice heaters.

In the case of vertical heaters the steam inlet branch is always fitted to the upper half of the shell and usually not further down than ¼ of the length of the shell. This high arrangement furthers the downwards travel of the condensate along the tubes and it prevents cracking of tubes. In particular when the steam velocity is high and the tubes long, the tubes infront of the steam inlet vibrate when the steam inlet is too far to the centre.

In the case of horizontal heaters, it is now also general practice to fit the steam inlet branch close to one end of the shell. This is also the most suitable place when baffles are to be arranged between the tubes which is also general practice now.

These baffles (1,2) serve a dual purpose. They guide the path of the steam and they collect the water from the tubes above them so that it does not gravitate on the lower sets of tubes. In this manner the lower tubes are prevented from being partly covered with water dripping from tubes above, which would otherwise interfere with proper heat transmission.

Probably the performance of vertical heaters could be enhanced too by providing the steam space with short horizontal baffles to guide the steam and collect the condensate (3).

When the baffles are arranged correctly the steam will drive the uncondensable gas (air) to the point where the condensate is removed and the air should be removed close to this place.

Vents. The decision where to remove the air, i.e., where the vents are to be fitted, depends more on factors as where the velocity of the steam will be smallest than upon the difference in densities between steam and air under prevailing conditions. Hence, we have to ask ourselves where will air collect and where can air be entrapped. For example, in the case of a vertical heater with baffles, we will place the vent close to the condensate outlet, because there the air will collect. However, an additional vent cock has to be fitted at the top corner of the shell diametrically opposed to the steam inlet to accelerate removal of air when starting up the heater.

Removal of gas (air) where there is a pressure below the atmospheric in the steam space. The same measures have to be taken to remove condensate and uncondensable gas in the case where the pressure in the steam space is below the atmospheric as taken in the case of the third or fourth vessel of an effect ; that is to say : the condensate has to be withdrawn with the aid of pumping steam trap or a condensate pump and the vent has to be connected to the condenser.

These measures have to be taken not only when the juices are heated by vapours bled from the effect, but in general in all those cases where a pressure below the atmospheric may occur in the steam space. For example, when a heater with too big a heating surface is throttled down, the pressure in the steam space can fall below the atmospheric and the condensate removal will start surging and the steam space becomes partly water-logged. In particular, such a phenomenon will occur when (cold) mixed juice is heated to liming temperature and the steam inlet is throttled down to adjust the juice temperature.

Gauges. The above illustrates how essential it is to provide the steam space with a vacu-manometer instead of with a manometer in all those cases where we may expect that the pressure occasionally drops below the atmospheric. In addition a pressure gauge is required at the juice inlet side of each heater or bank of heaters so that we are consistently aware of the load on the juice pump and on the heaters. In this way a clogged up nest of tubes of a heater will soon be discovered.

Each heater has to be fitted with thermometers at the inlet and outlet branches of the juice, apart from the recording gauge which indicates the performance of the heater or bank of heaters consistently. The additional thermometers on each heater are required to check the individual performance of each heater. In this manner short-circuiting or a fouled heating surface will soon be discovered.

Other Fittings : Tromp (4) recommends providing 4 ins. bore side branches on the juice inlet and outlet branches for caustic soda and washout connections.

Each top compartment of a vertical heater has to be provided with vent cocks. This arrangement is particularly necesssry where the juice contains gas, as occurrs where the juice previous to heating has been saturated with CO_2 or SO_2 gas.

The shell has to be insulated with foam-glass, magnesia or vermiculite.

Comparing Vertical with Horizontal Heaters: So far as ease of cleaning is concerned, the amount of floor space required, the general accessibility and ease with which the piping can be arranged, the vertical heater wins (3). The horizontal heaters, particularly when provided with well arranged baffles has, however, according to the present author a greater heat transmission, which could be explained by the fact that the horizontal tubes are less covered by condensate.

CAPACITY ; OVERALL HEAT TRANSMISSION CO-EFFICIENT ; JUICE VELOCITY ; MEAN TEMPERATURE DIFFERENCE

The capacity of a juice heater, i.e., the rate of heat flow or heat transfer per unit time (kcal. per h.) across the heating surface is proportional to the available area, the mean temperature difference and the overall heat transmission co-efficient.

Since the area of the outer surface of a tube differs markedly from the area of the inner surface, it should always be stated how the heating surface is calculated. It is Continental practice to base the heating surface on the inside measure (5), while English manufacturers derive the area from the outside diameter of the tubes. Lyle (6) suggests taking the surface at the side where the transmission is more difficult. Since the overall heat transmission co-efficient depends so much on the degree of scaling, the inside diameter of the tube should be taken when we interpret Lyle's suggestion correctly.

(N.B. In the case of a heater with 31 x 35 mm. tubes, the difference between the inside or the outside surface amounts to 11%).

In combination with the overall heat transmission co-efficient (k), the mean value (t_m) for the temperature difference between steam and juice has to be used. According to Grashof (Theoretische Maschinenlehre I), the mean value is equal to :

$$t_m = \frac{d_i - d_f}{\log_e (d_i / d_f)} = \frac{(d_i - d_f)}{2.3 \log (d_i / d_f)}$$

in which formula d_i denotes the initial and d_f the final temperature difference between steam and juice.

The overall heat transmission co-efficient is a function of several factors and varies among others according to the prevailing form of condensation. Under certain conditions steam may condense not as a continuous film (film condensation), but as separate droplets, giving a vastly increased rate of heat transfer as far as as the heat transfer from steam to tube metal is concerned. Only in exceptional cases 100 percent drop condensation occurs and the best we may hope for is that partly drop, partly film condensation may occur.

The steam-to-tube-metal transfer rate is also dependent on the vapour velocity. Theoretically this rate doubles when the steam velocity is raised from very slow to 80 m./ sec. Hence, the tubes in front of the steam inlet will have a higher steam-to-tube-metal transfer rate than those remote from the steam inlet.

The steam-to-tube-metal transfer rate depends also on the temperature of the steam. In general live steam will have thus a higher transfer rate than exhaust steam. Regarding the heat transfer rate in the case of superheated steam, it is generally understood that 30°C. superheat is about the limit, otherwise the heat transfer rate will be markedly less. In normal cases, however, the temperature of the exhaust steam will seldom exceed this limit and even when it occurs it will only be for a short period of time.

The effect of the tube metal on the overall heat transmission co-efficient is in general of minor importance as we discussed already. More effective is the juice velocity, the juice temperature (viscosity), the degree of scaling at the inside and the degree of fouling of the outside of the tube. The effect of all individual resistances is for practical purposes usually combined in one formula comprising two terms. One term accounts for the degree of scaling, the other for the effect of the juice velocity on the heat transfer rate.

N. B. These formulae do not indicate the to be expected overall resistance, but its reciprocal value, i.e., the overall heat conductivity (per unit time per unit area and per unit temperature difference).

According to some authors, the effect of juice velocity on the heat transfer is directly proportional (8), according to others proportional to the square root (9) and according to another author proportional to the cubic root (10). Finally there are formulae ignoring the effect of the juice velocity. The reason for this difference in opinion is caused by the different degrees of scaling which have been assumed when the formulae were derived. Speyerer (11) calculates on theoretical considerations that in the case of clean tubes an increase in juice velocity from 1 to 2 m./sec., will increase the overall heat transmission co-efficient by 20-22%, however, in the case of scaled tubes the same increase in velocity will only add 4.9-5.1% to the overall co-efficient. To account for the effect on the heat transmission by the steam and juice temperatures, Speyerer introduces in his formula the final juice temperature ; assuming that the steam temerature is 5°C. above the final juice temperature. For heaters which have to be cleaned each week, Speyerer gives the following formula :

$$k = 240 + 3.6\ t_s$$

Substituting for t_s the value 100°C. gives k equal to 600 kcal./m.^{2}/h./°C. (Speyerer formulae are based on a juice velocity of 1 m./sec.)

The Sugar Research Institute, Mackay, Queensland, has recently investigated the relation between juice velocity and overall heat transmission co-efficient and also between the rate of scale deposition and the juice velocity. It appeared that the overall heat transfer co-efficient increased when the juice velocity was raised from 1.22 to 2.44 m./sec. in one case with 21% and in another case where the degree of scaling was greater with 15% only. There were some definite indications that scaling becomes less with increased juice velocity and that particuarly at very low velocities a greatly increased rate of scale disposition occurs, but this phenomenon will be further confirmed when the tests are to be continued.

Since the tubes of juice heaters will always scale and since juice heaters have to heat the juice to the required temperature also when the tubes are scaled, values of overall heat transfer co-efficients to be used to estimate the required heating surface ought to be based on scaled condition of the heater. Since the degree of scaling depends on varying operational conditions, different formulae should be used for each case. For example, when heaters are cleaned several times a day by changing over, the final thickness of the scale layer will be less than where the heaters are cleaned once a week. Further, the overall heat transfer co-efficient of a clarified juice heater will in general be higher than of other heaters, becuase juice and steam temperature are higher and a clarified juice heater scales less. Finally the degree of scaling depends on juice qualities and on applied process of clarification.

It is obvious that with a view to the so widely varying conditions not a general formula or value for the overall heat transfer co-efficient can be given.

To illustrate the large variability of the overall heat transmission co-efficient of juice heaters in actual practice we quote hereunder data found by nine Java sugar factories which participated in the " Special Steam Control " survey of the Java Sugar Experiment Station (7).

The overall heat transfer co-efficients of these factories are tabulated in five groups. The first group comprises the values found for juice heaters heated by exhaust steam ; the second group those claculated for heaters using vapour bled from the first vessel ; the third group using vapour from the second vessel ; the fourth group heaters using vapour from the third vessel and finally the fifth group comprises the values calculated for heaters placed between the last vessel and the condenser.

The values of the overall heat transmission co-efficient of the first group range from 225 to 1127 kg./m.^{2}/h./°C. ; of the second group from 212 to 1080 kg./m.^{2}/h./°C. ; of the third group from 201 to 630 kg./m.^{2}/h./°C. ; of the fourth group from 129 to 612 and of the last group from 276 to 517 kg./m.^{2}/h./°C. It shows that particularly the highest values diminish gradually from the first to the last group. This reduction is as it should be, because the temperature of the heating medium and the final temperature of the juice diminish in the direction from first to last group.

The above figures concern all factories with vertical heaters as is common practice in Java. However, the data of one factory (Petaroekan) equipped with horizontal heaters are also given. Since this factory uses throughout vapours for heating purposes only, the values belonging to the second and the third group are shown. These values range from 1258 to 1625 which the second group concerns and from 651 to 783 kg./m.^{2}/h./°C. as far as heating with vapour bled from the third vessel is concerned. The high values of Petaroekan are attributed to the design of the heaters, the oil-free surfaces (no exhaust steam being used), in addition to proper venting and condensate drainage. They are certainly not to be attributed to low scaling characteristics of the juice ; on the contrary Petaroekan had to clean every single day one of the six vessels which formed the quintuple effect to maintain its capacity (Sulphitation process).

It has been mentioned that a high juice velocity is beneficial with a view to heat transfer rate and to reduce scaling tendency. It has also been pointed out that with a view to short-circuiting and leakage the pressure across the heater is limited, a recommendable limit of 4 kg./cm.^{2} (g.) being mentioned. Hugo (13) calculates that the pressure across a heater comprising sixteen passes of 31 mm. bore tubes will be 2 kg./cm.^{2} when the juice velocity is 2 m./sec. When we raise the velocity to 2½ m./sec. the pressure across the heater will increase to 3 kg./cm.^{2} and when we connect two of such heaters in series, the pressure in the inlet branch of the first will be raised from 4 to 6 kg./cm.^{2} When the tubes become scaled, the resistance will rise with another 10 to 20 percent.

Increasing the juice velocity is generally carried out by increasing the number of passes. This cuts twofold, the resistance being increased due to the higher juice velocity and owing to the increased number of U-turns the juice has to perform when passing from one nest of tubes into the next.

TIME OF RETENTION OF THE JUICE IN THE HEATERS

Since the reaction between lime and some of the juice components (more particularly between lime and phosphates) requires time to be completed, the time required to pass through the heaters is of interest. In order to arrive at an approximate figure for the time of retention, let us assume :
that per 100 tons of cane crushed per hour 95 tons or 90 m.^{3} of juice has to be heated from initial temperature to 101°C., that when exhaust steam is used throughout as heating medium 320 m.^{2} H. S. is required and that this area is composed of 3283 m. length of 31 mm. bore tubes.

In order to obtain a juice velocity of 1.80 m./sec. each nest of tubes has to comprise 19 tubes and assuming that the length of the tubes is 3.60 m., 48 passes will be required to make up for the total length of 3283 m. tubes. Consequently the time required for the juice to pass through all nests of tubes will be 48 x 3.60/1.80 =96 seconds. To this time must be added the retention time of the juice in the 48 heater compartments. Assuming that the cubic capacity of a compartment is equal to that of a nest of tubes, the total time required to pass all nests of tubes and all compartments is three minutes, approximate.

N. B. The total of 48 passes can be divided over two heaters of 24 or three heaters of 16 passes. The assumed area is the heating surface in operation. In the case where a spare heater is required, it will be higher. The same can be said when heating is completely or partially carried out by vapour bled from the effect. Particularly when vapour from the last vessel is used for the first stage, the required area of heating surface will be considerably more.

TEMPERATURE OF HEATING AND DISTRIBUTION OF THE TOTAL HEATING SURFACE

When all the lime is added directly to the cold mixed juice, it is customary to heat the limed mixed juice from its initial temperature to the final temperature in one stage, without interruption. In the case of hot liming and also when fractional liming is practiced, the heating is carried in two successive stages.

The decision at which definite temperature the hot liming will be carried out, or the second dose of lime will be administered in the case of the Fractional Liming-Double Heating Process is basically a processing question. However, it also concerns the total heating surface required as it has its effect on the distribution of the total heating surface over the different heating stages. This question is particularly of interest where the heaters are cleaned by periodically changing over from one stage to the other. For example, where exhaust steam is used throughout for heating, the juice has to be heated in the first stage to at least 60-65°C. when we want to keep the ratio of heating surfaces in use by the first and second stage not higher than as 1:2. Where vapour bled from the first vessel is used throughout, the final temperature of the first stage has to be at least 70-75°C. in order that a ratio as 1:2 will do.

TEMPERATURE CONTROL AND AUTOMATIC TEMPERATURE CONTROLLERS

The adjustment of the final temperature of each heating stage can be carried out by manual control or by automatic controllers.

The most primitive temperature control is the manual adjustment of the steam (or vapour) valves according to the readings taken from an ordinary thermometer. This system can be improved by providing the heater with a temperature recorder, because the operator will adjust the steam valve more correctly with the aid of a temperature graph than by the most frequent reading of an ordinary thermometer.

Since it is impossible to consistently maintain the correct temperature, even when using a temperature recorder graph as guide, such a graph will show a series of deviations from the correct temperature, and it will never show a straight line. Hence we should not indicate the correct temperature on the recorder chart by a red circle at the required temperature, but we should draw two circles with red ink on the chart (one circle 5°C. above and the other 5°C. below the required temperature) and instruct the operator to keep the temperature curve between these two circles.

Another question with respect to temperature recorders is the most suitable range. We often notice recorders with too wide a range, commencing at 0°C. and going up as far as 150°C. What we want are recorders with a main working range from 50°C. to 110°C. because they possess a larger scale in the part in which we are chiefly interested.

Manual temperature control depends too much on the human element even when the heaters are fitted with suitable recorders (and even when we control the operators by studying daily the graphs produced). When we want to cut out the human factor, then we have to equip the heaters with automatic controllers.

Automatic Temperature Control. Automatic temperature control intends to relieve the operator of two duties, viz., of the necessity of determining frequently the temperature of the juice and of the task to make those changes in the flow of the heating medium to maintain the variable, i.e., the tempeature of the juice, constant. This does not include, however, that automatic temperature control intends or expects to relieve the operator of all responsibility for correct operation. Supervision remains necesssry. The automatic control can become out of order and there is the possibility that an exceptional situation may arise with which the controller cannot cope. (For example, when the controller adjusts the exhaust steam flow and the pressure falls suddenly to zero).

An automatic temperature controller consists of a sensitive or detecting device which measures the temperature and conveys impulses to the controller which moves the valve to bring about changes in the flow rate of the heating medium when the temperature departs from a predetermined value called the control point.

The detecting device can be any form of thermometer, either a pressure-spring, a vapour-pressure, a gas-pressure or an electrical resistance thermometer. The impulses of the detector are too weak to operate the valve directly ; they are amplified by a relay or servo system ; the operating medium being air, oil or electricity.

The control valve in the supply line of the heating medium can either be a butterfly valve or a gate valve. A butterfly valve is balanced and requires therefore less energy to operate than a gate valve. Moreover by operating the butterfly valve with the aid of a crank system, the flow characteristic of the control-valve can be improved to a great extent.

Open By-Pass. An arrangement sometimes used is to allow a portion of the heating medium to by-pass the control valve by means of a handvalve set partly open. This may be done to reduce the required control-valve size, in an attempt to " improve " control. It is seldom a practical expedient and should be avoided whenever possible. Even in the ideal case where system pressure drop is maintained constant, the usable flow range of the valve is seriously reduced. In a valve having a flow range of 50 to 1, a flow of 6 percent in the by-pass reduces the flow range to 12 to 1. It is important to realize that if the pressure drop tends to increase as the flow is decreased, the flow range is still further reduced (14).

Analysis of Recorder Charts. Even the best automatic temperature controller will not produce a straight line graph ; there will always be smaller or bigger deviations from the control point. These deviations can be due to the characteristics of the system concerned and they can be caused by the demands exceeding the potentialities of the system. The latter can either be caused by a supply or by a demand disturbance ; a supply disturbance being caused by an exessive rate of flow of the juice and a demand disturbance by lack of pressure of the heating medium. The deviations due to the characteristics of the system or process lags can be divided into three distinct classifications, i.e., velocity-distance lag, capacity lag and transfer lag.

The velocity-distance lag is the delay between the time a supply or demand disturbance occurs and the effect is experienced by the control system. For example, the time which elapses between the increase of the juice flow rate and the reduction of the temperature of the out going juice being " felt " by the detector.

The capacity lag in the case of a juice heater should be the retardation of the reduction of the temperature of the outgoing juice due to the heat capacity of the heater itself. It can be considered negligible in the case of a juice heater.

The transfer lag-again considering a juice heater-is the temperature-lag due to the resistance to heat flow from the heating medium to the juice.

Honig (15) recommends the analysis of recorder charts when discussing pH recorders. Applying Honig's method on temperature recorder charts, the instantaneous temperature values should be classified by five minutes intervals, during a period of 24 hours, in groups of 2°C. units. The distribution of values so obtained should be plotted on probability paper. In this manner the average temperature is graphically obtained and simultaneously the variability as the co-tangents of the plotted line with the abcissa.

CLEANING OF JUICE HEATERS

Since after running some time heaters lose efficiency owing to deposition of scale on the tubes, juice heaters have to be cleaned periodically, either by changing over, mechanically or by chemical cleaning.

Cleaning of heaters by the changing-over system can only be carried out when heating is performed in more than one stage and mixed juice is not limed higher than 6.1 to 6.5 pH, previous to first heating stage. The usual method of changing over is with the aid of two juice lines and four-way duplex by-pass valves fitted to the heaters. Another method of changing over is described by Perk (16).

Cleaning can be carried out by admitting steam to the steam space with the heater cover doors opened. The scale will dry and crack and can be removed by scouring the tubes with steam at 100 p.s.i.g ; a special 1 ins. bore steam lance with flexible high pressure hose has to be provided for this purpose. A light brushing of the tubes with a soft wire brush should be done before reclosing the covers.

Mechanical cleaning methods can be replaced by chemical cleaning, or chemical cleaning can precede mechanical cleaning. Chemical cleaning consists of circulating a light caustic soda solution through the juice paths, while at the same time applying heat. Chemical cleaning is usually only carried out at the end of the season followed by a thorough scraping of the tubes by steel wire brushes, or with the aid of a light hammering tool.

Up to this juncture the fouling and cleaning of the juice side of the tubes have been discussed, however, the steam side also demands our regular attention where power is partially or completely generated by reciprocating engines. Since valves and cylinders have to be lubricated, the exhaust steam of such prime movers will always be more or less contaminated by lubrication oil which will deposit on the heating surfaces. Also in this case prevention is better than cure and it is better to protect the heating surfaces by installing oil separators in the exhaust steam lines than to be forced to remove the oil periodically from the heating surfaces.

A summary of different solutions used to dissolve the deposits on the steam side is given by Davies (17).

In this respect it had to be mentioned that the use of vapour also has a cleaning effect. Juice heaters which are alternatively used with vapour and exhaust steam seldom show such a gradual diminishing heat transfer rate due to fouling of the steam side as heaters which are consistently used on exhaust steam.

APPENDIX

CONVERSION FACTORS

Heat :

1 kcal.=3.968 B.T.U. and 1 B.T.U.=0.252 kcal.
1 kcal./kg.=1.79856 B.T.U./lb. and 1 B.T.U./lb.=0.5560 kcal./kg.

Specific Heat per unit mass :

1 kcal./kg./°C.=1 B.T.U./lb./°F.=1 kcal./kg./°C.

Specific Heat per unit volume :

1 kcal./dm.^{3}/°C.=62.4 B.T.U./ft.^{3}/°F. and
1 B.T.U./ft.^{3}/°F.=1.60×10^{-3} kcal./dm.^{3}/°C.

Heat Transfer per unit time :

1 kcal./h.=3.968 B.T.U./h. and 1 B.T.U./h.=0.252 kcal./h.

Heat Transfer per unit time per unit area (*HEAT FLUX*) :

1 kcal./m.^{2}/h.=0.3687 B.T.U./ft.^{2}/h. and 1 B.T.U./ft.^{2}/h.=2.712 kcal./m.^{2}/h.

Heat Transfer per unit time per unit temperature gradient :
(HEAT TRANSFER COEFFICIENT) (*k*) :

1 kcal./m.^{2}/h./°C.=0.2048 B.T.U./ft.^{2}/h./°F. and
1 BT.U./ft.^{2}/h./°F.=4.882 kcal./m.^{2}/h./C.

Heat transfer per unit time per unit area per unit temperature gradient per unit length of path (THERMAL CONDUCTIVITY) :

1 kcal./m.^{2}/h./°C./m.=0.672 B.T.U./ft.^{2}/h./°F./ft. and
1 B.T.U./ft.^{2}/h./°F./ft.=1.488 kcal/m.^{2}/h./°C./m.

REFERENCES

1. Davies, J. G. 1938. *Principles of Cane Sugar Manufacture*, p. 43.
2. Spencer, G. L. and Meade, G. P. 1944. *Cane Sugar Handbook* ; p. 143 ; fig. 50.
3. Webre, A. L. and Robinson, C. S. 1926. *Evaporation* ; p.166 fig. 3 ; p. 167-168.
4. Tromp, L. A. 1936. *Machinery and Equipment Cane Sugar Factory* ; 362.
5. Hugo, E. 1950. La Sucrerie de Cannes ; p. 299 (*Definition de la Surface de Chauffe*).
6. Lyle, O. 1947. Efficient Use of Steam ; section 345 (*What is Heating Surface* ?)
7. Proefstation voor de Java-Suikerindustrie ; 1940. *Eindstaat Controles.*
8. Schiebl, K. 1937. Suppl. Zeitschr. Ver. deut. Ing.; p. 93.
9. *Proc. Q. S. S. C. T.* 1936 (*I. S. J.* 1936 p. 438).
10. Hausbrand, E. Verdamfen, Kondensieren und Kuhlen. 1912. p. 371 ; *Formula* 245.
11. Speyerer, Helmuth ; Zucker. 1953. p. 247.
12. Sugar Research Institute ; Mackay ; *Techn. Report. No* 19 ; Febr. 1954.
13. Hugo, E. loc. cit.; p. 301.
14. The Instrument Engineer ; Vol. 1 ; No. 6 ; Oct. 1954.; p. 119.
15. Honig, P. *Sugar* 46 No. 9 ; Sept. 1951.
16. Perk, Chs. G. M. 1954. *S. A. Sugar J. Dec.* 1954 (An Alternate Method of Changing over Juice Heaters) p. 825.
17. Davies, J. G. 1953. *Principles of Sugar Technology* edited by P. Honig ; p. 554.

DISCUSSION

Dr. H. W. Kerr observed that scale is indicative of the changes taking place in the liquid. Scale is due to the precipitate being formed. Scaling is minimised by interposing a reaction tank in which juice is held for sometime before admitting the juice to the heaters. The temperature of 218°F. to 220°F. should be aimed at the juice heaters so that air bubbles occluding on the bagacillo escape.

The Chairman remarked that the solubility of $CaSO_3$ decreases at higher temperatures and previously the cause of high scaling was the cold sulphitation. Cold sulphitation was practised in Java before 1915, after which as a result of Vander Linden's work on sulphitation at high temperatures, the sulphitation at 70°C. to 75°C. has been followed. This has resulted in reduced scaling at the juice heaters and evaporators appreciably.

Mr. Nicklin pointed out the effect of juice velocity on heat transmission in juice heaters.

Mr. Leclezio stated that considerable reduction of scale in distilling column's was achieved by preheating fermented wash to 90°C. before admitting it to the wash column.

In the absence of the author, Mr. Clayton presented the following paper.

Paper

OBSERVATIONS ON THE SETTLING PROCESS

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INTRODUCTION

Essentially the clarification process consists of the removal of impurities from cane juice by forming a precipitate and separating this from the clear juice by allowing it to settle under gravity. The latter process is carried out in subsiders or clarifiers of various types all designed for the efficient separation of mud and juice in the shortest possible time.

The separation of the precipitate from the clear juice is conveniently considered as occurring in two stages. In the first, the flocs formed settle at a comparatively fast rate and the major part of the clear juice is removed, this being the " settling " process. In the second, the mud layer becomes more compacted with time and a further quantity of clear juice is removed. This slower process of concentrating the mud is referred to as the " thickening " process.

In the older methods open tanks were used and operated discontinuously, one set of tanks being used for settling and another set for thickening. This has been replaced by a continuous process in which settling and thickening take place in different compartments of the same vessel.

THEORY OF SETTLING

Investigations on the settling characteristics of the floc produced by the clarification process may conveniently be carried out in wide glass tubes kept at constant temperature. When a homogeneous precipitate is obtained, that is when the individual flocs are roughly of the same size, the boundary between the settling mud and the clear supernatant juice can easily be seen. The rate of settling is then measured by the decrease in height of this boundary with time.

At the start it is found (1, 2) that the rate of settling, v_s, is constant, i.e.,

$$v_s = V \tag{1}$$

where V is a constant.

When the mud begins to compact the flocs do not fall freely and the interaction between the flocs becomes very important, decreasing the rate of settling markedly with time. This is the thickening process and equation (1) does not now apply. Instead, the process can best be represented (2) by the empirical equation

$$v_t = \frac{(H - H_\infty)^2}{R^2} \tag{2}$$

where v_t is the rate of thickening when the boundary height is H, and H_∞ the boundary height at infinite time. Both H and H_∞ are expressed as a percentage of the height of the original juice settled. R is a constant.

The significance of R in equation (2) can be seen by considering $(H—H_\infty)^2$ as the " driving force " of sedimentation. R^2 is then seen to be in the nature of a " resistance " to settling. When the mud level has stabilized $v_t = 0$ and (2) gives $H = H_\infty$, i.e., H_∞ is the smallest volume of mud obtainable.

From observations on a large number of juices, the rates of settling, v_s, have been found to be 3-12 cm./minute, according to the quality of the juice. The thickening process can be regarded as starting at a mud level of about $3H_\infty$ and the initial rate of thickening, v_t, will be about 0.25—1 cm./minute. From (2) it is seen that v_t falls rapidly as the mud thickens and after 2-3 hours' thickening time the mud level H has fallen to 1.1—1.5 H_∞ corresponding to thickening rates v_t

of 0.003—0.03 cm./minute. It will thus be seen that the thickening process is very slow compared with the settling process.

By carrying out experiments on the thickening qualities of the floc produced by clarification, it is possible to characterise the juice by two variables, H_∞, which is a measure of the quantity of mud, and R, which is a measure of the slowness of thickening of the flocs formed in the juice.

So far the thickening process has been considered to take place undisturbed in a stationary tube. In continuous clarifiers, however, gentle stirring of the thickening mud is always practised and it is likely that the rate of thickening obtained is higher than that found in a stationary tube. Although the rates obtained from laboratory experiments may be different from those acquired in a factory, it is to be expected that a certain relationship exists between them. Therefore, the behaviour of the settling process in a factory may be predicted, at least qualitatively, from the thickening constants H_∞ and R found from laboratory experiments.

FACTORS AFFECTING SETTLING

The factors which affect the settling characteristics of a juice can be divided into two kinds, (I) those beyond factory control, such as cane variety and the conditions under which the cane is grown, and, (II) those affected by operational conditions in the factory, such as the method of liming, the amount of lime used, etc.

(I) *Factors beyond Factory Control*

Apart from the deterioration which occurs between the time of cutting and of milling the cane, the settling and thickening process is affected greatly by the variety and the growing conditions. It is well known that certain varieties are more difficult to clarify than others and also that manurial treatment, especially that of the application of phosphate, affects the ultimate clarification of the juice.

The climatic conditions of cane growth are an important factor. Clarification difficulties caused by slow settling muds are experienced from time to time and although often associated with certain varieties and certain localities, they have been observed to become particularly acute during periods of severe drought. Experiments on cane grown in Trinidad in a green house have shown(3)that drought conditions lead to the formation of slow settling muds.

(II) *Factors within Factory Control*

Since the quality of the juice varies from time to time, due to changes in the cane variety and in growing conditions, it may be necessary to modify the operating technique to suit the type of juice being processed.

The basic method of clarifying cane juice involves the use of lime and heat. Consequently, the variations in the operating conditions which are discussed below are restricted to those which may be applied when this technique of clarification is employed.

(a) *Effect of Brix*

It is to be expected that the higher the density of the mixed juice, the slower the settling of the mud. It has been found (3) that R is directly proportional to the Brix of the solution, i.e.,

$$R = k \times \text{Brix} \qquad (3)$$

where k is a constant for any one juice. The value R/Brix therefore characterises the speed of the thickening process when comparing the properties of juices of different Brix values. It is seen that the effect of the density will be marked, since the velocity of thickening is related to the square of R as shown in (2). Thus a 10% increase in the Brix value will decrease the rate of thickening by approximately 20%.

(b) *Effect of Method of Liming*

The defecation process is based upon the addition of lime and the application of heat to mixed juice, but many different combinations of time and heat are used in the industry. Since the way in which the floc forms is important, the various lime and heat sequences have a great bearing on the settling properties of the mud.

In the simple defecation process where the juice is limed in cold and then heated, comparisons have been made (4) between batch liming (i.e., adding all the lime required in one batch) and slow liming, where the lime is added dropwise.

The average of a large number of runs indicated that the settling rates were very similar for the two processes, but that the mud volume, H_∞, was about 10% higher in the case of the batch liming. The length of time during which the cold limed juice was stirred prior to heating had little or no effect on the thickening rate, R, or the mud volume, H_∞, when slow liming was practised, but affected the mud volume of batch limed juice. In this case, as the strirring time is increased (up to 25 minutes) the mud volume decreased and approached that of juice which had been limed slowly.

The fractional liming and double heating process (5) which uses a lime-heat sequence has proven, in practice, to be able to handle the muds from refractory juices. In laboratory investigations it has been found (6) that the R value of juices treated by the fractional liming and double heating process varies little whether a normally fast settling juice or a refractory juice is used.

(c) *Effect of Mechanical Treatment of the Floc*

The floc formed by the clarification process is prone to mechanical damage, and if broken up seldom reforms to yield flocs of the original size. It has been found (7, 8) that, in general, centrifugal pumps have a detrimental effect on the floc, and it is highly probable that the violent turbulence in modern high velocity juice heaters may cause a permanent degradation of the floc.

The effect of centrifugal pumps has been found particularly harmful when the fractional liming and double heating process is practised, the secondary floc being more easily damaged than the primary floc (4). Thus, in general, it could be said that the later in the clarification process the mechanical damage is introduced, the worse the effect will be.

(d) *Effect of Temperature*

The effect of raising the temperature of the limed juice is to complete the formation of the floc, and to expel air bubbles occluded in the precipitate. It is generally agreed that temperatures slightly above the atmospheric boiling point are most advantageous.

(e) *Effect of the pH of Liming*

Practical experience has shown that the higher the pH of the limed juice the greater is the mud volume. It has also been found in laboratory experiments (6) that in the simple lime-heat defecation process, both H_∞ and R increase as the pH of the juice is increased by lime. However, in refractory juice, such as that obtained from growing cane under drought conditions, it has been found (3) that the R value decreases slightly when the pH of the limed juice was raised from 8.0 to 9.0.

(f) *Effect of Auxiliary Chemicals*

The object of adding a chemical to the mixed juice during the clarification process is to effect either a better clarified juice or a faster settling mud, or both.

Phosphate. Of all the additives suggested, it is probable that the most important is phosphate, since it is generally and widely used throughout the world. For satisfactory floc formation a certain minimum quantity of phosphate is necessary and if the juice itself is deficient in it, phosphate must be added to the juice before clarification.

The addition of phosphate to the mixed juice prior to liming and heating affects the thickening process as determind by the constants, H_∞ and R, increasing the values of both H_∞ and R and resulting in a slower thickening mud. When larger amounts of phosphate are added, R increases and eventually approaches a constant value (6). The amount of mud, H_∞, increases steadily with increasing phosphate concentration.

Bentonite. Clay, in particular bentonite, is used as an auxiliary defecant in the clarification of cane juice. The addition of bentonite at the rate of 0.3—1.5 lb./ton cane produces a much clearer juice but the mud volume, H_∞, is larger, and a slower rate of thickening is obtained.

Lytron. The addition of small quantities of Krilium or Lytron X-886 has been reported (9,10,11,12) as producing a faster settling mud and a better clarified juice. With a refractory juice, such as that produced by growing cane under prolonged drought, the addition of Lytron X-886 has been found (3) to increase the rate of thickening of the mud only when very large quantities are used, *Formaldehyde.* It may well be that the largest effect on the rate of thickening of the mud is that produced when formalin is added to the juice (13, 14.) The action of the formaldehyde when added to juices which are subsequently treated by a simple defecation process, is to increase the size of the floc considerably and so the rates of settling and thickening are greatly increased. Indeed, it has been found possible by this technique to handle even the slow settling muds obtained from the highly refractory juices of canes grown under drought conditions. The amount of formalin required to produce reasonable settling rates with such juices under factory conditions was found to be about 0.5—1.0 ml. of 35% formaldehyde per litre of juice.

CONCLUSIONS

In a cane sugar factory, thickening of the mud is never carried to finality. The amount of mud which is handled per unit time therefore depends on two factors, (i) the quantity of mud present, and (ii) the speed with which this mud thickens. Whatever method is used to judge the efficiency of the settling process it must be such as to be able to separate these two effects and to provide measures of comparison. The technique discussed in this paper provides one such method.

In practice, the efficiency of the settling station may be judged by its ability to separate the clear juice from the mud in the existing equipment without loss of grinding time and in such a manner that the best possible clarified juice for further processing is obtained. Probably the more important consideration is that the throughput of the factory should be maintained at an adequate level. Although the settling characteristics are greatly influenced by the cane supply, there is a range of factors controllable within the factory which may alter the settling characteristics of the mud. Of the factors discussed above, some, such as the addition of phosphate or bentonite, improve the clarity of the clarified juice, others, such as adding formalin or using the fractional liming and double heating process, increase the rate of settling. The decision as to which measures should be adopted in any given factory, must be made by the superintendent concerned, who will probably decide on a compromise between maximum clarity and maximum settling rate after considering the efficiency of the factory as a whole.

ACKNOWLEDGEMENT

The author acknowledges the help of the British West Indies Sugar Research Scheme in fostering his own work in this field. He also thanks the Director of Research, Prof. L. F. Wiggins, for help in preparing this paper and Messrs. R. D. E. Yearwood and W. S. Wise for helpful discussions.

REFERENCES

1. Deerr, N. 1920. *Int. Sug. J.*, 22, 618.
2. Schmidt, N. O. 1953. *Proc. 8th Cong. I.S.S.C.T.*,729.
3. Schmidt, N. O. ,Wiggins, L. F., Williams, J., Howarth and Yearwood, R. D. E. 1954. *Proc. B. W. I. Sugar Tech. Meeting*, 172.
4. Levy, C. E. and Glasford, R. M. D. 1955. *Thesis presented for the Associateship of the Imperial College of Tropical Agriculture.*
5. Davies, J. G., Duncan, S. and Yearwood, R. D. E. 1936. *Int. Sug. J.*, 38, 298.
6. Schmidt, N. O. Unpublished data.
7. Davies, J. G. and Yearwood, R. D. E. 1942. *Int. Sug. J.*, 44,246.
8. Agarwal, R. N. 1942. *ibid.*, 44, 319.
9. Lee Ching-an. 1953. (November), *Sugar*, 48, 33.
10. Bonneville, A. Briggs. 1953. (November), *Sugar*, 48, 36.
11. Thibaut, J. H. 1954 (March), *Sugar. J.* 16, 28, No. 10.
12. Ghosh, S. K., Manohar Rao, P. J. and Sanyasiraju, K. R. 1954-55. *Indian Sugar*, 4, 637, 641.
13. Schmidt, N. O. and Wiggins, L. F. 1954. B. P. Appln. 34301.
14. Schmidt, N. O. 1954. *Proc. B.W.I. Sugar Tech. Meeting*, 183.

DISCUSSION

Mr. Parashar observed that mud-volume decreases after stirring for a long time and allowing a longer time of reaction. Clarity and mud-volume have a strong correlation. Muds are of two types, viz., compact mud particles have even surface and flocculant muds are those where the flocs form an uneven surface and the particles are still in suspension. Compact mud with no particles in suspension is desired.

Dr. K. S. G. Doss stated that muds which form a small volume could be redispersed very easily and those which form a high volume were difficult to redisperse. He also pointed out that all the centrifugal pumps are not similar in their action. Their turbulence and dispersing effect on flocs would depend on the design and operation of the pumps.

The Chairman considered that one of the common reasons for the dispersing action was over capacity pump.

Mr. Kelly referred to the need for viewing the paper as an approach to the quantitative measure of the settling process in which extreme conditions do occur. The settling process itself would consist of three stages, viz., settling, intersettling and compression settling (which is mud thickening). In the thickening of mud, we are concerned with the compression settling where the problem is one of upward movement of the liquid. The effect of mechanical agitation will no doubt be the breaking of flocs. Formalin referred to in the paper would be used only under conditions of difficult settling. Referring to a question from Mr. Parashar, Mr. Clayton observed that stirring of juice during prolonged addition of lime did not mean stirring of mud.

Dr. Kerr observed that the rate of settling improves by stirring but there is the need for observing exact conditions. A right kind of soil by itself if present in the juice will give a good settling.

Dr. Doss pointed out that in India the cane is quite clean, but the lime is not clean.

In the absence of the author, Dr.H.W. Kerr presented the following paper.

Paper

VIBRATING SCREENS FOR MILL JUICES

Milton C. Marsh

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INTRODUCTION

The screening of mill juices is a necessary technological operation to achieve different aims :

(1) The mill juices have to be screened before they are returned to the mill tandem as imbibition juice to have the counter current extraction process in milling. The screening of the juice of the individual mills is a necessity where for the equal distribution of the juices over the whole width of the bagasse blanket perforated pipes, nozzles or similar devices are applied.

With the introduction of chokeless pumps it became possible to transport juices, containing a high percentage of coarse suspended matter such as fine bagasse. With the endeavour to simplify the distribution of fine bagasse containing juices in the imbibition process special type of imbibition troughs have been developed. The simplest device is an inclined distributing plate.

It is not our intention to discuss in this paper the advantages and disadvantages of different types of imbibition devices, but only to indicate that the necessity for a screening of the last mill juices to remove the bagacillo and fine bagasse has been reduced considerably by the introduction of suitably arranged chokeless pumps, with a proper arrangement for charging such pumps regularly and uniformly and the development of suitable designs for the distribution of juices when they are returned to the mills for imbibition.

The majority of the mill tandems still apply a screening of all the juices before pumping. The screens used in the majority of the mill tandems are the so called drag carrier type screens with stationary screens, usually consisting of a perforated screen plate, constructed in copper or stainless steel.

(2) The juices to be processed, consisting of a mixture of primary and secondary juice, have to be screened before liming, heating and weighing, as the presence of suspended matter in the form of disintegrated bagasse results in mechanical difficulties in the handling of juices as clogging up of valves, pumps and juice heaters.

In all modern mill tandems it is essential that the juices are subjected to a screening process to remove the disintegrated bagasse as completely as possible. The quantities of fine bagasse present in mixed juice show tremendous variations from mill to mill. The quantity depends on the quality of the cane, system of disintegration before milling, and last but not least the mill settings and particularly a proper setting of the bagasse carriers in relation to the feed rollers of the mills. The throughfall of fine bagasse, as it can be easily observed in visiting different mills, is more or less the result of the perfection that has been realized in a proper setting of the carriers.

A second important element in the introduction of fine bagasse in mill juices is the amount of bagasse removed by the scrapers from Messchaert grooves.

(3) It is desirable to remove as far as possible completely finely disintegrated bagasse, commonly known under the name of bagacillo or cush-cush, from mixed juice to obtain a proper settling in the clarifiers, as the bagacillo by its specific gravity is very difficult to settle. When it is present in considerable quantities it increases the volume of the juice mud or cachaza, and it is one of the main suspended non-sugars to which remains attached small air bubbles,which can only be removed by an intensive heating and boiling in flash tanks or defecation pans, as otherwise this fine bagacillo combined with fine air does not settle at all, but remains as suspended matter in the clarified juice.

TYPES OF SCREENS USED FOR MILL JUICES

The drag carrier type screen with stationary perforated plates commonly uses 12×12 or 15×15 perforations pe· sq. inch. The majority of the mills are equipped with the 12×12 perforated screens. These are round perforations, sometimes tapered. The linear opening is for the 12×12, 1.3mm. and for the 15×15, 1.1mm. The open area is 28% of the total screen area for the first type of screens and 37% for the second type of screens. The results of these screen types in the elimination of fine bagacillo from the screened mixed juice are far from perfect.

In modern mills with an intensive preparation of the cane before milling the amount of fine bagacillo present in the screened mixed juice varies from mill to mill from 0.6 to 1.5g. per litre. But a reduction of the fine bagacillo in screened mixed juice with stationary screens to a value under 1 g. per litre of juice becomes extremely difficult and in many cases even impossible.

The modern types of vibrating screens are using woven metal cloth as screen with the following specifications :

Screen's mesh per inch	Linear opening in mm.	Screen opening % screen area
30x30	0.5	37
20x20	0.8	44
15x15	1.1	56

The common type of screen used for modern vibrating screens is the 20×20 mesh woven from monel or stainless steel.

According to a special investigation made by Dr. P. Honig of the West Indies Sugar Corporation at the factory Boca Chica in the Dominican Republic it is possible to reduce the amount of bagacillo in mixed juice to an average value of 0.5 g. per litre of juice with this type of screen.

The difference in screening effect, expressed as the amount of bagacillo left in the treated juice, is for fine screens to a certain extent not substantial. With the 30×30 mesh screen it was possible to have a bagacillo content as an average value of 0.4 g. per litre.

The determination of the amount of bagacillo left in mixed juice after screening is as follows :

(a) Take a measured volume of screened mixed juice, for instances 5 litre, and screen this juice over a 100 mesh laboratory sieve (Tyler standard screen 8″ diameter, 2″ height, opening in mm. 0.147).

(b) The fine bagacillo retained by the screen is washed thoroughly with a spray of hot water till it is absolutely free of sugar and that the off-running water is perfectly clear.

(c) The retained bagacillo is collected, dried for 3 hours at a temperature of 110°C., cooled in an exsiccator and weighed.

The amount of bagacillo determined in this way is expressed as grams per litre of juice.

According to special investigations that have been made by a repeated screening of the juice that had been pre-screened over the 100 mesh, over screens of 150 and 200 mesh, it is shown that practically all the bagacillo present in mixed juice is retained by a 100 mesh screen.

We feel confident to state that by the application of vibrating screens, using 20×20 mesh as screen type, it is possible to reduce the bagacillo content in mixed juice under all conditions of milling to an average value of 0.5 g. per litre or less.

VIBRATING SCREENS

There are an increasing number of sugar factories throughout the world utilizing vibrating screens for the straining of mill juices. The capacity, dimensions, and ease of installation of the type of screen being furnished for such applications permit a great deal of flexibility in meeting existing space requirements and location.

Many factories have installed Link-Belt NRM-138 screens with overall dimensions of 8′×4′ ½″. It has to be understood that similar screens are made by other manufacturers. The feed tank to be used in combination with this screen will extend the installation an additional 2½′ lengthwise, depending upon capacity required. This screen equipped with the finest type of screen, recommended 30 mesh stainless steel screen cloth, with a clear opening of 0.0203 inch, a wire diameter of 0.013 and 37% open area, has a capacity of 300 to 325 U.S. gallons of mixed juice per minute under normal operating conditions. This corresponds with a grinding rate of 1500 metric tons of cane per 24 hours. This capacity will vary somewhat with the conditions of the juice and the cleanliness of the screen cloth. This same screen equipped with 15 × 15 mesh cloth with a wire diameter of 0.017 inch, an opening of 0.050 and 56% open area, has a capacity of 500 to 550 U.S. gallons per minute (3000 tons of cane per 24 hr.). Screens are selected with a liberal capacity in order to allow for possible increase in grinding rate and to prolong the intervals between necessary cleanings.

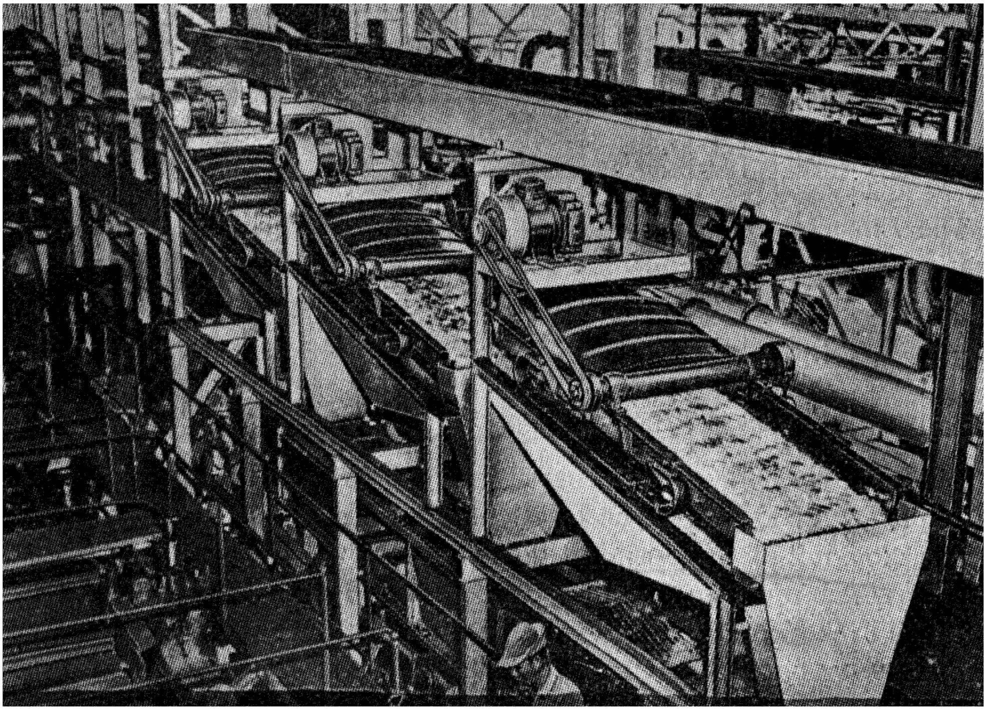
The Link-Belt vibrating screens were specifically designed for efficiently separating solids from liquids. The special construction of the deck permits the use of even finer mesh cloths than those mentioned above and prevents liquids from travelling on the underside of the cloth. There is little or no build-up of slime or fungi on the underside of the screen cloth as is found frequently under the perforated plates used in the conventional trash drag strainer and elevator.

The unbalanced type of mechanism which is used produces vibrations of high frequency (1800 R.P.M.) and small amplitude (1/32″ to 7/64″) to effecitively minimize clogging of the openings in the cloth and to ensure maximum liquid passage. Where multiple screens are required to handle the capacity, they may be installed in tandem or in line—all discharging into a common conveyor either of the screw or flight type for the return of the trash to the bagasse blanket of the intermediate carrier.

A vibrating screen installation has the particular advantage of being easy to clean and maintain, with relatively low maintenance cost and relatively low power consumption (2H.P. for each screen). For cleaning, automatic steam and hot water devices have been designed and installed, but in most cases factories have found a simple steam or hot water hose with nozzle to be satisfactory. Cloths can be removed and replaced in a matter of minutes and if maintained at " drumhead tension " will have a durability commensurable to a reasonable maintenance cost.

The selection of a proper chokeless pump is obviously of primary importance; however, there are a number of very reliable manufacturers of these pumps with numerous successful installations. The piping delivering the juice to the feed tanks of the screens must avoid sharp angle bends to prevent clogging of the trash in the pipes, and the design of the feed tank as well as the sump tank provides a capacity so as to avoid settling of the trash.

The photograph of the installation at Woodford Lodge in Trinidad shows a tandem arrangement which was necessary because of available space; the trash discharged is collected by a flight conveyor.



Three Link-Belt Liquid Vibrating Screens receive raw cane sugar juice from chokeless pumps. Screens are equipped with 20x30 mesh cloth and bagasse discharge from screens is returned to the first mill. Woodford Lodge Estates, Trinidad. Feb. 1950.

DISCUSSION

Dr. Doss desired to know if use of extra pol has been able to reduce the amount of bagacillo.

Mr. Leclezio asked if less bagacillo would adversely affect floc formation.

Mr. Jenkins stated that he saw no particular disadvantage by eliminating bagacillo. It is likely, however, it helps. The fact, however, remains that the fine screens for juices which were in use some 25 years ago in his country have long been discarded.

Mr. Gairola observed that it would be very important to remove bagacillo in carbonation factories due to the high pH values, under which condition, bagacillo would contribute to colour formation and undesirable non-sugars would get dissolved.

Dr. K. S. G. Doss referred to the highly alkaline conditions obtaining in the Saha-Jain process of clarification and stated that the use of bagacillo to improve the filtration conditions did not give rise to any increased colouration.

Mr. S. N. Gundu Rao observed that Saccharetin being colourless in acid medium does not worry the sulphitation or carbonation White Sugar Technologist, but the possibilities of other objectionable non-sugars getting into solution under alkaline conditions is a point which has to be taken note of.

Before Mr. Nestor Sabi presented his paper, the Chairman suggested that the discussion on this and the subsequent three papers by Mr. Davies, Mr. Storrar and Mr. Ibanez should be held jointly.

Paper

PRINCIPLES OF CLARIFIER DESIGN

NESTOR SABI

Manager, Cane Sugar Division Dorr-Oliver Incorporated, Stanford, Conn. U.S.A.

INTRODUCTION

For more than 35 years, design of the continuous cane juice clarifier has been the subject of extensive study and numerous research programmes conducted by the manufacturers of both cane sugar and clarification equipment. A focal point in the processing of cane, clarification actually begins long before juice enters the clarifier. This discussion, however, will be confined primarily to the design of the unit itself in its application to the clarification of juices previously subjected to any of the known combinations of heating and liming with or without additional reagents. It will be assumed that the juice has been properly heated and limed before it enters the clarifier. The discussion will be applicable to the clarification of carbonated juice in only a very limited sense.

Considering that sedimentation is an apparently simple process which occurs under the influence of natural forces, there should have been greater progress and less disagreement over the years in the design of a universally accepted clarifier. The fact remains, however, that the exact mechanisms of some aspects of sedimentation are not yet fully understood nor formally given a theoretically sound mathematical interpretation. At the present time fundamental research is yet in progress on the subject of sedimentation.

In the case of cane juice the mechanism becomes more complicated for the characteristics and composition of this material are extremely variable. It is highly probable that data obtained from the study of clarification or design variables in two similar units operating side by side will be valueless unless identical feed is used in both instances. Absolute values mean little in this type of work and comparative terms must always be considered. Unfortunately, considerable absolute data have been used in arriving at various conclusions, thus leading to many conflicting convictions.

Another point often overlooked in conducting otherwise sound experiments is the testing of the statistical significance of data. Tests should be extended over much longer periods than are normally allowed so that the validity and significance of the data may be ascertained. For example, two clarifiers operating side by side may produce extremely limpid juice overflows but one may contain twice as much suspended matter as the other. Erroneous conclusions often result unless it is realized that at that degree of clarity the difference, great as it may be numerically, has little significance. Given sufficient time, additional data may well show opposite results.

It is obvious, therefore, that the apparently simple unit operation of sedimentation is not easy to study. This is particularly true in the case of cane juice clarification. In the ensuing discussion present knowledge of the art will be outlined and a clarifier design will be derived based on that knowledge.

OBJECTIVES

The two objectives of cane juice clarification are the production of the cleanest possible juice and the densest possible mud. The first of these objectives is obvious. However, reasons for classifying the production of a dense mud for as an objective, are not as clear-cut thinner muds can be handled merely by providing greater filtration capacity. While this point is unquestionably true, an economic study based upon presently available equipment indicates clearly that it is most advantageous to reduce the size of the filter station as much as possible. This resulting saving in initial investment is far greater than the cost of extra mud thickening capacity. Thus economics dictate this second objective.

A common objective of equipment of any type is the accomplishment of the task in a unit of the smallest possible size in order to reduce the installed cost. This point is doubly important in the case of cane juice. It is a perishable substance and every effort should be made to reduce volume of juice in process and to increase the rate of processing.

BASIC FACTORS AND THEIR CONTROL

After a definition of the objectives of clarification, basic factors affecting the subsidence of suspended solids must be considered. These factors include the force of gravity, the density and viscosity of the liquid, the density of the solids and the size of the solid particles. In addition, another factor enters into the picture when sedimentation occurs in a continuous apparatus ; namely, the turbulence or liquid mass motions that are produced by density differences, high liquid velocities or thermal convection.

Logically, the question arises " Can these factors be controlled ? " The force of gravity and the density of the solids cannot be altered. Density and viscosity of the liquid can be changed, but the practicability and desirability of such changes are not a function of the clarifier and should not be considered here. Thus particle size and turbulence become the only two factors which can be controlled.

Control of particle size is possible in the sense that optimum conditions for the solids in cane juice to grow by collision and adhesion can be provided. This particle growth or flocculation can be a separate function preceding clarification. As a matter of fact, such is the case in many other industries, where separate apparatus are employed for promoting flocculation prior to feeding the suspension to the sedimentation unit. Cane juice flocs, however, are particularly fragile and flocculated juice should be subjected to a minimum of handling to prevent floc disintegration. Flocculation should be carried out as closely as is possible to the area in which the solids are to be removed by sedimentation. Therefore, flocculation becomes a function to be performed in the clarifier and not in a separate preceding unit.

In the conventional multi-compartment clarifier this function is carried out in an upper chamber. However, recent test work has shown that this arrangement is not entirely satisfactory as some floc rupture is possible as feed passes from this upper chamber to the settling compartments.

Of the three types of turbulence, that due to thermal convection can be minimized by good insulation and that arising from high-speed streams can be reduced by proper sizing of all passages. The third, mass motions due to density differences, can be controlled by recognizing the possibility of occurrence and by isolating zones in which turbulence may be prevalent from zones that require quiescence.

To summarize, the two basic factors affecting sedimentation to be considered in the design of a continuous clarifier are flocculation and turbulence. Efforts should be made, of course, to improve flocculation and to reduce turbulence, but beyond that no other control over basic factors is possible. Whatever results are obtained are the result of the force of gravity on a given feed material. A clarifier, therefore, can " make " clean juice and thick mud only to the extent that flocculation is improved and turbulence reduced. Nature sets the limits of performance, and conditions within the clarifier must approach those limits as closely as possible.

GEOMETRICAL RELATIONSHIPS

1. *The Vertical Plane*

In a body of liquid undergoing continuous subsidence there is a gradual change of solids concentration from the upper to the lower layers. At some intermediate level the concentration is the same as that of the feed. Suspensions of different concentration act very much like liquids of different densities and tend to maintain their identity. If a third liquid of intermediate density is added to two immiscible liquids one above the other in a vessel, a rapid flow towards the interface occurs and the third liquid immediately spreads itself between the other two.

A similar situation exists when a suspension is fed into a mass of liquid undergoing subsidence. Regardless of whether the feed enters at a point above or below the layer of feed density, there is a very rapid flow towards that layer and feed spreads itself over the entire area. Such mass motions occur in liquids even where density differences are minute, as opposed to discrete solid particles which require larger density differentials to sink or float with any appreciable speed.

If the feed is introduced at a level which is distant from its density layer, the plunging or rising stream will set up currents or rollers which tend to spread out and interfere with orderly settling. Feed should thus be introduced as near as possible to the proper density layer. Above the layer of feed concentration a very sharp decrease in concentration is observed. In other words, feed concentration exists relatively close to the level generally recognized as the surface of the mud accumulation.

As illustrated in Figure 1, showing a proper vertical relationship, feed entry should be at or near the height at which the mud level will be carried. In practice this can only be approximated but every effort should be made to carry the mud level at about the same height as the feed entry.

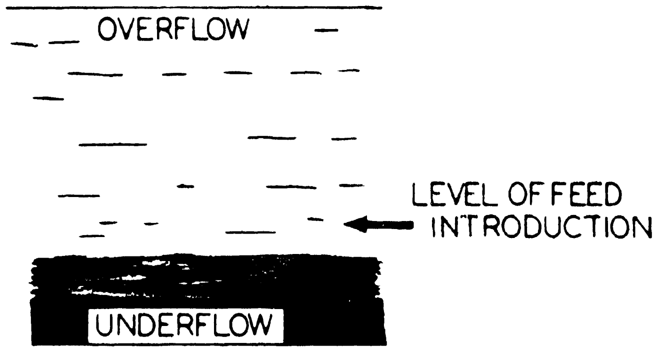


FIG I

DENSITY RELATIONSHIPS IN VERTICAL PLANE

Ideally, feed should be introduced at the proper level through a multiplicity of openings. Likewise overflow and underflow should be withdrawn over the entire area. Of course, such can be accomplished only at great cost. However, this ideal vertical displacement can be approximated quite closely by simpler methods. As a matter of fact, feed will automatically spread itself over the entire area and displacement will then proceed vertically upwards as well as downwards. Such is the flow pattern in the greater part of the liquid mass. Near the level of both the overflow and the underflow an approximately horizontal motion again exists towards the side where withdrawal occurs. This flow pattern is shown in Figure 2.

Horizontal motion towards the exit points takes place after the juice has become clear and after mud has thickened so that this departure from the ideal vertical flow pattern is unimportant. It should be pointed out, however, that the above pattern is approached only when adequate vertical distance is allowed. In a shallow space, the flow lines are slanted, resulting in less efficient displacement and lower capacity. The importance of small density differences in establishing flow patterns in a clarifier has not been generally recognized. This has led to many false interpretations of exactly what happens inside a clarifier as well as to improperly designed units.

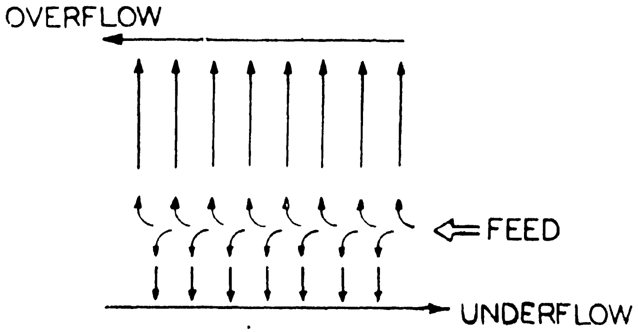


FIG. 2
IDEAL FLOW PATTERN
VERTICAL PLANE

2. *The Horizontal Plane*

Three practical geometrical arrangements are possible with respect to the horizontal relationship between feed entry and overflow exit, as illustrated in Figure 3.

A square or rectangular cross section is not generally approved for cane juice clarification. It would be mechanically difficult, if not impossible, to do a complete job of scraping mud from the corners, and mud stagnation is, of course, intolerable. Tests carried out in the water treatment field do not seem to indicate that there is any difference, hydraulically, between square and round tanks, nor is there any sound theoretical reason to suspect that there should be a difference. Space saving is apparently the only advantage of a rectangular cross section, but in the case of cane sugar clarification that saving is not an important consideration.

With the more practical circular cross section there is a choice between central and peripheral feed. Remembering that regardless of entry point, there is an immediate tendency for the feed to spread out horizontally in its density layer and to then rise vertically, either arrangements should be satisfactory. In either case the main flow pattern is vertical and it is only at feed density level that a differentiation between the two types is possible. There is a difference, however, as illustrated in Figure 4.

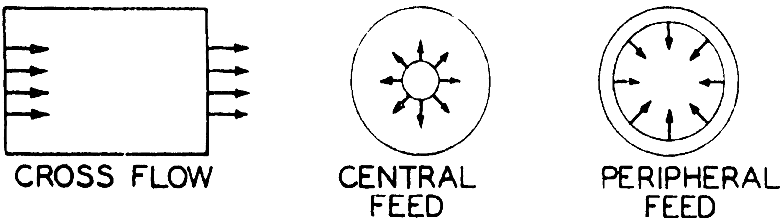


FIG. 3
HORIZONTAL FLOW PATTERNS

Since overflow is removed at the highest point, it follows that the upper partitions must slope in different directions. In either case the level at which the overflow is removed is shown by the dotted line A. As long as operation is normal and the mud level is low either design should produce equal results. It should be noted, however, that above level B cross section begins to diminish and therefore the upward velocity increases. In the case of peripheral feed the cross section diminishes at a much faster rate.

Let A_c=cross section in central feed unit at distance y from A and
A_p=cross section in peripheral feed unit at distance y from A.

It can easily be shown geometrically that

$$\frac{A_c}{A_p}=\frac{Dm}{y}-1$$

where m=tray slope and D=diameter of unit.
For example, if D=24 ft. and m=1/6 ft./ft.

$$\frac{A_c}{A_p}=3 \text{ when } y=1$$

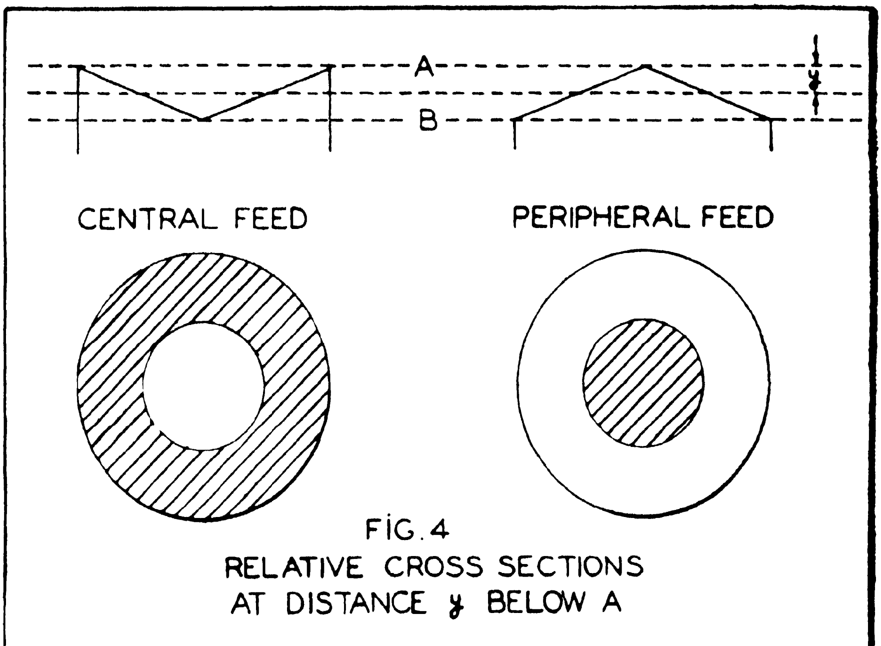


FIG. 4
RELATIVE CROSS SECTIONS
AT DISTANCE y BELOW A

In other words, at a distance of 1 ft. from the outlet level the central feed unit has three times greater area. Hence the upward velocity is only 1/3 as great at that level.

Another way to look at it is to show the comparative levels at which equal upflow velocities exist. This is shown in Figure 5, based on a typical slope of 1/6″, for 18′, 24′ and 30′ diameter clarifiers. For example, in a central feed unit the upward velocity 6″ from the top is the same as the velocity 18″ from the top of a peripheral feed unit, when the diameter of each is 30′. In this case there is a safety factor of 12″. This can easily mean the difference between getting past a tight spot and having to slow down to avoid dirty overflow. As abnormal conditions are be a common occurrence due to changes in the type of juice or to irregularities in liming or heating, the design which allows greater safety at all times with all other things equal must be selected.

Another factor favouring the central feed unit is volume economy, which was the third objective of clarification. Withdrawal of mud must be at the centre of the unit for practical reasons and the bottom should slope down towards the centre. In a centre feed unit the bottom is thus parallel to the top of the compartment resulting in minimum volume. On the other hand, in a peripheral fed machine substantial volume would be wasted.

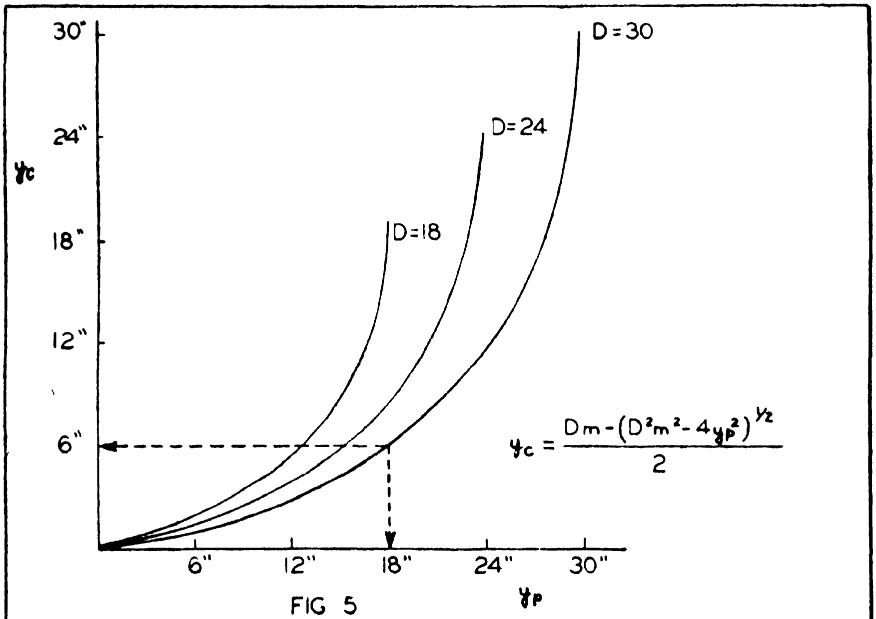


FIG 5

EQUIVALENT AREA LAYERS IN CENTRAL AND PERIPHERAL FEED SYTEMS

$m = 1/6$

THE SETTLING UNIT

Proceeding on the basis of central feeding in a circular cross section, details of the resulting unit, particularly as regards feed introduction, overflow removal and mud movement are next to be investigated.

1. *Feed Introduction*

As demonstrated, feed should enter at a level corresponding to its density. At the same time high liquid velocities are undesirable. The simplest method of introducing feed with due regard to these two factors is shown in Figure 6 which outlines the arrangement developed thus far for a settling unit. This arrangement also provides flocculating space near to the area in which subsidence will occur.

The central feedwell should have sufficient diameter to provide time for flocculation. Cane juice solids are so voluminous that there is a high probability of collision and non-mechanical means of promoting flocculation are sufficient. The natural eddying of the liquid in the feedwell is sufficient to promote flocculation if adequate time is allowed. About 10-15 minutes are usually required in a feedwell which is about $\frac{1}{3}$ the diameter of the tank.

The ratio of entrance velocity to upflow velocity in the settling compartment will be in proportion to $\frac{(D^2-d^2)}{d^2} \times \frac{F}{O}$

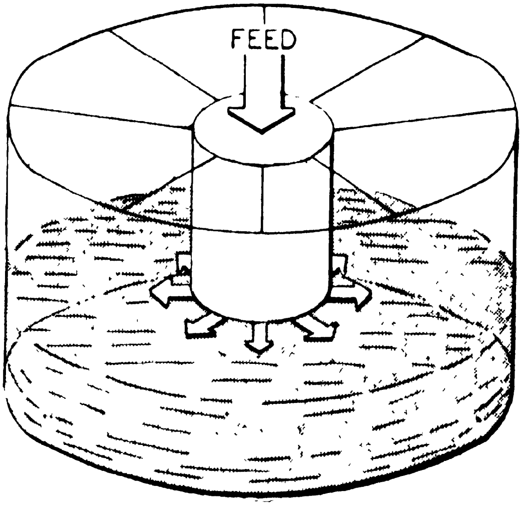


FIG 6
SETTLING
UNIT

where d=feedwell diameter, D=tank diameter and $\frac{F}{O}$ is the volumetric ratio of feed to overflow. If $d=\frac{D}{3}$ and $\frac{F}{O}=\frac{100}{80}$ the ratio is about 10. In other words, if the upflow velocity is 24 in./hr., the entrance velocity is 240 in./hr. which is only 4 in. per minute. It is hardly probable that such a velocity could create any disturbance.

The lower edge of the feedwell is located approximately at the level of the upper layer of mud which, as previously noted, is the layer of feed density.

Therefore, there will be no tendency for plunging or rising of feed and the possibility of the resulting turbulence is minimized.

2. *Overflow Removal*

The clear juice must now leave the settling unit through openings in the tankside. These openings should, of course, be located as high as possible. The problem now becomes the determination of the number of openings that should be employed. Obviously, the number should be minimized from the economic viewpoint. On the other hand, if too few openings are used there is the undesirable possibility that high exit velocities may develop. In the absence of a sound theoretical analysis of the problem, conclusions must be drawn from experimental evidence.

Figure 7 shows the results of a plot of turbidity vs. flow rate, when comparing the overflow turbidities from two compartments of the same clarifier, one fitted with 24 outlets and the other with only 3. The two curves, A indicating the compartment with 3 outlets and B the one with 24 outlets, are practically coincident over the entire range studied.

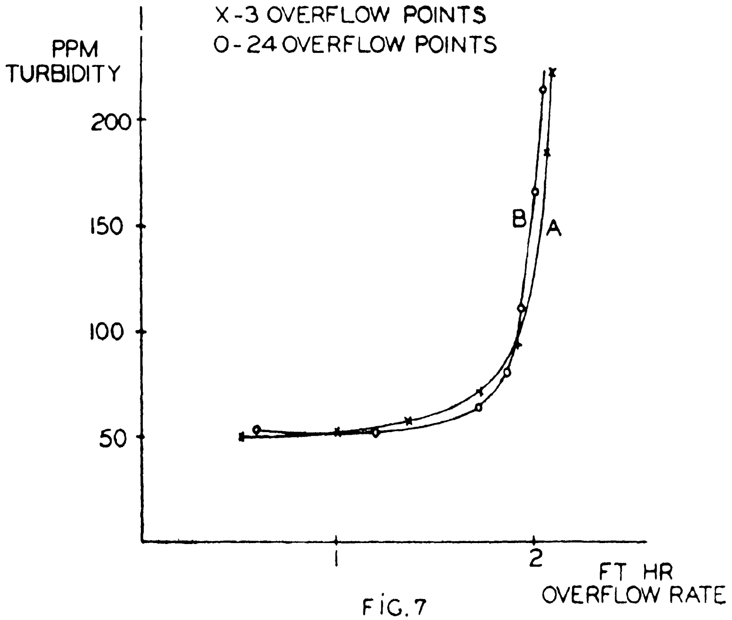


FIG. 7
TURBIDITY VS OVERFLOW RATE
PERIPHERAL OVERFLOW
THREE OUTLETS
AND
TWENTY FOUR OUTLETS

Going to a further extreme, there are many clarifiers in Louisiana that have only a single outlet per compartment. Such design has been specified because the usual overflow collecting pipes have a tendency to scale up very heavily in some localities. No direct comparisons have been made in any one factory but of 39 clarifiers of the same type in that area, 21 have a single overflow point and 18 have three or more. There appear to be no statistically significant differences in the ratings of one group as against the other in terms of the average tonnage ground by the respective factories. Evidently, inspite of the higher velocity at the outlet point, the velocity of the streamlines leading to that point decreases very rapidly as the distance from the outlet increases.

The point may be raised that with a single outlet point there will be stagnation at the opposite side. However, within the clarifier is a continuous vertical upflow of juice over the entire area so that all the juice must be displaced. On the side opposite the outlet the displaced liquid simply travels around the periphery once it reaches the highest point as there is always fresh liquid rising from below.

Nevertheless, a single outlet is not recommended as the flow pattern cannot be expected to be 100 percent ideal and displacement can be expected to be somewhat slower at 180 from the single outlet. Two or three openings, however, are certainly sufficient as verified in settling units handling not only cane juice but many other types of suspensions.

3. *Mud Movement*

Cane mud, although for the most part it requires little help to move along, adheres with great tenacity to surfaces once contact is made. When it stops moving it forms a crust to which additional mud adheres, thus gradually building up a focal point of deterioration. Mud should be scraped, therefore, and the conventional method of flexible blades set at an angle on rotating arms appears to be the most logical type of construction. The staggered arrangement of the scrapers on the various arms is the simplest solution to the geometrical problem of sweeping the entire tank area. Such problems as structural rigidity of the arms and speed of rotation are impossible to derive theoretically and only years of experience can serve as a guide. In the settling unit thus far described the scrapers should be arranged for centripetal flow if for no other reason than to facilitate mud withdrawal.

Blades should be of sufficient height to aid the thickening process. Although area is the primary factor in the determination of final mud thickness, the mechanical motion of the blades seems to help rearrange the particles into a more compact mass. Tests have been carried out using more elaborate stirring apparatus but it appears that the final thickening phase occurs relatively close to the bottom of the chamber and strirring above a height of about one foot is not necessary.

FUNCTIONAL RELATIONSHIPS

Discussion of the design of the settling unit have been concerned thus far only with fluid motion and arrangement of physical elements. Functional relationships, too, enter into the design. It is now necessary to determine whether the unit described can achieve the two main objectives of clarification to the same degree. If not, the design must be modified to correct the situation. To study this problem thoroughly an understanding of the mechanisms of clarification and mud thickening is essential.

A laboratory batch settling test will indicate generally the settling rates in full scale continuous operation. However, this method only tells part of the story. Schmidt (1) has conducted a mathematical study of various settling curves and has shown that there exists a general relationship between clarification and thickening rates. Talmage and Fitch (2) have worked out a graphical method of determining thickening unit area based on a mathematical analysis by Kynch (3). In addition, they have obtained very good correlations between laboratory and plant data. While these studies have been of great help in understanding the mechanism of settling and in giving an indication of the behaviour of a given suspension in practice, it is still necessary to employ full-scale experiments to obtain complete and unequivocal data for design purposes.

An empirical approach will be used in this discussion of functional ralationships rathter than a purely mathematical derivation as the latter, with the present stage of knowledge, would leave room for doubt.

1. *Clarification*

The clarification process takes place above the layer of feed density. It is a common falacy that the permissible upflow rate is the same as the initial bulk settling rate as determined by batch experiments. This bulk settling rate, however, cannot be used for design purposes because clear juice is seldom obatined immediately upon subsidence of the top layer of mud. The remaining haze must be allowed time to achieve final flocculation and the settling rate after this flocculation is not necessarily as rapid as the bulk subsidence rate. Sufficient area must be available so that the upflow velocity does not exceed this final settling rate, and sufficient height provided for given unit area to obtain the desired detention time.

In addition, two other factors—detention efficiency and the safety factor—influence design. In the preceding discussion of flow pattern it was noted that the efficiency of detention, that is, the closeness to ideal vertical flow, was also dependent upon depth and that such ideal flow could be approximated to a greater or lesser degree. Clarification, unlike mud thickening in which there is a certain amount of flexibility, is more sensitive to changing conditions. As overflow turbidity can increase very abruptly, an adequate margin of safety must be included in provisions for clarification capacity.

All three factors-final clarification rate, detention efficiency and safety margin-are difficult to establish on theoretical grounds and consequently actual plant experience is needed to determine capacity.

2. *Mud Thickening*

Thickening occurs below the layer of feed concentration. As the solids crowd together settling becomes slower. However, the required cross-sectional area does not increase indefinitely, for the quantity of upflowing liquid decreases as the lower layers are approached. The procedures of Kynch and Talmage and Fitch enable determination of the critical area requirement, but, as before, these methods have not been developed to perfection and for the present actual plant data provides the most reliable design basis.

Nevertheless, the concept of a critical area requirement is valuable. Looking upon it as a bottleneck, if sufficient area is furnished so that all solids can pass through at the concentration of the critical layer, thickening will proceed to the ultimate degree. If the area available is less than the critical requirement for a given tonnage of solids, the rate of accumulation at the critical layer will be greater than the rate of settling. As a result, mud will build up until it reaches the overflow, unless it is removed at a faster rate and hence at a higher dilution.

Since cross-sectional area limits capacity, it follows that there is no need to allow mud to build up to great depths. From an economic standpoint, prolonged detention will increase sugar losses and may cause gas evolution. It is, therefore, recommended that the slope of the bottom of the clarification chamber be very flat. The use of a small mud discharge well is also recommended to act simply as a surge volume to compensate for any intermittency in mud flow rather than for any value it may have as an additional mud thickener.

3. *Relative Capacities*

Based on data obtained in actual plant operation, it appears that the ratio between clarification and mud thickening capacity per unit area is approximately the same over a wide range of conditions. This is confirmed by Schmidt's (1) mathematical studies. Regardless of the difficulty or ease of juice clarification, the difference between the ratios is slight.

In the settling unit described thus far, the area ratio is 1 : 1. In short, the same cross-section is used for the two phases. Although detention efficiency is improved by increased height and inspite of the excellent flocculation possible in the large diameter feedwell, clear juice can not be obtained from such a unit when the full mud thickening capacity is in use.

Reduction of juice upflow velocity by 50% by superimposing a second compartment above the first will double the clarification area, producing a 2 : 1 ratio. With properly designed compartments and a 2 : 1 area ratio it has been found that balance between the two capacities more closely approaches the ideal. Clarification capacity is slightly greater than thickening capacity when the area ratio is 2:1 as it is more desirable to provide a safety factor for the former. Therefore, mud thickening capacity becomes the controlling factor for the described design and it is this figure that should be employed for comparative purposes. As long as adequate thickening capacity is supplied, it follows automatically that sufficient clarification capacity will be available. Additional compartments will only serve to increase volume without adding to the capacity.

4. Specific Capacities

Permissible upflow rates may vary from 2 to 10 ft. per hour while mud volume may range from 5 to 25% depending upon cane variety, method of harvesting, weather and degree of liming. In view of this wide variation it is impossible to state specifically the area or volume required per ton of cane ground without an exact knowledge of specific local conditions. At the same time, the adequacy or inadequacy of the filter station will have a profound effect on the work of the clarifier.

Generally speaking, however, design based upon a capacity requirement of 0.30 sq. ft. of mud thickening area per short ton of cane per day will suffice in most instances. Other cases with minor exceptions will fall within ±30% of that figure. Design of the clarifier developed in the preceding discussion calls for a height of 10 ft. above each thickening tray. Thus a volume of 3 cu. ft. per short ton of cane per day is provided under average conditions.

THE COMPLETE CLARIFIER

1. Number of Compartments

The 2:1 ratio of clarification to thickening area was established on functional grounds. The total number of compartments depend now upon engineering economics. As long as an even number of compartments are included, the functional requirements are satisfied and it becomes necessary only to determine the optimum number on a cost basis. It is obvious that an increase in the number of this compartments increases the number of auxiliaries such as mud pumps. On the other hand, the greater the number of compartments the smaller the diameter of the unit and the lower the foundation costs. Numerous variables must be considered and a complete economic analysis in this instance is beyond the scope of discussion. In summary, a four compartment clarifier such as the unit shown in Figure 8, appears at the present time to be the most economical arrangement. It consists of mud thickening compartments and, above each, an extra clarification compartment to reduce the upflow velocity to the desired value.

2. Compartment Height

A height of above 4 ft. is required for clarification. In other words, at the highest upflow rate consistent with the final sedimentation rate the 4 ft. height permits the desired detention time and provides maximum detention efficiency. Considering a typical case in which the upflow rate is 2 ft. per hour, total calculated detention is 4/2 or 2 hours, ample time for final flocculation of the smaller particles which escape bulk settling.

In the mud compartments a mud depth of about 2 ft. is ample to secure final thickening and to allow some variation in mud height. Consequently, these compartments should be approximately 6 ft. high. In addition, design of each mud compartment should include an additional surge volume at the centre to permit withdrawal at uniform

3. *Feed Compartment*

As incoming feed is flocculated at the entrance of each of the compartments the feed chamber at the top need not be very large. It should be just of sufficient size to dissipate the entrance velocity and to provide sufficient area for foam removal. The smaller the feed compartment the more in keeping with the objective of reduced volume.

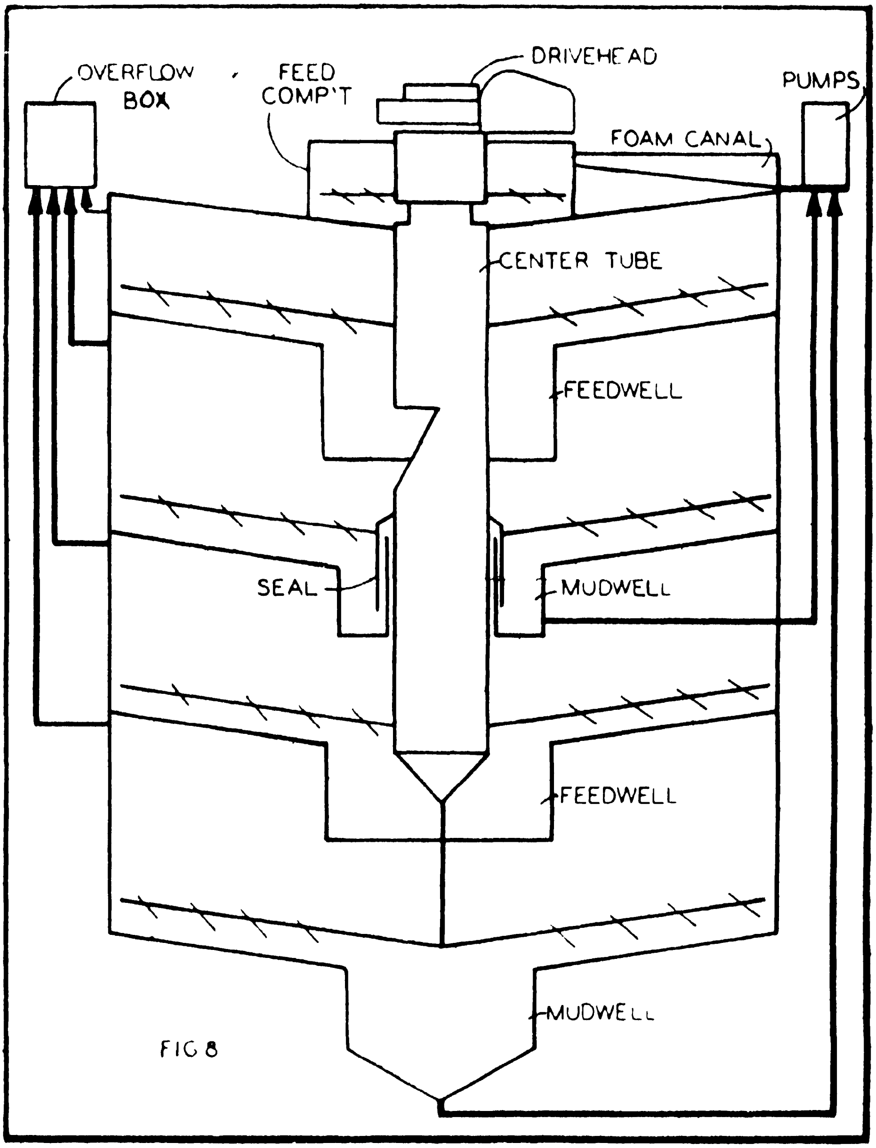


FIG 8

Foam removal is particularly important. The more fine solids that are skimmed at the top the fewer to be removed later by sedimentation. Another point of perhaps greater but not generally recognized importance is that foam, if not removed, will harden and build up. It will eventually plunge carrying with it large amounts of entrapped air subsequently released in the settling compartments. When this occurs, overflow turbidity increases sharply and excessive gassing of the vent pipes is noted. It is thus important to ensure that the liquid level in the feed compartment is at the proper height so that skimming of foam into the foam canal is as effective as possible.

4. *Centre Tube*

A centre tube is employed to deliver feed to the two internal feedwells. It is equipped with two inlets flush with the bottom of the feed compartment and is divided vertically to ensure equitable feed distribution. This same tube carries the mud scraper mechanisms and the entire assembly rotates continuously. The top of the tube is attahced to a drivehead which in turn rests on structural supports spanning the top of the clarifier. Because it is not necessary to extend the entire tube beyond the lower feedwell, the lowermost mechanism is attached to the tube by a shaft. A seal, formed by a tray extension and a tube extension, permits mud accumulation in the intermediate mud compartment.

5. *Overflow Box*

Overflow can be controlled by means of valves,swing pipes or sliding sleeves. Experience has proven the latter method to be most satisfactory. A recent refinement has been the installation of weirs in the overflow box to measure the individual compartment overflows, thus ensuring that all compartments are evenly loaded.

6. *Mud Extraction*

Withdrawal of mud can be either by a simple gravity overflow with an adjustable sleeve or by means of pumps. Experience not only in cane juice clarification but also in hundreds of other applications has clearly demonstrated that the diaphragm pump is the most satisfactory for this purpose. In an effort to reduce the capital investment a gravity overflow will often be specified. While this method can work quite well, it can also be very erratic and it is possible to discharge large quantities of thin mud and to overflow the receiving tanks before an abnormal flow is noted.

Pumps, on the other hand, are a more positive and precise means of controlling mud withdrawal. This is particularly desirable in this type of clarifier because accurate apportioning of the load and mud withdrawal in equal proportions from both thickening compartments will ensure maximum utilization of capacity in each section of the unit. During runs in which grinding rate and cane type are relatively constant, pumps, pre-set to maintain the proper mud level, require little supervision. It is generally agreed that mud pumps are well worth the additional initial investment.

7. *Accessories*

To complete the picture, the following accessories form a part of a well designed clarifier :

1. Good insulation
2. Air venting pipes
3. Mud sample cocks
4. Drain piping and valves
5. Sump tank
6. Auxiliary pump, piping and valves for liquidation and circulation.

8. *Materials of Construction*

For the most part, ¼″ steel plate has been found to be a very satisfactory material of construction. Units of this construction have been in operation for over 30 years. Brass is recommended at a few points—air vent piping, mud sample cocks, foam blade hinge pins, mud squeegees and overflow sleeves. Tankside plates can be welded but it is difficult to weld tray segments so that they will not buckle. Although a proper weld is possible with sufficient care, riveted trays are usually preferred especially in larger diameter units.

CONCLUSION

The clarifier design outlined is based on a research programme conducted in many factories under varying conditions over a four-year period. Two years of preliminary study led to development of a prototype which was subsequently modified to the present final form after an additional two years of investigation. Concurrent studies on the fundamentals of sedimentation carried out in many other fields led to a better general appreciation of the basic factors involved in cane juice clarification.

The net result has been the demonstration beyond doubt that juice can be clarified using a unit at least 30% smaller than the conventional type, with equal results. Thus both capital investment and the losses generally associated with the clarification process are substantially reduced.

REFERENCES

1. Schmidt, N. O. 1953. "The settling of defeacted sugar juices", (*Proceedings, Eighth Congress*, ISSCT p. 729.
2. Talmage, W. P. and Fitch, E. B. 1955. "Determining Thickener Unit Areas", *J. E. C.* Vol. 47, p. 38.
3. Kynch, G. J. 1952. *Transactions Faraday Society* Vol. 48, p. 161.

In the absence of the author Mr. Jenkins presented the following paper.

Paper

TECHNOLOGY OF CONTINUOUS CLARIFIERS

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INTRODUCTION

Almost any tank of any shape or size could be made to perform the functions of a continuous clarifier provided there is a treated juice inlet, a clear juice outlet and a mud withdrawal connection. But the efficiency with which a particular arrangement may perform and its capacity, will depend very largely upon the skill with which the designer has interpreted his observations on the phenomenon of the subsidation of mud particles in cane juice. When such particles are allowed to separate in an intermittent defecator, the main disturbing factor which may come into play is the buoyancy imparted by convection currents. If these are absent, then the classic conditions of static subsidation are present. An automatic sizing of the mud particles takes place in the mud bed since the larger particles settle first and form the lower layers of it. When convection currents are present, then something akin to the operational conditions in a continuous clarifier are to be seen. In a continuous clarifier, the treated juice flows in a more or less horizontal direction across a tray surface towards the juice outlet. During its passage, it sheds the precipitated mud particles whose tendency is to subside in a vertical direction, were the juice static. The resultant of these two velocities and the length of path of flow decide whether the juice arrives at the outlet, free of suspended material or not. The smaller the particle and the more hydrated it is, the less tendency there is for it to settle out while its vehicle is in horizontal movement. So that in continuous clarifiers, juice, or vehicle, velocities and particle size are of prime importance. A clarifier designer will therefore arrange for the rates of flow to be such that a critical value is not exceeded and he will endeavour to provide whatever means he may to ensure optimum particle size.

FACTORS AFFECTING CAPACITY

(i) *Floc characteristics.* The difference in specific weight between the particles precipitated in treated cane juice and the mother liquid is comparatively small. The liquid is in movement, the whole time that subsidation is taking place. Hence a large sized, well-formed floc will allow of a higher velocity of flow of the mother liquid than a small, fragmented or degraded floc. The maximum velocity, or volume of throughout, which can be allowed in a particular machine, consistent with the desired attributes of the clear draw-off is governed by the rapidity with which the floc settles.

The physical characteristics of the flocs, upon which the performance and capacity of a continuous clarifier depend so much, are firstly inherent in the juice from which it is derived. No clarifier however well designed can settle a floc which will not settle. Such cases are occasionally encountered. In one notable example, a well lagged and covered defecator full of hot treated juice showed no signs whatsoever of subsidation taking place after 12 hours. Thus a comparison of clarifier capacities in terms of size or area and throughput must be thought of in relation to the particular character of the floc which it is sort to remove.

A juice which has been heated and to which chemicals such as lime, phosphoric acid and perhaps one or more of a host of others have been added, contains at first an evenly dispersed precipitate of small floc particles. If stirring action is applied, one of two effects will take place. When the velocity of the stirred juice is above a certain value, which cannot be defined, the flocs will collide, adhere and, due to their lack of mechanical strength, then become fragmentated and torn apart again. The process is repeated an infinite number of times until the stirrer is stopped. When this takes place and the velocity of motion lessens, the second effect can be observed. If the initial velocity of stirring is below a certain value, or after higher speed stirring has been stopped but the liquid is still in motion, collision takes place, adhesion takes place and the strength of the floc can withstand the tearing action. Floc size increases by coalescence in both cases, with the difference that if high speed stirring had first been applied, then small fragments of degraded floc will be present as well as the large agglomerated ones. Fragmented floc is very difficult to separate in a moving decantation system because of its physical condition. This is the reason why most clarifier manufacturers provide a part of the volumetric capacity of their machine as a flocculating chamber. The stirrer gear therein may be elaborated to incorporate a means of multiplying the chances of collision of the flocs in the incoming juice. Woodcock (7), for example, refers to the use of vertical vaned panels for this purpose. The flocculating chamber therefore has an important effect on throughput capacity. Such a flocculating zone should be so located that it is within the body of the clarifier and immediately preceding the subsidation zones. The necessity is then removed of having to conduct the floc-bearing conditioned juice to the settling areas in pipes at velocities measured in terms of feet per second. Velocities in flocculating zones are measured in feet per hour and are those which encourage a slow rolling motion which brings about gentle collision with adhesion and build-up. The start of this process takes place at the liming station, and continues through the heaters. During the passage of the juice through the factory from the formation of the initial floc to its arrival in the clarifier, any step liable to cause fragmentation should be eliminated as far as possible, consistent with mechanical limitations. But since the juice must be passed through a heater and to do so must be pumped to get it from one place to another, it is logical to provide a zone of very low velocities within the clarifier so that the damage sustained during processing can be repaired as far as possible.

(ii) *Rate of flow.* Sufficient has been said in the preceding section to emphasize the importance of the floc characteristics in relation to capacity. If floc characteristics are optimum, then a machine can produce an acceptable clear juice at relatively high rates of flow across the tray. But since floc characteristics do vary so much, so does the capacity of a machine of any size vary in the amount of juice which it can handle satisfactorily. The critical velocity of cane juice undergoing subsidation is usually taken at about 40-50 feet per hour. This means that at velocities in excess of the critical, the floc will be carried along with the moving juice. A great deal could be learned from some fundamental studies on the effect of varying velocities of flow on the subsidation of particles of varying characteristics. The literature on continuous subsidation processes as applied to the settling of cane juice is remarkably barren on this point. And yet the highest allowable velocity of flow across the tray in relation to the floc undergoing removal is the basic factor which defines a machine's capacity or throughput. For example, in an experimental arrangement of single tray, rectangular subsiders in Trinidad, it was found (1) that with a juice flow across the tray of 11.9 ft. per hour, there was little appreciable decrease in turbidity at a distance greater than 7 ft. from the feed well. Since it was a a rectangular tank, the velocity was constant across the tray. This means that the velocity of 11.9 ft. per hour was above the critical one for the suspended material creating the turbidity. Hence critical velocities do undoubtedly vary with the size and type of particle in suspension.

(iii) *Return of Filtrates.* The return of filtrates here refers to the re-circulation of cloudy filtrate and of turbid clear filtrate from rotary vacuum filters through the clarification system.

Any re-circulation of liquid will obviously increase the velocity of flow into and over the settling surfaces at a given rate of throughput. In installations of marginal capacity, the return of the filtrates may quite easily be sufficient to preculde the possibility of proper settling of the juice itself. The great danger arises, however, in the fact that even under good conditions of operation, a rotary filter will seldom retain more than 70% of the insoluble solids fed to it. After mixing with bagacillo and after some of the mud particles have been drawn through the fine mesh screen on which filtration takes place, the structure of the resultant floc deteriorates rapidly and breaks up into fragments. Thus, when these filtrates are recirculated, a high proportion of the mud particles which leave the main clarifier are returned to it in a degraded condition. Subsidation of such particles is difficult at the best of times and their critical velocity is comparatively low. The mud thickening compartment becomes overloaded with an ever increasing quantity of degraded floc, except that which may be carried over in the clear juice outflow due to the low critical velocity. This snow balling of floc fragments can have a very appreciable effect on the capacity of the machine, especially if high standards are set forth clarified juice and mud. Turbidity tends to increase once the effect is established, muds are of lower density and mud volumes may become uncontrollable. In assessing capacities or rate of throughput it is therefore essential to recognise this fact and to allow for it in making comparisons.

(iv) *Length of path of flow.* The length of the path along which the juice flows from tray inlet to clear juice outlet is determined in a rectangular clarifier by the length of the tank and in a cylindrical clarifier by the radius of the tank. In the former, the velocity of flow is constant and hence the length of path must be sufficient for all particles whose critical velocity is above the velocity of flow, to be eliminated. If the critical velocity is below the velocity of flow, then the particle will be carried over. In the latter, a different condition arises along the path of flow. Here, the velocities decrease or increase as explained later in para 2 (ii). But the diameter or radius of the tray is also of interest. This is demonstrated in the appended tabulation where it is assumed that the initial entrance velocity is 10 feet per hour and the critical velocity of the floc is 40 feet per hour. The tabulation is calculated for a peripheral feed clarifier, but if it is read in reverse the figures will hold true for a central feed clarifier.

TABLE I

Tray diam. ft.	Volume of liquid cu. ft./hr.	Velocity of liquid (ft./hr.) at a diam. of 25ft.	20ft.	15ft.	10ft.	5ft.
30	942 (26.7 m³)	12	15	20	30	60
25	785 (22·2 „)	—	12.5	16.6	25	50
20	628 (17.8 „)	—	—	13.3	20	40
15	471 (13.3 „)	—	—	—	15	30

The volume of liquid is calculated on the basis of a depth on the tray of 1 foot.

It will be seen that in the larger tray diameters, the length of path is longer before the critical velocity of 40 feet per hour is attained. In terms of percentage distance, in each case the juice will travel about 75% of the radius before it exceeds 40 feet per hour. Thus in larger diameter clarifiers the shape of the mud bed will be much flatter than in the smaller sizes. There is no reference in the literature to this aspect of clarifier design and it would be of interest to know if any practical significance is attached to it. It may also be added, that in each of the four cases, and at the chosen velocities, at the centre 7% of volume is ineffective for settling purposes.

(v) *Standards of Capacity.* The capacity of a subsiding machine, in terms of cu. ft. per T.C.H. or sq. ft. settling area per T.C.H., should be defined in terms of the limiting factor. The limiting factor in turn defines the standard of acceptance for the product. In the ordinary jargon of the industry, this means the clarity and suspended material content of the clarified juice and the density of the mud. Thus, if means were devised of assessing numerically the settling characteristics of the floc and these were related to rates of flow and the resultant clarified juice and mud characteristics, then a purchaser would have a much better idea of what a machine would do under his conditions than a simple statement of his requiring so many cu. ft. or sq. ft. per ton cane per hour or per day. His standard for an acceptable clarified juice might be entirely different from someone else's. A start has been made by Schmidt (2) in expressing by a simple figure the static subsidation characteristics of cane juice flocs. Behne (3) remarks upon the lack of a suitable yardstick for judging clarifier efficiency. And it is unfortunately true, even in an industry so highly developed technologically as ours is.

It would appear therefore, that the ideal method of defining the required clarifier capacity would be (a) to specify the required standards of the clarified juice and mud, (b) to determine the subsidation characteristics of the particular juice, (c) to relate these characteristics to a critical velocity and (d) to calculate the required clarifier dimensions from these data.

Industry does not lack means of measuring turbidity or suspended material. Instruments such as the Luximeter or CSR Turbiditimeter have in fact been applied to the cane industry. But they are seldom used. What is wanted is a simple reliable indicating or recording instrument which is part and parcel of the clarifier station. Such are beginning to appear in other industries. Similarly, instruments used for density control, for example of lime, could be adapted to the indication or recording of mud density.

In terms of cubic capacity or square feet settling area per T.C.H., but not related to the attained standards of the products, Copp (4) and Behne and Jenkins (5) mention some values and a tabulation of low, average and high values has been recorded elsewhere (6).

If the installed capacity is high relative to the requirements of the particular juice or throughput, then time of residence will be unduly long. This can be calculated for any one set of conditions, and it is instructive to do so. Assume an installed capacity of 100 cu. ft. per T.C.H., 15° Brix mixed juice 100% on cane, which is equivalent to 34 cu. ft. (0.96 m^3) mixed juice per ton cane. Suppose the clarifier is such that :

20% of its volume is occupied by a flocculating compartment.

35% of its volume is occupied by a mud thickening compartment, leaving 45% of its volume for settling.

100% equals 100 cu. ft. (2.83 m^3) handling 34 cu. ft. juice per hour.

All the juice passes through the flocculating compartment, hence retention time is 20/34 or 0.59 hrs.

All the juice is assumed to pass through the settling zones, hence retention time is 45/34 or 1.32 hours.

15% of the mud laden juice passes to the mud thickening chamber, hence average retention time is 35/34×0.15 or 6.86 hrs.

Since, however, juice is always drawn off from the mud compartment, it is more than probable that the actual time taken to thicken mud would be longer than 6.86 hours. The times quoted refer only to the stated conditions which are assumed and arbitrary.

Referring back to Table I, the area and volume of liquid data can be presented in another form :

TABLE II

Tray diam. (ft.)	Tray area (sq. ft.)	Cu. ft. juice per hr.	Sq. ft. per cu. ft. juice/hr.
30	706	942	0.749
25	490	785	0.624
20	314	628	0.500
15	176	471	0.373

This means that when a velocity of 10 feet per hour at the periphery, either inwards or outwards depending on position of feed, is chosen then under the assumed conditions, larger diameter trays will offer more settling area per unit volume of liquid than smaller diameter trays. Similar relative conditions would of course obtain at other chosen minimum velocities. It is, however, a point in favour of larger diameter trays. Conversely, for the same sq. ft. settling area/cu. ft. liquid ratio, larger diameter trays would allow of a higher velocity of flow resulting in a greater relative throughput. This in turn would reduce the retention time, as discussed above.

TYPES OF CONTINUOUS CLARIFIERS

(i) *Direction of flow.* Continuous clarifiers may be classified into two main types in accordance with the direction of flow of the juice therein. In its simplest form the counter-current flow type, upon which principle most of the successful designs are based, provides for the incoming treated juice to flow to the juice outlet and in so doing to shed the precipitated and suspended material by subsidation. The lower layer or mud bed thus formed flows back counter to the treated juice and is withdrawn. The mud outlet is therefore in about the same vertical plane as the treated juice inlet. In the parallel-current flow type, both the clear juice layer and the mud layer flow parallel to each other, and the mud outlet is in about the same vertical plane as the clarified juice outlet.

While it is true that successful parallel-flow type clarifiers have been designed and operated, general experience reveals that the counter-current types are more consistent under the varied conditions of the industry in producing the desirable mud-thickening action. The relative amounts of suspended material present in the clear juice outflow of the two types is controversial.

The reason for the improved mud-thickening action of the counter flow type is that a sludge bed thickens more rapidly when the particles forming it are induced to flow counter to the liquid in which they are suspended. Such a system is capable of elaboration, and is well established in industrial technology.

Again, in the counter-current type, the incoming treated juice enters the subsidation zones through a cloud, curtain or bed of heavily floc laden juice. During its passage through it, light highly hydrated suspended particles such as bagacillo or trash or degraded floc come in contact with the mass of mud particles and may be entrapped. In a parallel flow type of machine, such is not the case. The treated juice separates into clear juice and mud in a straight-through flow. There is no contact between the incoming feed and the floc once it has separated from the main body. Removal of light suspended material can only take place by the ordinary processes of subsidation.

Each type of clarifier as defined above contains variations as to the points of entry and draw-off and so on, which are discussed in later paragraphs.

(ii) *Shape of tank.* The shape of the main tank is either rectangular or round. In all clarifiers, the juice outlet is remote from the juice inlet. Thus in rectangular tanks, the velocity of flow across the tank is constant. In round tanks, the velocity varies. There are three cases (a) The juice inlet is diametrically opposite the juice outlet in which case the velocity increases and then decreases, (b) the juice inlet is at the periphery and the outlet at the centre, in which case the velocity increases to the outflow and (c) the juice inlet is at the centre and the outlet at the periphery in which case the velocity decreases to the outflow.

Most round tank clarifiers belong to (b) or (c). In one case the zone of higher velocities is situated where the juice has or should have discarded all the suspended material and in the other case the zone higher velocities occurs where the juice is heavily floc laden. In either case at some point along the path oı travel (see Table I) juice velocities must exceed the critical value and before or after that point, subsidation either cannot commence or no more will take place. The critical velocity for large flocs is higher than that for small ones, hence with a centre feed machine there will be a classification of floc sizes as the liquid travels across the tray at an ever decreasing velocity. In the peripheral feed machine, the whole bulk of floc laden liquid starts at the lowest velocity value and then undergoes a slow acceleration. Hence there is probably a mass subsidation at the entrance to a tray or in the annular feed channels. If, however, a particle is carried into a zone the velocity in which is greater than its critical one, it must be carried over in the clear juice out flow.

(iii) *Number of trays.* A single tray unit is a self contained unit in that it is not only equipped with the basic requirements of juice inlet and outlet, but it must also be provided with the means for thickening mud. A multiple tray unit is usually designed so that there is only one mud thickening chamber to serve the multiplicity of settling areas situated above it. A recent multiple tray design of which no performance data have been published yet, provides a mud thickening zone for each pair of trays and in which there are usually two pairs or four trays in the unit. Apart from the floor area and other constructional considerations, all designs of the past twenty years have embraced the multiple tray principle. Unless some special provision is made to channel the separated sludge from the upper trays direct to the thickening compartment, it can be seen in counterflow type clarifiers that the proportion of suspended floc in the feed to the lower trays will gradually increase. Thus it is usual for the number of trays to be five or less, in order to obviate overloading the mud thickening or lower compartments with too high a proportion of insoluble precipitated material. The relationship between the capacity and hence the residence time in the settling zones and of the thickening zones is important. The requirement vary widely and partly explain the varying performances of a machine with juices of different types.

SCUM REMOVAL

Some of the particles precipitated in treated juice together with some of the suspended material rise to the surface to form a scum. Provision must be made to remove this scum prior to the start of the subsidation process otherwise the scum particles will be carried over in the clear juice outflow.

In one design, the scum removal gear is elaborated into a steam heated feed box to induce flotation of the particles, which are then removed by a scroll, The action is more positive than in most of the other methods and the principle is worthy of more attention. It is basically sound to add a means of inducing the flotation of light particles prior to subsidation, because the system is then purged of particles which will not settle.

Another method is to provide for scum removal outside the clarifier and prior to the introduction of the juice to the subsidation zones. This is not too successful a method as control is difficult in practice and some of the lighter entrapped particles may be released in flowing at fairly high velocities to the juice distributing wells.

A typical scum removal device of another type is one illustrated by the patent of Coulter (10). It takes the form of surface skimmer blades which sweep the scum to a canal for removal. This type is also difficult to operate satisfactorily because floating scum-forming particles tend to accumulate on the upstream side of the gutter.

It is conceivable that, by paying more attention to scum removal, the small highly hydrated and fragmented particles which will or would float could be eliminated almost entirely before the body of juice and precipitated material enters the flocculating chamber or subsidation zones. This would result in a mud bed of larger average particle size with all the benefits which are derived therefrom. In a continuous subsidation process, it is the " marginal " particles which limit the critical velocity of flow and control the quality of the clear juice. If these were in fact eliminated by some simple and practical means, higher rates of flow could be envisaged for any predetermined standard of acceptance of clarified juice.

JUICE INLET

(i) *Point of entry.* The point of entry of the hot, treated conditioned juice on to the settling surfaces will depend upon the shape of the tank and, if a round one, whether peripheral or central feed. This has been discussed in para. 2, (ii).

(ii) *Distribution of feed to settling surfaces.* In an installation of more than one unit, it is of obvious importance for each unit to receive its proportional share of the juice to be settled. An ordinary distributing manifold is not sufficient. A means of positive regulation is necessary. Webster (11) describes such a method comprising a distribution box with 3 weirs fitted with sliding horizontal gates for adjusting the proportion of juice going to 3 subsiders. The arrangement is such that the proportioning is not affected by changes in rate of juice flow. This ensures that one unit is not overloaded in relation to the others. Such a device should be part and parcel of any multiple unit station and especially so if the performance of clarifiers of different types or designs is to be compared.

Once in the clarifier, the next task is to see that each tray receives its proportional share. This is regulated to some extent by the rate of draw-off from the tray, but pecularities in design might be such that undue high velocities might exist in certain parts of the machine.

Diaz Compain (12) provides deflectors in the feed channel of a peripheral fed clarifier so as to proportion the solids entering each tray. Bach (13) suggests a number of pipes hanging from a launder round the periphery so that the juice is introduced over a substantial depth and at a number of points. McHugh & Weber (14) patented a means to provide feed channels of ample cross section to the different clarifying compartments of a centrally fed unit. Lasseter (15) has a patent for a similar device.

(iii) *Path of flow over settling surfaces.* In the central feed machine and in a peripheral feed machine when the juice enters the tray from all points round its edge, the path of flow must be radial. Thus each arc of the tray surface is evenly loaded. In some peripheral feed designs, the juice is introduced to the settling areas at two or more points either downwards, inwards, outwards or tangentially. Such a means produces disturbing eddy currents which may result in relatively stagnant zones on parts of the tray. On the other hand, such eddy currents provided they are not too strong, may produce an agglomerating action and help in building up floc size. But it is considered that the possibility of stagnant zones is of more importance. A straight through flow rectangular tank is more likely to give an even loading of the settling surfaces, because of constant velocity of flow all along the path.

JUICE OUTLET

(i) *Point of draw-off.* In central draw-off designs, the clarified juice is withdrawn at the point of highest velocity. There is no choice as to where the pipe should be located. In peripheral draw-off designs, it is at the point of lowest velocity of flow. In single tray, radial flow, peripheral draw-off units, it is usual to provide a weir round the whole circumference, and the same principle can be applied to the spiral flow type. Discussion arises when the multiple tray peripheral draw-off design is considered as to whether the clarified juice should be taken off at a relatively few points or whether a multiplicity must be provided. It is thought that the former leads to channelling and therefore stagnation and to an uneven load on the tray surfaces. Waddell (16) examined this aspect. He increased the number of draw-off points from 3 to 6, 9 and then 12 and finally introduced a ring with perforations. He claims that by so doing, channelling and turbulence are decreased and settling efficiency increased.

(ii) *Regulation of rate of draw-off.* The amount of clear juice drawn off from a clarifier is equal to the volume of feed less the volume of mud. Thus a means of regulating the total outflow is superfluous. It must be done by regulating the inflow. In multiple tray units, however, means are always provided for regulating the proportion of outflow from each tray. This may take the form of butterfly valves, but more often of sleeves, the height of which can be regulated by a threaded hand wheel. In the former design, the overflows from the different compartments are set at the same level. The butterfly valves act as throttles. With the latter, the head of the flow can be changed at will and is a more positive and delicate contrivance.

It is necessary for proper operation that the draw-off regulator from each tray should be a fairly sensitive one. The reason is that in practice there are small differences in head due to friction, temperature and so on, of the juice over the draw-offs from the different trays. In order to obtain the best performance from each tray, it does not necessarily follow that each will discharge the same quantity of clear juice. At present, the setting of the rate of draw-off from each tray is probably done by trial and error or observation. It can vary with juice type in the same day at the same factory.

(iii) *Balancing flow from individual trays.* Under practical operating conditions it is therefore often necessary to alter the proportionate rates of flow from the different trays. Until recently, no clarifier manufacturer supplied the means of measuring this as standard equipment for his machine. Consideration has been given for some time as to the best method to use for such a purpose. It is not necessary, but it is desirable, that the relative flow indicator should be calibrated in units of quantity. A weir or V-notch would probably be the easiest, but development might show that a simple U gauge, or a Rotameter would do just as well. A device such as this could be made to yield a considerable amount of useful information and to lead to a better insight into the conditions which exist within the body of a clarifier. This is another aspect of continuous clarifier design which requires further study.

MUD THICKENING AND MUD REMOVAL

(i) *Mud bed level indicators.* A positive, simple and rapid means of determining the level of the mud bed in the thickening compartment is a most essential piece of ancillary equipment because without it, intelligent operation of the filter station is impossible. Some designs provide simple test cocks, another one incorporates a swivelling, calibrated test pipe, which is better. Information regarding depth, shape and consistency of the mud bed is used to control the rate and quantity of mud removal. Mud depth may vary in various parts of the compartment with rate of draw-off. Cases have been observed when the draw-off of mud has resulted in a rupture of the mud bed and the appearance at the mud pump of cloudy clarified juice although the indicator showed several inches of mud to be present at the periphery.

(ii) *Mud thickening*. Mud thickening is the result of time and motion, which implies space or area. Thickening is brought about by a crowding together of the mud particles. The bed becomes compacted so that the density of population of the particles increases. Conversely, the space or capillaries between the particles decreases in size. Thickening can be brought about by gravity and one manufacturer provides a large steep conical mud thickening compartment, with the draw-off at the bottom. As the particles descend the inverted cone, so the cross sectional area becomes less and a thickening action takes place. In other designs in which the bottom of the mud compartment is flatter, but still slightly sloping, the arms of the stirring gear carry a series of squeegee scrappers which gently urge the mud particles towards the point of draw-off. In so doing, the particles rid themselves of the liquid in which they are suspended. Triggs (8), Weber and Geissler (9) and others have obtained patents for thickening gear of this nature. Some manufacturers provide a second but smaller diameter tray in the thickening chamber. This increases the area on which a thickening action can take place and also positively isolates the inlet or clear juice outlet from the point of mud draw-off.

The object of mud thickening is to reduce as much as possible the volume of sludge to be handled by the filters. In cases where filtrate is recirculated, recirculation losses are likewise reduced, and washing is more effective.

(iii) *Mud removal*. Mud removal takes place in two stages. The first is to move the sludge layer from the settling areas to the thickening compartment, and the second is to remove the thickened mud from the clarifier itself.

The use of the term " stirrer gear " is really a mis-application because it implies the use of a meachanism to mix together two or more ingredients or to maintain a suspension in that state. In a clarifier, the object of the stirrer gear in the settling compartments is to move the precipitated mud particles in order to avoid the building-up of a stagnant layer or crust on the tray surface. Settling trays are always sloping to a greater or lesser degree and the mud is discharged from the individual tray at the lower end. The stirrer gear is designed to 'nudge it forward. In its simplest form, it consists of two or four radial arms to which a length of chain is attached at either end. The action depends upon the chain maintaining contact with the metal of the tray. There is very little sweeping action. It is more of a lifting action so that the mud moves down the tray slope. The squeegee scraper type is more positive. Usually four radial arms are employed so that the scrapers on one arm are staggered with those on the next one, thus the whole radius is covered twice each revolution. The dual effect of preliminary thickening will also take place. Similar equipment is installed in the thickening compartment, the centre of which may be formed to the shape of a mud drum, from which the mud is withdrawn from the clarifier.

The final removal may be accomplished either by an inverted syphon pipe or a pump of some kind. In either case, the essential point is that means should be provided to regulate flow, with a minimum of disturbance to the structure of the mud bed. The actual rupture of the mud bed can occur if, for example, the pulsations of the pump are too pronounced, or if the pump displacement is too high for the rate of flow of the mud bed to the pump suction.

The actual regulation of the rate of mud removal offers several practical difficulties. The mechanics of the process are simple. What is referred to is to know at what rate the mud should be removed. Mud thickening is a time reaction. Muds thicken to different degrees in the same time, hence the removal of a constant volume per unit of time does not answer the problem. There is no rapid means of defining mud density, without resource to laboratory facilities, except the expressive and descriptive " scale of thickness " which has grown up in our industry. Most practical operators work on the principle of maintaining a mud level which experience has taught will yield a mud of desirable density and to assess the density visually.

CLARIFIER SANITATION

The sanitation of a clarifier depends primarily upon its freedom from stagnant pockets of juice and mud, and the efficiency of the mud scraping gear. It is a matter of design. During operation, stagnation manifests itself in producing abnormal analysis of clear juice and filter juice. Sometimes gas may be released. In terms of time and cost, as long as a clarifier continues to give a normal performance there is little point in liquidating it. After liquidation, there are always varying amounts of mud clinging to the horizontal, sloping or vertical surfaces, especially in the areas of low velocity. It is a time consuming job to clean them. Thus, one school of thought leans towards a liquidation at the end of each run or each pair of runs, and the other operates the machine as long as possible within the limits set out above.

In some of the steep sloping mud compartment designs, evidence of mud stagnation may be noticeable upon liquidation. This takes the form of the release of a quantity of sour smelling mud when juice from the bottom compartment is being withdrawn. It seems that unless some form of positive scraping gear is supplied, mud will cling to the inside of the cone bottom and can build up to a layer of appreciable thickness.

One manufacturer supplies an automatic steam valve which opens once each revolution of the stirrer gear. It's purpose is to inject steam at the lowest point of the mud bed to release any gases which may accumulate therein and to provide ' sterilization."

Probably the ideal arrangement, especially in the bigger factories, is to extra capacity when the need arises, and of (b) providing the means of using the units in rotation so that one of them can be liquidated on the run while another is filling. This empty one is then properly cleaned before being put on stream again.

CONCLUSIONS

It would appear that the technology of clarifier design has developed by borrowing ideas from other industries and applying modifications in accordance with observations made under actual crop conditions. This has served to produce some very useful machines for the cane industry. But there is still enormous scope for development research of a very fundamental nature. This work should include, for example, an evaluation of floc characteristics, the determination of critical velocities, the development of scum removal by flotation, the setting up of standards of acceptance for clarified juice and mud and so on. At present, it is almost useless to try and compare the work of one clarification station with that of another. Figures expressing capacity or area give no information as to juice characteristics or velocities, for example. There are wide gaps in our knowledge here. The literature is almost barren on some points. Real advances can not be made till these gaps are filled.

ACKNOWLEDGEMENTS

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REFERENCES

1. Davies, J. G. 1941. et. al. I. S. J. 43. 335.
2. Schmidt, N. O. 1953. Proc. 8th. I.S.S.C.T. 729.
3. Behne, E.R. 1942. I.S.J. **44**. 233.
4. Copp, E. M. 1938. I.S.J. 40. 467.
5. Behne, E.R. and Jenkins, G.H. 1940. I.S.J. **42**. 209.
6. Honig, P. 1953. "Principles of Sugar Technology " p. 567.
7. Woodcock, G.A.N. 1941. I.S.J. 43. 84.
8. Triggs, W.W. 1945. U.K. Patent 564355 of 8.12 42., I.S.J. **47**. 167.
9. Weber, W.C. and Geissler, W.E. 1942 U.S. Patent 2253542 of 26.8.41., I.S.J. **44**. 277.
10. Coulter, H.B. 1955. U.S. Patent 2681151 of 15.6.54., I.S.J. 57. 25.
11. Webster, J.H. 1954. 1955. Proc. 21st Q.S.S.C.T. 151. I.S.J. 57. 84.
12. Diaz Compain, J. 1947. Proc. 21st A.S.T. Cuba. 155.
13. Bach, N.B. 1950. U.S. Patent 2467003. I.S.J. 52. 165.
14. Mc Hugh, P.M. and Weber, W.C. 1945. U.S. Patent 2340132. I.S.J. **47**. 221.
15. Lasseter, F.M. 1946. U.S. Patent 2355875. I.S.J. **48**. 26.
16. Waddell, C.W. 1940. I.S.J. **42**. 350.

In the absence of the author Mr. Nicholls presented the following paper.

Paper

PRINCIPLES OF CLARIFIER CONSTRUCTION

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The intermittent clarifier or settling tank which served the industry for so many years and which in its later designs still does good work, is rarely supplied for new factories and is disappearing rapidly from existing factories, so this paper will deal only with the continuous clarifier. In essence this is a tank generally cylindrical in which the scums and muds are separated from the juice by gravity, the clear juice drawn off continuously and the muds concentrated then metered out.

The three most popular types work on the same principle and are regularly made in sizes from about 12′—0″ diameter to about 35′—0″ diameter. Special machines may sometimes be built outside this range. Inside each main tank is a series of trays dividing the clarifier into compartments. The number of trays varies between three and seven. Clear juice is drawn off from each compartment while the mud is scraped off the trays and allowed to fall into the bottom compartment for concentration.

Subsider or clarifier capacity naturally depends on the condition of the juice entering the unit. A maximum figure is 2½ hours average time for juice to pass through the tank. With very refractory juice this may be exceeded though this is not often recorded ; on the other hand a west Indian factory operated last crop with less than one hour's capacity in the clarifier with reasonably good results. To do this very careful supervision was required that is a uniform temperature must be maintained in the clarifier, mud discharge should be regulated to keep the mud as low as possible in the lower compartment. Another unit is being added which will, however, raise the capacity to one and a half hour's juice only.

Capacity may also be assessed from tray area and this seems the most logical method. With well designed machines the area varies between 25 square feet and 18 square feet per ton cane per hour.

The speed of juice entry and exit from continuous clarifiers has been the subject of careful study and figures established by the simple means of observing the action of settling in glass or perspex models—both under factory and simulated conditions in the laboratory. The figures given are those based on the experimental observation applied to actual machines in operation. Most of this work, with which the author is familiar, was done by N. B. Bach and relates to the clarifier with which his name is associated, so may not apply to all designs.

Juice inlet to main Clarifier 3 to 4 feet/minute.
Flow of juice across trays 0.06 to 0.09 feet/minute.
Juice withdrawal pipe speed 72 to 144 feet/minute.
Mud withdrawal 9 to 12.6 feet/minute.

Mud is concentrated by turning it over with scrapers—the rolling action seems to free some of the liquid so that the area has some importance. In one standard machine the bottom is steeply sloped which increases the concentrating area and helps greatly to increase the amount of clear juice drawn off when liquidating the tank.

The principles of continuous clarification as applied in practice may be best illustrated by description of a modern machine. The detailed data available to the author refer to a particular machine which embodies all the fundamental points.

The apparatus shown in Fig. 1 comprises a mild steel flash and liquor level regulating tank connected to the main subsider tank which is of mild steel,circular shape, with sloping conical bottom. Inside the tank is a series of trays sloping upwards toward the centre, each tray being provided with a chain scraper gear actuated from a central shaft. Similar scraper gear works on the conical bottom. Juice distributing and draw-off pipes are provided.

The control box has a simple butterfly valve for regulating the flow of juice from the outlets. As can be seen, the design is such that the position of the handle gives the operator an indication of the amount the valve is open. Sampling cocks are arranged over a trough which is covered by a fine gauge screen shaped to take test tubes. A cover is fitted which can be easily raised to examine valves, while a vent is provided to allow hot vapours to pass out clear of the operator.

The surface of the liquor is sealed from the atmosphere by means of a floating film of oil or other similar means and this stops surface evaporation of the hot liquor, thus avoiding heat loss and preventing the resulting uncontrollable radiation and convection movements in the tank which take place without the use of this seal. The volume of juice in the oil sealed tank would appear to be less than in other types as can be seen from Fig. 2. Heated juice is distributed around the wall of the tank, the main delivery being below the lowest tray. This regular entry of hot juice around the periphery of the tank keeps up the temperature throughout the apparatus, there being no radiation from the centre of the tank to set up currents where juice is drawn off. The outside of the tank, including the bottom, is also covered with insulating material.

The trays slope upwards toward the centre where the clear juice is drawn off at one point for each tray and the mud is swept gently off the trays toward the periphery, where the large area reduces the velocity, so that no mud is carried back by the incoming juice. The shaft turning the scrapers may run at about 4/5 revolutions per hour, but recent developments suggest considerably higher speeds.

As is well-known, gases which are largely CO_2 dissolved in the juice are present where large quantities of mud accumulate and which if not vented, will accelerate inversion of sugar in the liquid. This is not serious in intermittent subsiders where tanks are emptied at regular intervals, but may be appreciable where large volumes of mud accumulate, as in the continuous type of clarifier.

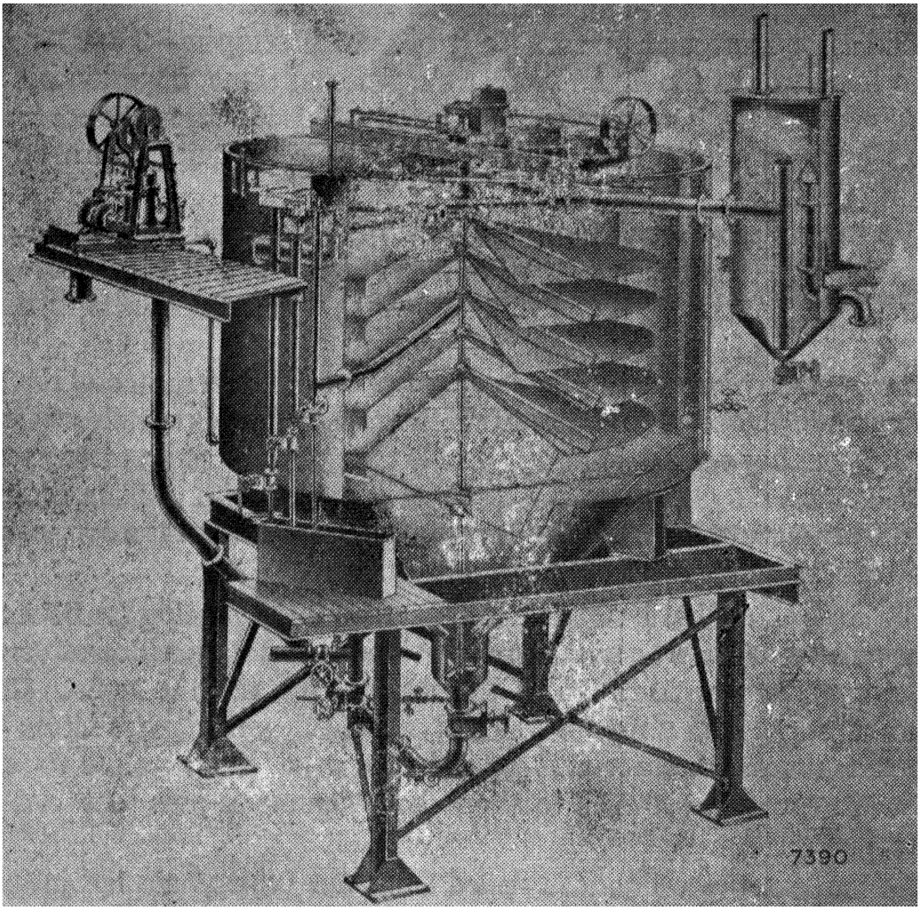

Fig. 1

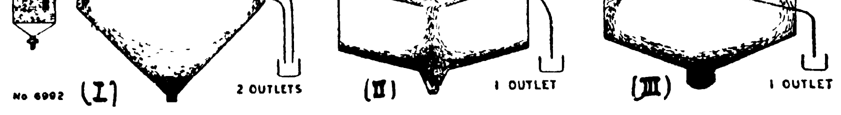

Fig. 2. Schematic drawing of oil sealed tank with 2 outlets for clarified juice ; juice inlet around the periphery with special tank for removal of scum (I).; juice inlet in the centre of the clarifier and juice outlet at the periphery (II) ; juice inlet at the periphery and outlet for clarified juice in the centre (III).

The risk of inversion may be reduced by the automatic introduction of steam at regular intervals. It has been found that the steam by raising the temperature of the juice mud mixture counteracts the effect of hydrostatic head in retaining CO_2 and thus frees accumulated gases, which rise to the top of the tank. To prevent accumulation under the cone trays, the trays are not fitted closely to the shaft, which allows gases to rise to the next compartment and so on until it is taken from the top compartment by a funnel through the film of oil on the surface.

The draw-off pipe in each compartment of the clarifier is placed at the focal point to which all clear juice rises, and one outlet drawn off uniformly and centrally from the point of optimum clarity.

The bottom of the clarifier is sloped at an angle of at least 45° giving a greater surface than a flat bottom on which the scrapers roll the mud over to concentrate the mud when operating and which allows a maximum volume of clarified liquor to be drawn off when liquidating the tanks at the week-end or during mill stops.

It is ncessary to have uniform temperature in the clarifier, so means are provided for keeping the contents hot should the mill be stopped for a short period and for re-heating should the clarifier be kept full during the week-end shut down. Silent steam blowers located on the bottom of the tank perform this service.

In Australia where long week-end stops are common, some operators withdraw the contents of the clarifier, cool to about 160°F. and return to the tank. This is reported to avoid inversion loss. Bullen notes that a reasonable temperature for holding juice over week-ends is 175 to 180° F. in British Guiana (I.S.J. Vol. 50, p. 261-262).

No surface scums enter the clarifier, as these are drained off in the liquor level regulating tank. The liquid entering this tank is separated from any vapour it may contain, and any scums which form are carried off at the overflow.

In the operation of continuous subsiders or clarifiers, it is essential that flow through the apparatus be uniform ; that is, the juice and mud overflow should be regulated to maintain pre-determined constant levels in the tank. The juice flow is easily regulated by raising or lowering the inlet level ; but the rate of flow of mud depends entirely upon the amount handled by the mud pump, where this is used for withdrawal. This pump should therefore be adjustable to allow very fine variations in output through a wide range. The pump can be of the single or two-throw type, and the rams are actuated by eccentrics on shaft carried on a framing of mild steel. The pump delivery may be adjusted by altering the stroke and this is done by the simple method of altering the throw of the eccentric. To do this a block is secured to the shaft and the eccentric sheave is moved on this block by small hand-wheel and screw. When the sheave is central with the shaft there is no movement of the rams ; movement can be given gradually by turning the small hand-wheel to push the sheave eccentric with the block. The degree of eccentricity governs the length of stroke. The level of mud in the tank is shown by means of continuously running outlets from the mud compartments, which are set at different levels.

Cleaning of tray surfaces must be done at regular intervals and is done by hand when the subsider is empty. The periods between cleaning varies greatly depending on the amount of scaling material in juice. Some machines run a whole crop while others have to be cleaned every two or three weeks.

In the absence of the author Dr. Doss presented the following paper.

Paper

FUNDAMENTALS IN THE DESIGN OF THE IBANEZ CLARIFIER

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INTRODUCTION

The working capacity of a clarifier is mainly governed by the settling rate of the juice handled.

The limit of working capacity is determined when the height of the cloudy juice zone, which fills the space between the mud and clear juice layers, can be held within stabilized dimensions to procure an almost constant thickness in the clear juice layer immediately on top, of such a magnitude that the relatively rapid flowing of clear juice through the collecting mouths of the draw off pipes cannot disturb the liquid at their vicinity and create turbulent movements, dragging cloudy juice into the draw off lines.

In leading mixed juice into a clarifying chamber of proper height the thickness of the layers of clear juice, cloudy juice and mud have to be formed according to before mentioned requirements; the value of thickenss of each layer could be 10 in. for clear juice, 20 in. for cloudy juice and 10 in. for the concentrated mud, the total height of liquid and mud being 40 in.

Supposing that the juice within the clarifying chamber, resulting from any type of cane and limed by the usual methods (not including the use of high cost chemical agents recommended to accelerate the juice settling rate), would have an average settling rate, the capacity would be 7.5 gallons of clear juice per sq. ft. of settling area per hour.

There are no mechanical means nor any methods which are able to increase this clear juice production; the settling rate of juice cannot be increased more than its actual intrinsic value, which depends on properties inherent to the juice flowing to the clarifier. For that reason we cannot take 8 or 10 gallons of clarified juice per hour where there are being produced only 7.5 per unit of time. It means that a clarifier with 3 or 4 compartments, having a higher volumetric capacity than others with 5 well distributed compartments, cannot produce more clear juice per sq. ft. of settling area than that with 5, because a juice volume per sq. ft. section and 40″ high, will produce only 7.5 gallons per hour as said before; any increase in the settling height will not affect the velocity at which solids in the flowing juice settle. The higher column would have only a thicker cloudy juice layer. The determining factor to fix the limit of maximum clarified juice capactity of a continuous clarifier with minimum volumetric capacity is the settling rate of the juice that is passing through it.

If the volumetric capacity of the clarifier is increased and the settling area is not increased in the same proportion, we will have a greater volume of juice within the clarifier but it will not produce more clear juice per unit of time than corresponds with the settling rate of that juice. Thus for a given area the juice will be held longer within a compartment. The minimum volumetric capacity relative to the settling area of one compartment, operated according to the settling rate of the juice will hold this juice for a minimum of time.

According to standard construction techniques clarifiers are provided with several processing compartments arranged each atop the other. This arrangement makes it possible to use the bottom compartment to increase the concentration of the muds, produced in each upper compartment and carried to the bottom one. This procedure is convenient because among other reasons it makes possible to unite the muds in only one compartment for further concentration.

The presence in the bottom compartment of all muds of the clarifier makes it necessary to provide additional space; the bottom chamber has to be somewhat higher than others and it requires special conditions when juices are settled producing large quantities of light muds.

This is the simplest and most rational way to handle great amounts of light muds produced in a clarifier, but it also introduce the difficulty that the mechanical means, generally used to clean the bottom tray, do not operate on light muds, because although these scrapers to carry some muds toward, the mud outlet revolving paddles are unable to carry liquids as light mud and this light mud is retained within the bottom compartment where it has the tendency to accumulate and reduces the clarifying capacity to an extent that makes the bottom compartment practically useless.

Another difficulty is that when juice stagnates in the bottom chamber the mass begins to generate gases, resulting from decomposition reactions, interrupting the operation of the preceding chambers, We have arrived at the following specification of the construction of a clarifier of a prefixed grinding rate :

SPECIFICATION PRINCIPLES IN THE CONSTRUCTION OF THE IBANEZ CLARIFIER

	British units	Metric units
Volumetric capacity per sq. ft. of settling area	30 glns /sq. ft.	1.2 m^3/m^2
Minimum dimension of height of sedimentation	40 in.	110 cm.
Minimum capacity of clarified juice per sq. ft. horizontal sedimenting area	7.5 glns./h./sq. ft.	0.3 m^3/m^2
Maximum peripherial speed of scrapers	5 ft./min.	153cm./min.
Maximum height of scrapers	8 in.	20 cm.

The arrangement of scrapers to move the settled mud on the trays towards the centre is given in Fig. 1.

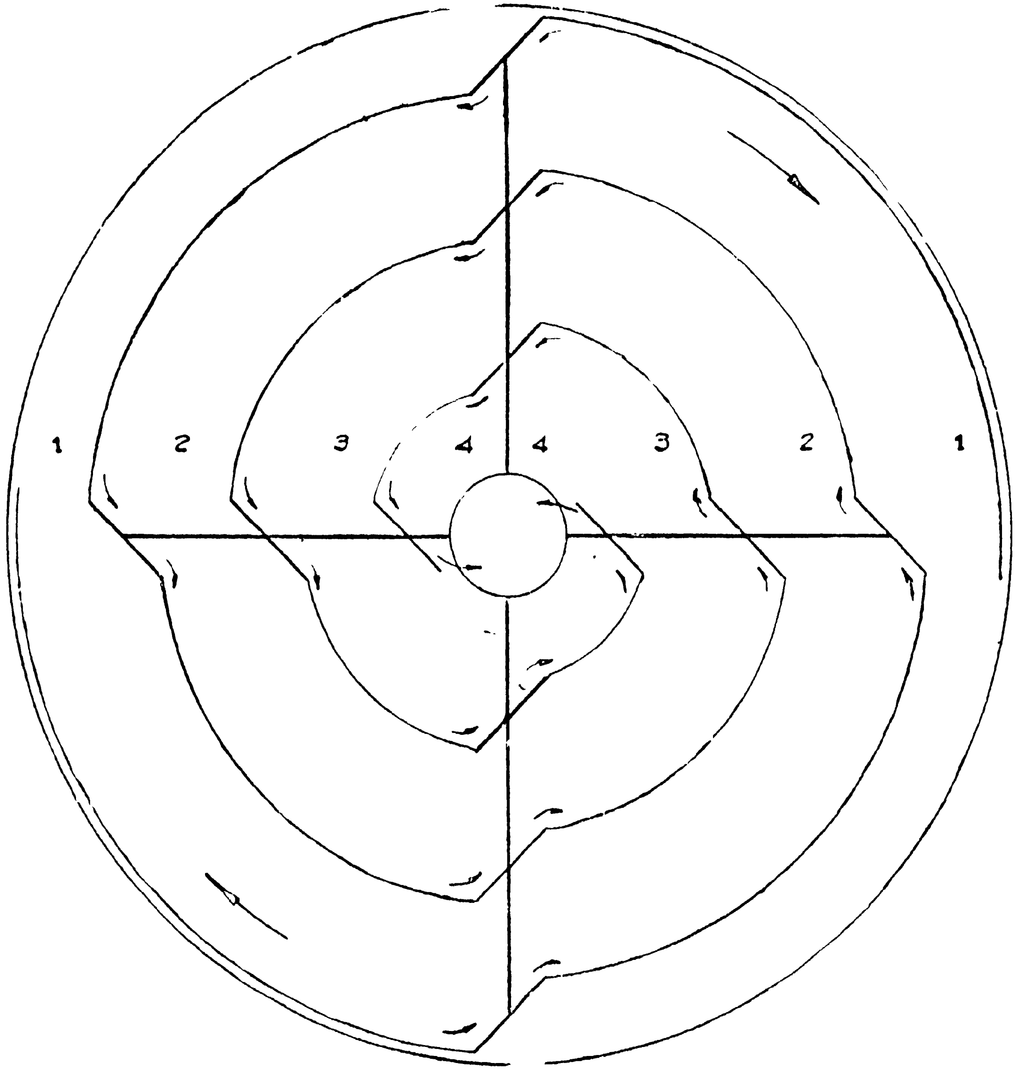


Fig. 1. Plan view showing the mechanical effect of mud scrapers.

In Fig. 2 a schematic drawing is given of the different juice levels in the bottom compartments for juices settling at a slow rate to a high density of the muds. With juices with good settling characteristics we obtain juice levels as given in Fig. 3.

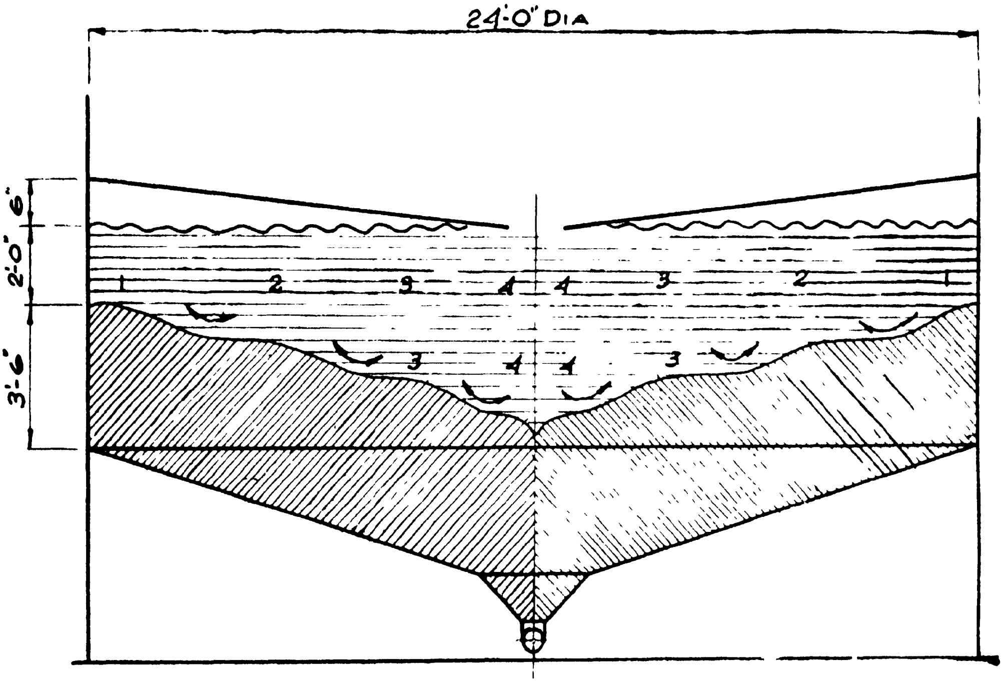


Fig. 2. Section view of clarifier bottom compartment showing the effect of scrapers with light mud.

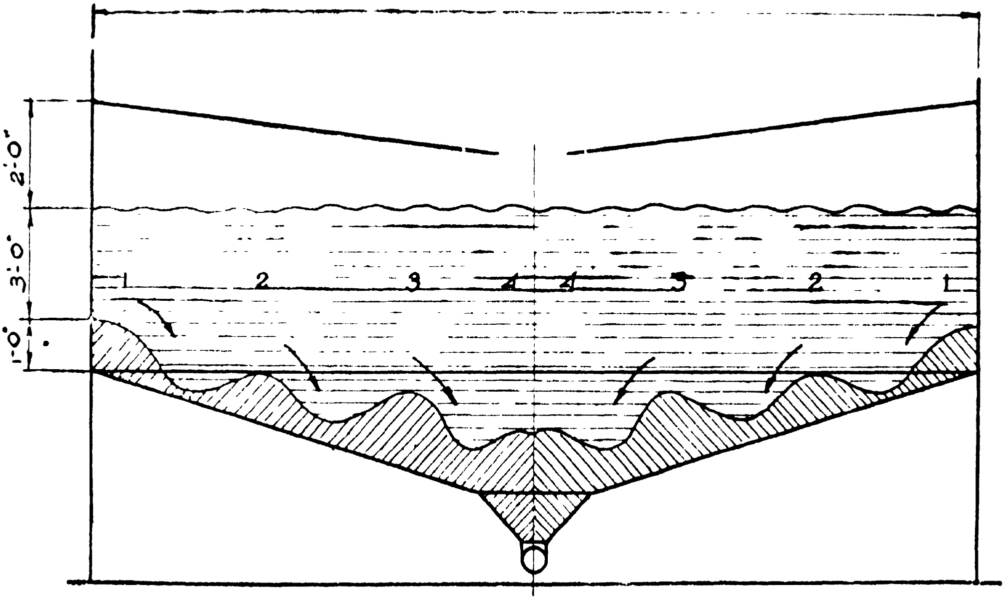
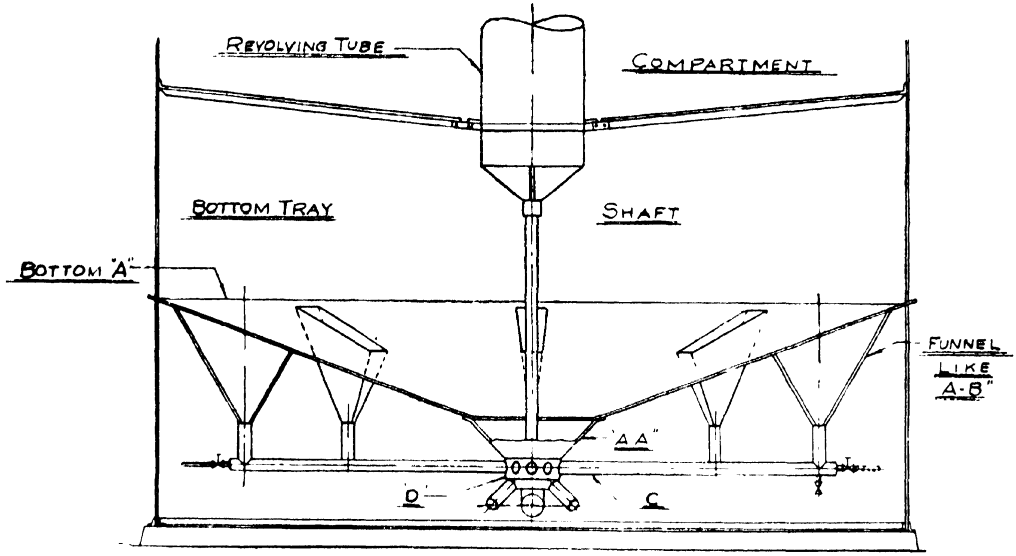


Fig. 3. Section view of clarifier bottom compartment showing the effect of scrapers with heavy mud.

To assist in the removal of settled muds at the periphery of the bottom trays an arrangement has been introduced as given in Fig. 4. This arrangement results in a lower level of the clear juice in the bottom compartment. The details of this design for the removal of muds from the peripheral zone of the bottom tray are given in Figures 5, 6 and 7.

FIG-4



Partial view of clarifier showing the specially arranged bottom with funnel type collectors and mud distributing rotary valve.

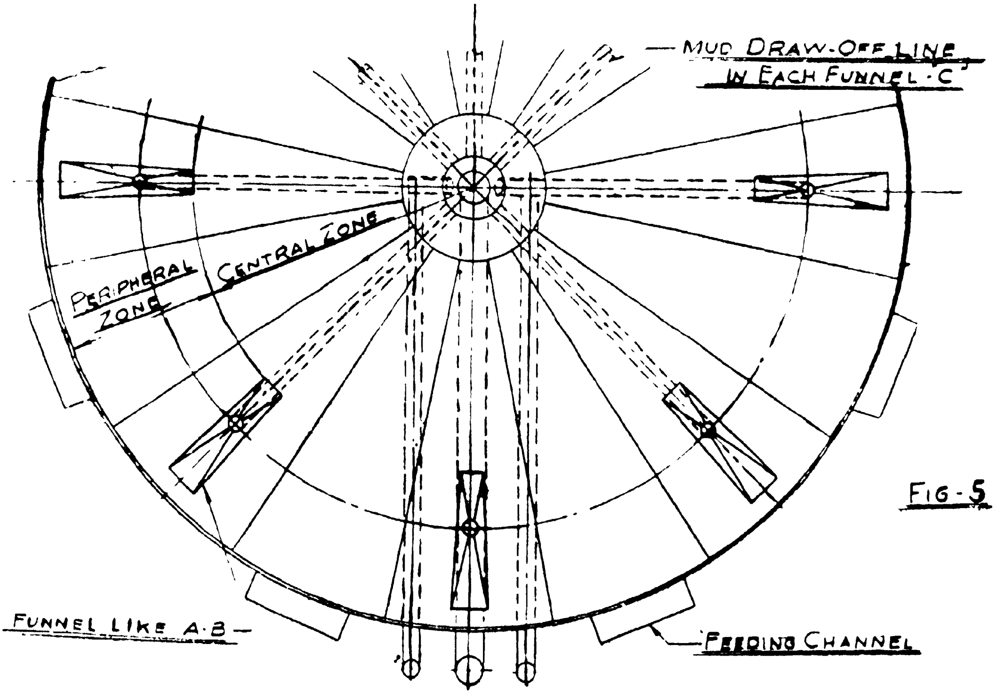
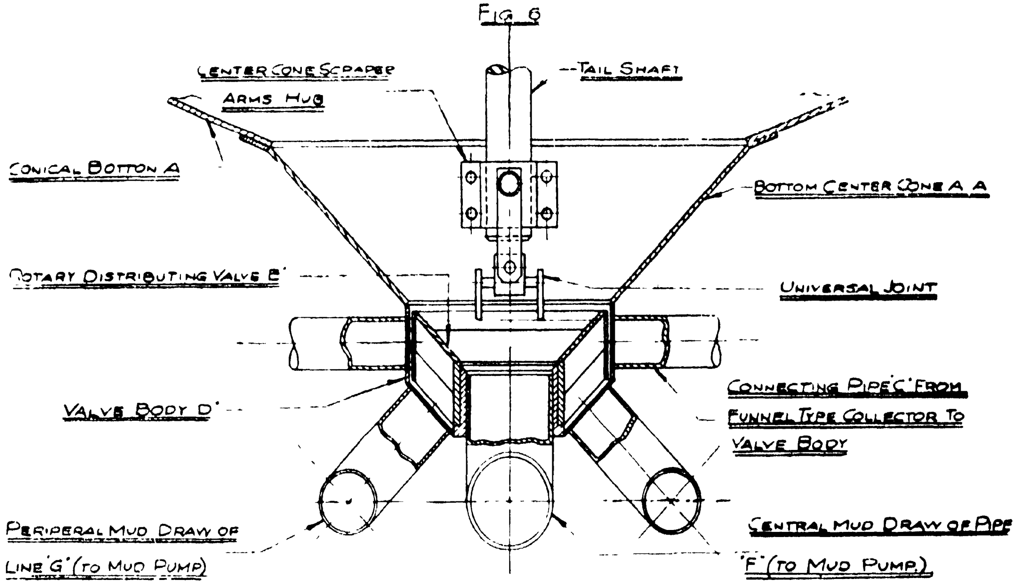


FIG-5

Plan view of clarifier conical bottom, showing funnel type mud receptacles spaced around the periphery of cone, to collect, the difficult to handle, light mud settled at said zone.

Fig 6



Section of Rotary Distributing Valve

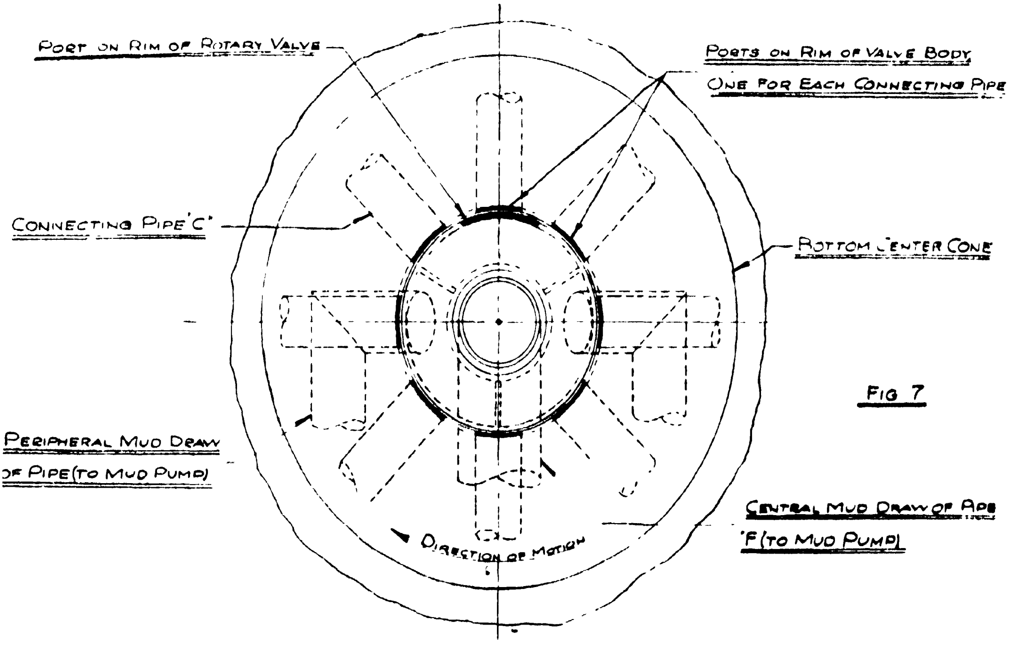


Fig 7

Plan View of Mud Distributing Rotary Valve

The effect of this arrangement for the offtake of muds at the periphery of the muds from the bottom tray is given in Fig. 8.

The relation between the settling area and the juice volume of the clarifier in operation is given in Fig. 9.

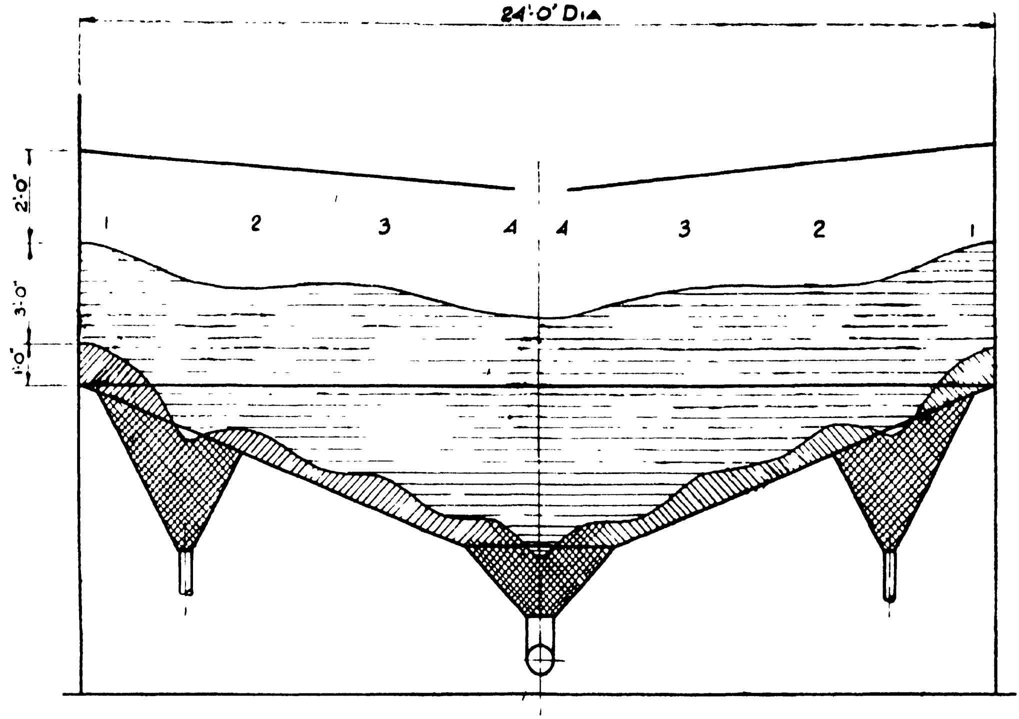
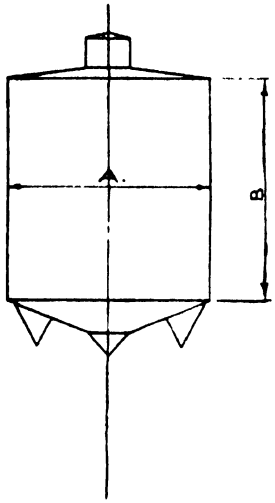


Fig 8. Section view of clarifier bottom compartment, showing the positive effect of funnel like collectors and scrapers with light mud.

Another feature in clarifier design is that in the upper part of the clarifier has been introduced a relatively small juice distributing tank with a stirrer to maintain a completely mixed raw juice. It is a well known fact that as soon as lime is added to the mixed juice that the flocculation begins. It is preferable that a part of the liming takes place in this distributing tank just before the juices enter the settling compartments. As with any kind of liming in tanks located at a certain distance from the clarifier, the large flocs are disintegrated by transporting the juices by pumps. The hot liming results in a better floc formation and if no additional stirring takes place, the result is that larger flocs are formed in the settling compartment and that a clarified juice of better quality can be produced. This system as it has been introduced is given in Fig. 10.

The distribution and inlet of juices in the clarifier compartments take place as follows :

The hot limed juice in the distribution tank on top of the clarifier, which can be agitated by a stirrer, enters the settling compartments via a number of vertical channels placed in the periphery of the apparatus, feeding each compartment at several points around the clarifier. The entrance for the juice to be settled in each compartment is constructed at the level of the bottom of each tray level.



IBAÑEZ CLARIFIERS

A	B	TRAY	TOTAL AREA	VOL.CAPACITY
12	13	3	339 3 Sq Ft	10,881 Gls.
14	13	3	461 7 "	14,806 "
16	17	4	804 4 "	25,299 "
18	17	4	1018 0 "	32,017 "
20	20	5	1571 0	46,502 "
22	20	5	1900 5 "	56,255 "
24	20	5	2262 0 "	66,956 "
26	20	5	2654 5	79,906 "
28	20	5	3078 5	91,123 "
30	20	5	3534 0 "	104,606 "
"IBAÑEZ" CLARIFIERS TYPE "TWO IN ONE"				
32	20	5	4021 0 Sq Ft.	119,021 Gls
34	20	5	4539 5 "	134,370 "
36	24	6	6107 4 "	180,779 "
38	24	6	6804 6 "	201,416 "
40	24	6	7539 6 "	223,172 "

Fig 9. Dimensions A and B in linear ft.

The clarified juice is taken out from the compartments in a number of outlet pipes placed around the commpartments close to the periphery at the highest level in each compartment. These pipes are connected to mains, leading the clarified juice through a vertical collecting pipe, conducting the clarified juice to the clear juice draw-off-box located on the top of the clarifier.

The removal of muds from each tray is done in the upper compartments via scrapers connected to the revolving central tube. The mud is moved from the periphery towards the centre of the apparatus. For each tray the central tube has an opening to discharge the mud to the bottom compartments.

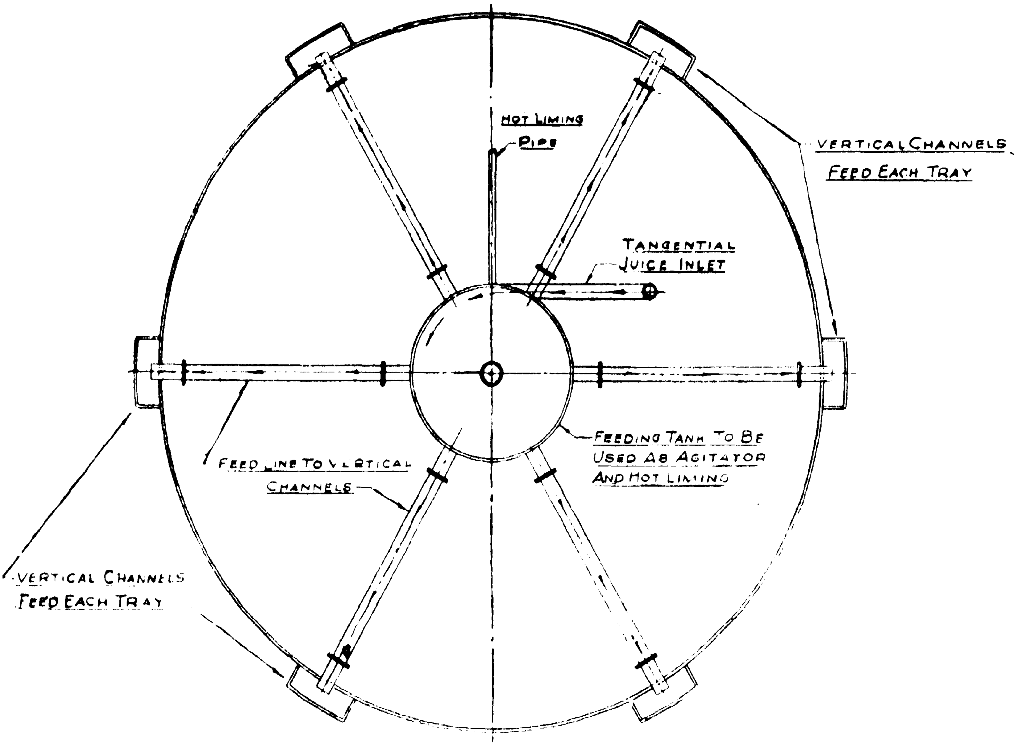


Fig. 10. Top view of clarifier with cover taken apart. Showing feeding and liming tank with radical distributing lines to vertical feed channels.

The central tube is divided vertically in as many sections as the number of trays existing in the clarifier. The mud of tray falls without any interference from each compartment to the bottom compartment. The muds taken from the periphery of the bottom compartments are removed via an independent pumping system through a revolving valve in the bottom independent of the central mud discharge system.

The variables that have been introduced in this type of clarifier are :

(1) the speed of the mud pumps ;

(2) the number of revolutions of the central tube and scrapers ;

(3) the hot liming in the liming tank on top of the clarifier.

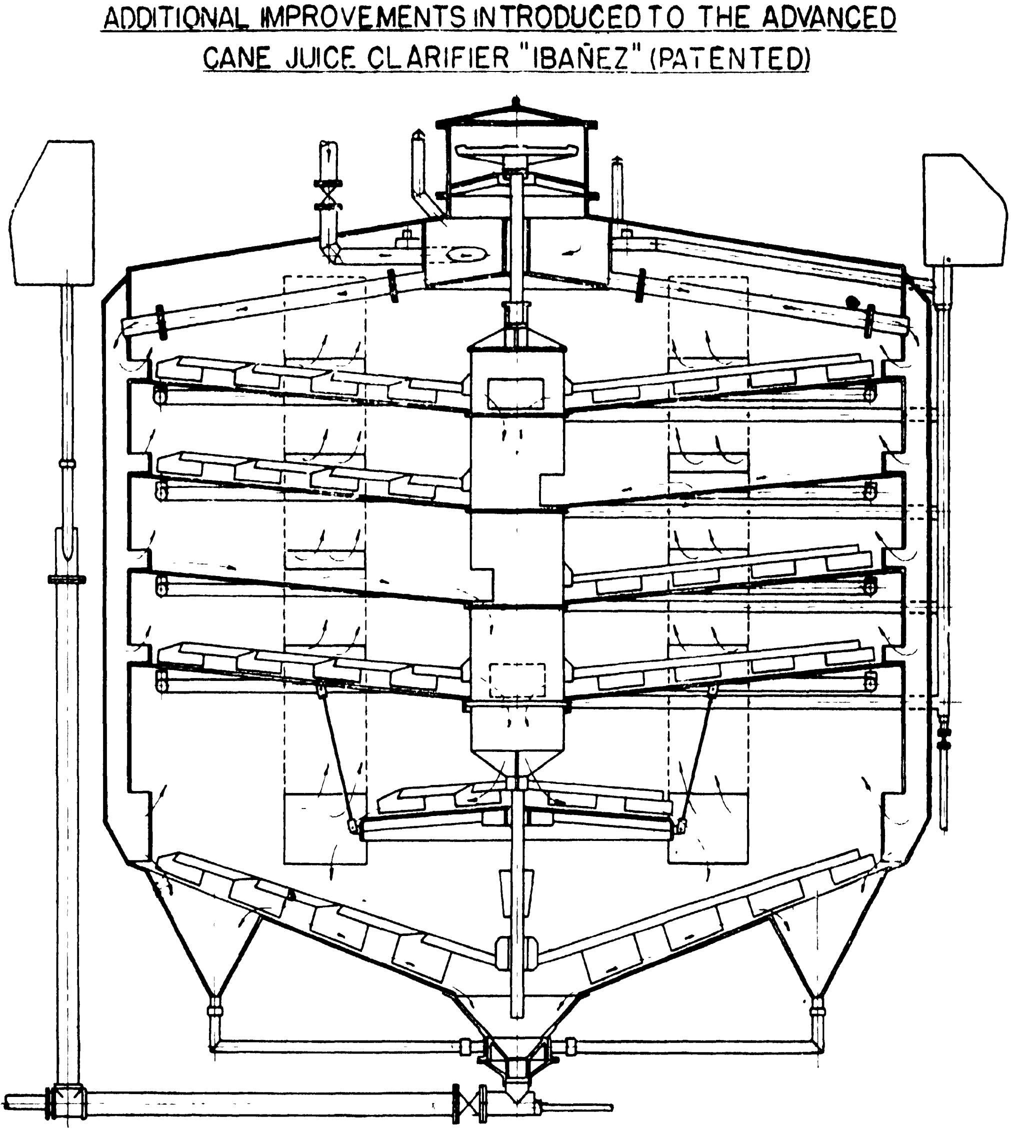


Fig. 11. Design of a modern Ibanez clarifier with 4 trays, enlarged bottom compartment, and off-take of the mud juice at the periphery and in the centre of the bottom compartment.

JOINT DISCUSSION

Mr. Constandse suggested the introduction of an additional plate to prevent disturbance of clear juice by the incoming juice flow.

Mr. sabi observed that it will be difficult to maintain such a plate clean. Further the entrance velocities are not great enough to create any disturbance.

Answering to another question of Mr. Constandse Mr. Sabi mentioned that the seal at the central mud chamber is not tight and need not be tight.

Mr. Dickinson asked if the Dorr as described is not a Dorr over a Dorr with a common feed tank.

Mr. Sabi mentioned that during experimental investigations it was found necessary to keep a ratio of settling area to thickening area as 1 :2 and further that engineering economics had shown the four compartment unit to be the best.

Dr. Douwes Dekker enquired as to which was the settling area and which the thickening area.

Mr. Sabi mentioned that thickening is in compartments 2 and 4.

Dr. Doss observed that the improved capacity of the Rapi-Dorr appears to be due to the increase in the depth of the settling compartment. With a constant stirrer depth of 10″ undisturbed settling depth would increase on increasing the depth of the compartment. Referring to the study of comparative performances of different types of clarifiers in use in factories in India undertaken by him, he stated that the earlier designs of Dorr (1937) were working very well even as compared to the later multifeeds etc. The variation in the working capacity of the clarifiers varied from 2½ hours juice capacity to 4 hours juice capacity. He referred to the differences of opinion in respect of feed distribution and clear juice draw off and stressed on the need for more fundamental studies on the internal working of the clarifiers and saw great possibilities for improving the designs.

Mr. Clayton referred to the numerous types of settlers which have been functioning satisfactorily in spite of the varying and sometimes extreme views of competitive clarifiers makers, as to their performances. The diaphragm pump in a number of cases is no longer used, the mud being discharged by gravity.

Mr. Jenkins considered that more information is needed on the most suitable slope of trays.

Mr. Kelly associated himself with the views expressed by Mr. Clayton. He again drew attention to the mechanism of thickening of mud and the problem of upward movement of juice through the descending flocs at this stage and thought that some form of tapping the bottom of the tray may help quicker thickening.

Mr. Foster enquired as to why one should not have a fairly large thickening region. Was there any information on possible reaction of sucrose with mud ?

Dr. Doss observed that increase in the slope of the tray would help mud thickening. He agreed with Mr. Kelly that possibly a vibrator of the proper type would also be helpful. He thought a rota-type mud-pump would minimise pulsations during mud withdrawal. He stated that the tabular centrifuge would give the simplest and most rapid method for mud-density measurements.

Concluding the Chairman said that the continuous settler is the most mysterious piece of equipment in so far as we are lacking in the overall picture of the mechanism of its working. It is likely that developments in the future may be entirely in a new direction.

SYMPOSIUM ON PAYMENT OF CANE PRICE

SYMPOSIUM ON PAYMENT OF CANE PRICE

Session-Tuesday, 31st January, 9-15 A. M.

SARDAR LAL SINGH, *Chairman*

The *Chairman* delivered the following address:

Gentlemen,

I accepted the honour of presiding over this symposium with a certain amount of reluctance. In this gathering of distinguished and eminent Sugar Technologists of the world, I see a large number who could do greater justice to the subject than myself and in all humility, I should have preferred to be a listener to benefit from their ripe experience. Further, since the Committee appointed by the Indian Sugar Development Council to explore the feasibility of payment of cane price on its quality of which I happen to be the Chairman, has not yet come to any final decision, it would look rather premature for me to express any definite views at this stage. Although we have sounded the views of some of the Sugar Technologists and Millers in India as also of those in Australia and Indonesia, whom we had the privilege to meet during our recent tour to those countries, I must confess that a really satisfactory method, free from all objections has not so far been found. As a result of today's discussions, we can look forward to hammer out a solution suitable to peculiar conditions in India.

In regard to the desirability of paying cane on the basis of quality, there can hardly be two opinions, because firstly it is sugar in the cane and not the bamboo or wood and water to be paid for, and secondly, because sugar is manufactured not in the mill but actually in the field. We all know such simple facts that certain varieties are sweeter than others, that ratoon crop ripens earlier than plant crop, a late variety if harvested early or any early variety if harvested too late or cane if kept too long after harvest suffers in sucrose content; and certain cultural practices are more conducive than others, to increase sugar content of cane and all these are more within the control of cultivators rather than that of miller. The Governments of some advanced countries accordingly ensure that the results of researches are translated in the cultivators' fields and the cane growers are also very eager to make full use of scientific discoveries placed at their disposal. As each lot brought by the growers is of sufficient quantity, the sugar mills are in a position to analyse each lot separately and pay according to its quality. An efficient farmer is thus compensated for his skill and effort, and the lazy one penalised for his indifference. In order to prevent exploitation by any party and to ensure justice and fair play, the Governments on their own part create an independent, expert and permanent agency which commands the confidence of all. For instance, the price fixation Board in Queensland at present comprises one elected representative each of cane growers and millers and is presided over by a judge of the Supreme Court. The Board is assisted by a Chemist and an Accountant of unquestionable authority. In the event of any one else other than a Supreme Court Judge being the Chairman, he cannot be removed before 15 years or before his death except by the adverse vote of the Parliament, so that he is above temptation or browbeating by any one. Findings of this Board are final and their legality cannot be questioned in any Court. Need for such an impartial and permanent Board arises not only because the work is of a complicated nature and requires experience, but also because a slight variation involves huge amount of money. In India a mere difference of Anna -/1/- per maund in the price of cane on the basis of 10% recovery and 18 lakh tons of sugar, means ultimately a gain or loss of over three crores of rupees to sugar manufacturers. Further the price of cane in India has so far been fixed on the basis of 9.6% recovery of sugar while it actually varies tremendously from factory to factory from 9 to 11% and changing the basis of recovery by mere ½% would mean a gain or loss of 5 lakhs of rupees in case of an average sized factory.

I would like to stress that in the matter of fixation of price for sugarcane or sugar, there should not be any mistrust or bitterness between the grower, the miller and the consumer. The Indian consumer has to appreciate that sugar in terms of its food or calorific value is at present a cheaper product than most other eatables. The price of imported sugar which constantly misleads him, is frequently a " dumping price " and not the real one. For instance, as compared to the price of Rs. 30/- per maund in India, the internal price of sugar in Indonesia last year was about Rs. 45/- per maund while its export price was only Rs. 20/- or so per maund. In Australia also, the price in the internal market was higher than the price realised on the surplus exported abroad. The loss on exports of sugar is made up by increasing the internal or home price of sugar. No one with any patriotic feeling in any country can countenance the idea of depending upon an imported product ' dumped " at a low price, when the same can be produced within the country. In spite of the fact that the recovery of sugar and acre yields of cane in India are low and the taxes on the industry high, the present price of Indian sugar cannot be considered high by any means. Our sugar price is about the same as in Australia, about 2/3 of that of Indonesia, Pakistan, Japan and Canada, ½ of Italy and ¼ of Iran. An attempt to reduce the price of sugar at the cost of the grower or the miller will be nothing short than killing the goose that lays the golden egg, i.e., killing an industry which supports 20 million cane growing families, gives employment to about one and a half lakh skilled and semi-skilled workers in the factories, produces annually about 120 crores of rupees worth of products and brings annual revenue of Rs. 21 crores to the Central and State Governments. The Miller must understand that just as he is fully entitled to reasonable profits, so is the grower. Millers, who resist paying the growers a reasonable price of cane, are doing great harm to their own interests. Many have suggested that the price of cane should be fixed in relation to other crops. It should, however, be realised that cane is the main cash crop of the farmers and if this source dries up, he will be forced to desperation and frustration. A more logical course would be to raise the level of prices of the other crops also to remunerative levels.

The Indian Sugar Industry is a very heavily taxed industry. While there are no Excise Duty,Cess etc., in Australia, in India the Government taxes amount to 23% of the total cost of the sugar. The growers and millers do not grudge paying heavy taxes as funds are needed to finance India's Develpmental Schemes. But they would like the consumers to appreciate that the blame for the high price of sugar should not be placed at the door of the grower or the miller. It is very important that out of the heavy amount of taxes collected by the Government, a certain portion specially the whole of the cane cess should be ploughed back to help the growers to improve their standard of farming and reduce cost of production. The Indian grower should also recognise that apart from safeguarding his legitimate interest he must grow varieties with highest sugar contents and make up his standard of cultivation and thereby contribute his share to improve the quality of sugar and the acre yields. As regards the bogey of over production it will be a long time before India can satisfy its own consumption requirements. However, if a country like Australia can export 50% of its production, India can surely, export 5 to 10% of her production if necessary.

I am sorry to have taken so much of your valuable time but I considered it necessary to give you a back ground of the conditions at present obtaining in the Indian sugar industry. I have now the pleasure in declaring this session open and we shall now proceed to our business. I would suggest that we must first read the papers and then have a general discussion on the subject at the end.

The author presented the following paper.

Paper

CANE PAYMENT IN MEXICO WITH REFERENCE TO THE GENERAL PRINCIPLES AND SYSTEMS USED AND PROPOSED MORE EQUITABLE SYSTEM OF PAYMENT

Alfonso Gonzalez Gallardo

Experimentales Union Nacional de Productores de Azucar,

S. A. de C. V., Mexico

In former times, when the factory and the field belonged to the same owner and the factory milled its own cane, there was no reason to worry about the industrial value of the sugarcane, as the factory took care of performing good cultural operations in order to obtain the best yield and quality and, besides, the limited consumption of sugar allowed the maintenance of a fairly acceptable balance between the agricultural and industrial parts, cultivating only the best class soils and properly prepared, that gave an acceptable yield of good quality cane.

But the need to improve the yields of sugar per hectare did not escape us, and a classical example is that of the Ingenio of Atencingo which, during the period 1930-35, succeeded in carrying the average yield to 180 tons of sugarcane per hectare by building a clay pipe drainage system all over the canefields, the increase of the available water and the conditioning and opportune preparation of the fields with heavy disk plows of 32″ and heavy disk harrows; cultural operations duly carried out, abundant and opportune irrigations, fertilization with Nitrophoska, at a rate of 600 kilos per hectare and the introduction of P.O.J. 2878.

On the other hand, in the year of 1931, the Ingenio del Mante—the first in Mexico to be supplied exclusively with cane from the "colonos"—at the initiation of its operations established the system of cane payment according to its content of recoverable sugar, system which is still followed to date with satisfactory results both for the planters and the factory and which does not cause considerable overload in the laboratory work.

However, during the years 1935-1940, the agrarian distribution of the sugarcane fields took place and changed the ownership of the land in the sugar mills, supplying areas, which passed to the ejidatarios and small owners; the sugar companies were changed from planters into cane buyers—at a rate per ton—with the disorders following a new fashion, which originated the crisis of low production we went through during the following lustrum for the new land owners lacked the experience and necessary means as independent farmers and the cane growing did not seem attractive to them.

To correct this inconvenience the Federal Government and the Union Nacional de Productores de Azucar took the necessary steps for the promotion of the sugar production granting the right credit, increasing the price of sugar and setting for the cane payment, a percentage of the factory yield which, just as it put an end to the haggles between industrialists and cane growers,allowed these to obtain an equitable price per ton of delivered cane; besides, other measures were dictated that emphasized the position of the planters and the industrialists as members of an agricultural-industrial unit. As results of this a raise to the level necessary to cover the domestic demands was achieved.

The first rules for cane payment were dictated on December 24, 1941—still in force with slight amendments—which stipulated a uniform price per ton of cane delivered at the factory yard during the crop, derived from the tonnage of cane ground and the sugar production in the crop season, which was the only acceptable means of general practical application at that time, because of the great diversity in the efficiency of the sugar installations and the almost complete lack of chemical laboratories in the sugar factories; however, the door was left open to payment per quality which was at once implanted by the Ingenio El Higo, Ver., which to date still pays for the cane by individual analysis.

Cane payment is ruled at present by the Cane Decree of March 29, 1944, which, with the amendments dictated on June 14, 1953, stipulates in its related part.

PRICE OF CANE FOR MANUFACTURE OF SUGAR

The price will be formed by adding the cane planters' share in the selling price of sugar, the share in the final molasses and the premiums and penalties applied during the crop season because of differences in the quality of cane, according to the following rules :

First—For the effects of this Decree, the yield will be the number of kilos of standard or refined sugar obtained from each ton of cane ground. For " mascabado " (raw sugar) a yield of 109 kilos will be taken as the equivalent of 100 kilos of standard or refined sugar. The average yield of the crop will be calculated by dividing the number of kilos of sugar obtained, by the total number of tons of cane ground.

For sugar or mascabado.

(a) The base price shall be computed per ton of cane delivered in the factory yard, on the average yield obtained during the crop by the equivalent in money (at the price paid by the Union Nacional de Productores de Azucar, SA. de C. V. for the standard granulated sugar) of 40 kilos of sugar, for a yield of 80 (eighty) kilos per ton of cane or less ; and for larger yields progressive increases shall be made as follow :

(b) More than eighty kilos per ton up to one hundred, 48% (forty eight percent) over the excess over 80 kilos.

(c) More than one hundred kilos per ton up to one hundred and ten, 45% (forty five percent) over the excess over one hundred kilos.

(d) More than one hundred and ten kilos per ton up to one hundred and twenty, 40% (forty percent) over the excess of one hundred and ten kilos.

(e) More than one hundred and twenty kilos per ton, 35% (thirty five percent) over the excess of one hundred and twenty kilos.

The above shares will exclude any charge to the cane grower on account of general expenses, administration and the like and tax stamps, as well as Federal, State or Municipal taxes and the additional ones corresponding to the industry or its products, which shall be paid, in its case, by the industrialist or by the Union Nacional de Productores de Azucar, S. A. de C. V.

SHARE IN FINAL MOLASSES

The industrialists are required to exhaust the final molasses as far as a good and applicable manufacturing practice permits, allowing the cane grower a share of 50% on their total net value, which shall be added to the price of the ton of cane with the quotient resulting from dividing said net value by the number of tons of cane. The net value of final molasses shall be computed as follows :

(a) For final molasses used in the manufacture of alcohol in the mill's distillery, the price obtained by the Union Nacional de Productores de Alcohol, S.A. shall be taken as the basis, deducting 30 per litre of alcohol produced to cover all direct and indirect production costs and expenses plus municipal, state or any other expenses incurred by the mill ; and the resulting difference per litre multiplied by the number of litres produced will represent the net value of the final molasses used in the elaboration of alcohol.

(b) For final molasses sold by the mill, from the selling price the sum of federal, state, municipal or taxes paid by the mill, plus the expenses required for delivery of such final molasses, shall be deducted, in order to obtain its net value in the storage tanks of the factory mill.

(c) The final molasses to be discarded with authorization of the Department of the Treasury, or those used for forage for animals belonging either to the mill or to the cane grower, shall be disregarded in computing increase on the price of cane.

PREMIUMS AND PENALTIES FOR QUALITIES OF SUGARCANE

Shall be computed as follows :

(a) The amount of penalties imposed during the crop on account of qualities of cane or damaged canes,according to Articles Fifteenth and Sixth of this Decree, shall be divided by the number of tons of cane not penalized ; the quotient will represent the bonus on the price of each ton of cane not penalized.

(b) The total amount of the premiums credited on account of superior qualities of cane, according to Article Five of this Decree, shall be divided by the total number of tons of cane on which no premium was allowed ; the quotient shall represent the discount to be made on the value of each ton of cane on which no premium was allowed.

Premiums and penalties on qualities of cane :

When the supply zone of a mill, alcohol or brandy factory, or "piloncillo" mill, produces canes of notoriously different qualities, differential prices may be established by common agreement between cane growers and industrialists for the content of sucrose, fibre and purity of each class of cane, penalizing those of inferior quality in favour of those of higher quality, that is that penalties agreed upon shall remain in favour of the cane growers and not the industrialists, in such a way that the average price paid for all the cane ground during the crop corresponds to the price derived from the application of Articles First, Second and Third of this Decree.

The great increase of the domestic market, which from 205,000 tons in 1930 raised to 734,722 in 1954, and shall probably reach to 765,000 tons in 1955, plus the quantities exported which are estimated in 75,000 tons, with prospects of reaching a domestic consumption of one million tons of sugar per year in the course of this second half of the present century, has made it necessary to extend the plantations to marginal zones, increasing the irrigated areas far more than the available water and good class canelands available, opening dry farming areas within regions with traditional irrigation and introducing rustic varieties capable of resisting the adversities of soil and culture, producing canes that have affected adversely the quality of the sugar cane, as the same price is paid for a ton of rich and juicy cane as for one of low purity and high content of fibre.

The above circumstances have brought to the conscience of all the components of the sugar industry, the conviction that sugar is produced in the field and that it is necessary to improve the yield of sugar per hectare by means of the only two logical ways; (1) Taking to the field the results of agricultural investigation and experimentation in order to improve the cane production, and (2) Putting at the cultivator's reach the product of his intelligence and effort to produce good cane, by means of a fair share, that is, paying more for the good cane than for the cane of inferior quality.

In the first aspect the Union Nacional de Productores de Azucar since the year 1951, established the Oficina de Campos Experimentales (Office of Experiment Stations) which operates 7 experiment stations in the country's strategic zones and that has already achieved important realizations for the improvement of cane production.

In the second aspect, the experience has shown to industrialists and cane growers :

(a) That as long as the value of sugar manufactured by the factory is allotted between the cane grower and the industrialist in the proportions fixed by the sugarcane Decree, the improvement of the cane quality will benefit both the cane grower and the industrialist, increasing the incomes of the factory and the field.

(b) That two canes apparently equal and with the same weight may have a very different industrial value according to its content of recoverable sugar and that, consequently, it is not only the weight of the cane which determines its price, but mainly the sucrose richness and the purity, as well as the extraction it yields in the factory mill.

(c) That for the purposes of the sugar industry, the cane is formed only by juice and fibre and has as much less juice, that is, will yield less extraction, the bigger its fibre content, and that this depends on what is called Variety Factor which deals with : The sugar cane commercial variety, the irrigation or temporal culture, soils where it is cultivated—lowland, hillsides and uplands— ; if it concerns cane plant or ratoon, raw or burnt cane, etc. and

(d) That if the planting of rustic varieties that give little work and good tonnages per hectare even when of lower quality,is extended everyday, it is because the cane grower, conscious of his interests, is not going to deliver cane which will cost him more to produce if it is paid at the same price as the cheaper one, but at the time of giving him an incentive will respond in benefit of his own interests producing cane of good quality.

The lack of a system of payment per quality simple and at everybody's reach, that will not require a troublesome analytical work, nor complicated calculations, but fair and of enough practical approximation and that, besides, solves the problems of lower quality cane at the beginning of the crop season, when the cane has not yet reached its highest richness and the deliveries at the end of the season, when the cane has already passed its industrial maturity, and that shall adapt to our mills conditions and the standing legal dispositions for the cane payment, has made it difficult for the sugar industry to make up its mind to patronize the general implantations of payment per quality.

For this purpose, a system similar to the Australian " Payment per General Yield and Related Percentage " is under study, and even though it is subject to objections from the technical point of view, might solve satisfactorily the difficulties noted for the payment per quality.

For the application of this system under study, it is required :

(a) Use for the analysis of cane deliveries the juice of the first expression that drips from the interior phase of the lower mass of the crusher or that of the cane mass from the first mill, if there is no crusher, which is the only juice without mixture or adulteration.

(b) Take the fall of the brix and the sucrose of the crusher's juice to the normal juice, as equal factors for all the cane varieties milled during the run.

(c) That the retention of sugar in bagasse is the same for all cane varieties ground during the run.

(d) That the extraction is inversely proportional to the fibre content of each variety ground, in relation to the mean extraction obtained in the commercial mill during the run.

(e) Accept that for each kilo of impurities contained in the normal juice entering the factory, half a kilo of sugar is lost in final molasses, press mud and other undetermined losses, which is not recoverable even with the most efficient apparatus or manufacturing processes.

(f) That as in general practice it would be impossible to analyse each delivery of cane received, it shall be accepted that the cane cut from one same area during the day has the same quality and analyse only daily the crusher's juice of one of the deliveries chosen at random and once or the most twice a week determine the extraction or the related fibre content of each area in relation with the mean extraction of the run obtained at the mill.

(g) The establishment for all the runs, of the same general price for the cane, estimated from the probable yield of the mill during the crop and the probable price at which the UNPASA will pay for the sugar, according to the standing legal dispositions.

DATA TO BE TAKEN

Once the field has been divided into the more convenient and reduced number of cutting sectors or areas, which include groups of several cane growers, the following data will be taken :

(a) Daily sampling of the crusher's juice from one cane delivery chosen at random from each sector in order to determine brix and sucrose.

(b) Once or twice a week, take an average sample for each sector of all cane deliveries, taking at random two or three canes from each bundle, which shall be gathered during the day in order to determine, in the afternoon, either the related extraction in the test mill or the related fibre content by the common laboratory methods.

In order that the related extraction may be worthy of confidence, it is required to have a test mill capable of giving an extraction of 60% or greater in order to calculate the compensated average—weight of juice divided by weight of cane—from the cane deliveries from each cutting area during the run.

(c) From the run's report we shall take: The extraction of normal juice, the brix and sucrose factors, that is, the relation between the data of normal juice and those of the crusher's juice; the total of sugar produced and estimated obtained in the run; and the sugar yield of the run.

CALCULATED YIELDS

Calculations are made as follows:

Be it: R Recoverable sugar
S Polarization of crusher's juice
B Brix of crusher's juice
C_s Correction factor per sucrose
C_b Correction factor per brix
E Extraction in normal juice
V Variety factor

we then have:

Recovery from crusher's juice $= S - 0.5\,(B - S) = 1.5S - 0.5B$
Recovery from normal juice $= 1.5SC_s - 0.5BC_b$
Recovery % cane $= 1.5C_sES - 0.5C_bEB$
Recovery of cane deliveries from each cutting area during the run
$R = (1.5C_sVE)\,S - (0.5C_bVE)B$—formula for calculations
$Y = 1.5C_sVE \qquad X = 0.5C_bVE$

If factors X and Y are calculated beforehand, which are equal in each run for all the deliveries received from a same area, the former formula is very easy to be solved in a single operation with a calculating machine. If a hand machine is used, then the sucrose factor Y is multiplied by the polarization of the crusher's juice of each delivery; we rub out the multiplicant and the multiplier keeping the product and with an inverse motion of the handle—as for dividing—we make the multiplication of the Brix's factor X by the brix of the crusher's juice of the respective delivery. The machine substracts automatically the products and the result is read in the products line. If it is an electric machine, the first multiplication is also made, the factors are rubbed out keeping the product, the substraction key is pressed making the second product and the result is read directly.

CORRECTED YIELD

The sum of the theoretical yields never coincides with the sugar obtained (produced plus estimated) during the run and the calculated recoverable sugar delivered by the colono shall have to be corrected, multiplying the theoretical calculated quantity by a correction factor which is the quotient between total actual sugar produced and estimated divided by the sum of theoretical yields.

RELATIVE PERCENTAGE

The cane from each run, independent of the actual yield, is paid at the average general price established beforehand for a yield to the average yield of the run; the canes producing larger yields are allowed a proportional premium and those producing lower yields are penalized also proportionally.

At the end of the crop season, when knowledge is had of the general yield obtained as well as the price that the Union will pay for the sugar, the necessary corrections to the provisional prices to be paid to the colonos in each run are made.

The former system means that if the average price corresponds to a mean yield of 10%, this same price is paid for the runs giving 9% as well as for the ones giving 11%, making the adjustments for the analysis of the individual cane deliveries according to the particular yield of the run.

The author presented the following paper.

Paper

PERSONAL NOTES ON CANE PAYMENT SYSTEMS

COLIN W. WADDELL

INTRODUCTION

The quality of cane delivered to the factory plays such an important part in its value and the efficiency of technical processes employed; that any measures which can be taken to improve it have far-reaching economic effects.

Whether cane is supplied from large estates or small independent farms, there is a growing tendency in most countries to find suitable incentives to raise cane quality.

Since these incentives involve technical problems of weighing, sampling, and analysis; as well as administrative problems of costs, sugar prices and the system adopted for division of proceeds between grower and miller; they occupy a considerable amount of skilled work and supervision. Therefore any improvements which can be found, either in the methods themselves or in their application to get cleaner, fresher, sweeter cane to the factory, become very important.

The cost of these incentives must be kept in focus with the rewards to the industry when they bring about even small increases in average crop quality.

OBJECTS

The objects of this paper are to present a convenient man-hour basis for comparing the cost of different cane payment systems; and to draw attention to some of the principles involved.

BASIS FOR COMPARISON OF SYSTEM COSTS

What is the best method of cane payment ?

It is obviously not possible to answer that question without a thorough understanding of local conditions which vary widely from one mill area to another, and from one country to another.

The size and location of farms ; methods of harvest and transport ; facilities for cane yard storage, weighing, unloading and crushing ; as well as the availability of trained personnel ; must all be taken into account before a choice can possibly be made of suitable methods for identifying, sampling and analysing the cane and calculating its value.

On the basis of observations made in Queensland, Philippines, Puerto Rico, Jamaica, Mexico and U.S.A., the writer considers that a cane payment system which requires *about 0.1 man hour per long ton of cane crushed per 24 hours* may be considered reasonably efficient.

For example :—

Employed by the Miller :

3 Weigh bridge Clerks weighing cane, full time	24	man-hours
3 Cane Samplers (Spotting trucks, etc.) full time	24	,, ,,
3 Juice Men (Handling Juices) full time	24	,, ,,
3 Fibre Sampling and Testing men, full time	24	,, ,,
3 Shift Chemists reading Brix and Pol, half time	12	,, ,,
1 Assistant Chemist, supervision, half time	4	,, ,,
1 Chief Chemist, supervision, quarter time	2	,, ,,
1 Unit Clerk calculating cane values, full time	8	,, ,,
1 Office Clerk on weekly cane payments, half time	4	,, ,,

Employed by a Government Authority :

3 Qualified Cane Testers, mainly supervision, full time	24	man-hours
1 District Supervising Cane Tester, one-eighth time	1	,, ,,
Total Man-hours devoted to cane evaluation	151	man-hours

If this mill crushed about 1,600 long tons cane in 24 hours, then $\frac{151\ \text{total man-hours}}{1600\ \text{long tons cane}} = 0.09$ man-hours per ton cane per 24 hours devoted exclusively to valuating cane from individual farmers, then the system of payment for quality appears to be within reasonable limits.

This must be regarded only as an approximate yard-stick for comparison and has often been found to vary between 0.05 and 0.2 under particular circumstances. The crushing rate of the mill exerts a big influence upon it, but as a rule it has been found that a figure over 0.1 indicates inadequate use of labour-saving devices, unnecessary refinement, or duplication; whereas a figure below 0.1 often indicates that insufficient care is being exercised.

PRINCIPLES INVOLVED

If a system of cane payment according to its quality is to achieve its primary objective of getting cleaner, fresher, sweeter cane delivered to the factory, it must reach the individual farmer or plantation field officer. Its object is not factory control or overall division of proceeds.

In dealing with cane farmers the writer believes that incentives are generally better than penalties, but they must be impartial, accurate, and free as far as possible from guesswork.

However, sugar cane presents an extremely difficult sampling problem because of its large and irregular unit size and the wide variation in composition from place to place in the field, stalk to stalk in the same load, and the extraneous matter which often accompanies the stalks.

A number of ingenious devices and methods for sampling cane by single stalk or small bundle analysis have been found suitable for particular purposes (1,2); but for cane payment it seems necessary to make use of the factory equipment to get sufficiently reliable bulk samples after the unloaders, carriers, revolving knives or shredders have broken down and thoroughly mixed the full loads.

This requires the preservation of individual and uncontaminated load identity beyond the weighbridge to the crusher or first mill.

Under Queensland conditions, load identity between weighbridge and unloading point is usually preserved by truck number or marker tag; and between unloading point and first rolls by indicators driven off the cane carrier (3,4,5 & 6). But it becomes necessary to calibrate these usually with the aid of a colouring dye, under operating conditions to determine how much cane is required to absorb the contamination of one grower's cane with another due to overlap and slip on the carrier; the scatter of chips from the revolving knives; and irregularities in feed to the first rolls. At some mills this band of contaminated cane on either side of the cane for sampling was as low as 1.3 long tons; while at others it was as high as 2.5 long tons.

Having established the minimum size load that can be accurately spot sampled for juice or for " fibre ", efforts are made to increase the size of load or contiguous loads arriving from any one field, in order to further reduce the risk of contamination and enable the collection of continuous first expressed juice samples by means of various automatic devices. Group harvesting can often be of assistance in this direction.

The average first expressed juice sampling rate in Queensland is one sample in about every 12 long tons of cane. In some circumstances this is as high as one in 4 tons or as low as one in 30 tons according to the size of farm and method of harvesting. The average number of independent farms supplying each mill in Queensland is about 250.

How detailed should be the analysis upon which payment is based ?

The key notes here appear to be simplicity and uniform treatment for all deliveries, but over-simplicity or unreliable sampling can defeat the main objective.

The brix and pol of first expressed juice with the application of a daily or weekly average Java Ratio or other factor takes care of the main variations in clean cane quality as between individual growers, but for the past 40 years Queensland has also recognised the fact that variations in the " fibre " or insoluble content of gross cane exerts a very important influence on the value of cane from different farms. It includes this in the well known C.C.S. formula (7) ; and is making some progress towards improvements to meet present day conditions. Reunion also recognises " fibre " in their 1954 formula (8).

CONCLUSIONS

It is the writer's belief that :—

(1) Cane farmers, the world over, do respond favourably to proper incentives which directly affect their payments for cane quality provided :

(a) these incentives reach the individual grower and are not lost in an over-simplified group or pool payment ;

(b) they are aimed at standards of canes sweetness, cleanliness and freshness which can be achieved by good farm practice ; and

(c) the system of sampling, analysis and payment is accurate and impartial and thus enables the law of averages to function over the crop from each farm.

(2) Individual load identity as far as the first expressed juice in the factory is preferable to stalk or bundle sampling.

(3) Queensland's C.C.S. formula, including some form of individual farm fibre test (9) is desirable provided an overall correction is made, based upon mixed juice weights and analysis.

(4) Some form of Relative Percentage Scheme (10) is desirable which relates each individual grower's cane value to the week's mill average quality, not that of the whole season when it is found impossible to harvest each grower's cane evenly throughout the whole crushing season.

(5) The cost and complexity of any system of payment for individual cane quality operates within reasonable bounds at about 0.1 man-hour per long ton cane per 24 hours.

ACKNOWLEDGEMENT

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REFERENCES

1. **Birkett, L.S.** 1954. " Determination of Polarization Per Cent Cane " International Sugar Journal. February--Page 38.
2. **Serbia and Fragoso.** 1955. " New, Accurate Method for Preparing Samples for Cane Analysis ". " Sugar ", May-- Page 39.
3. **Strugnell, R. H.** 1934. "Automatic Timing Device for Cane Sampling ". Proceedings Q S. S.C.T.—Page 183.
4. **Waddell, G.E.** 1939. " A New Method of Obtaining Juice Samples for Cane Payment ". Proceedings Q.S.S.C.T.—Page 55.
5. **O'Mara, F.D.** 1950. " Notes on the Juice Sampling and Cane Payment Systems at Mossman Mill ". Proceedings Q.S.S.C.T.— Page 223.
6. **Webster and Chaplin.** 1955. "Sampling First Expressed Juice for C C.S. Determination." Proceedings Q.S.S.C.T.—Page 13.
7. " The Regulation of Sugar Cane Prices Acts, 1915 to 1954 "- -Page 51.
8. **Hugot, E.** 1955. " Cane Payment on Quality Basis " International Sugar Journal. July—Page 187.
9. **Waddell, C.W.** 1953. " Effective Fibre Determination in Sugar Cane ". Proceedings I.S.S.C.T.— Page 828.
10. **Waddell, C.W.** 1954. "Relative Percentage Unit Values". "The Producers' Review", June—Page 38.

The author presented the following paper.

Paper

SOME PRACTICAL PROPOSALS FOR LINKING PRICE OF CANE WITH QUALITY

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In practically all the sugarcane growing countries of the world excepting India, sugarcane is paid on the basis of quality (its available sugar) and/or the realization from the same, i.e., sale price of sugar (raw or refined). Peculiar circumstances listed separately below have forced a system of flat payment on the basis of weight of cane only in India. Whatever may have been the reasons for adopting this system or for continuing the same, the evils connected with it are already, responsible for a number of difficulties seriously facing the industry, growers and the consumers.

It is too well known that by a change in variety and agronomic operations, yield of cane can be increased at the expense of sugar or vice-versa, and unless certain measures to bring about harmony of interests of the miller and the grower are taken, there is bound to be a clash of interests, which is not in the larger interests of any of the parties, namely, grower, the industry and consumer. If, however, the price is linked not with weight only but quality also, the grower will be conscious of both the vital aspects namely sugar-content and yield and will aim at the golden mean. With the need to bring down the sale price of sugar in parity with the prices of other commodities, there would be an endeavour to serve all the three interests in harmonious manner. It is, therefore, obvious that a change in the present system of payment is long overdue, as otherwise the clash of interests anticipated on the basis of payment, is already significantly evident.

At this stage a distinction may be drawn between the linking of price of cane with quality and the linking of price of cane with realization of sugar made from it. In case of the latter, the price to be paid for cane should bear relation to the price at which sugar is sold enabling the grower to share the advantages or disadvantages of a change in the sale price of sugar. If in this case the recovery is also taken into consideration and the realization per unit production of sugar is linked with the quantity of cane required for producing the same, we will have a system as per the second clause. It is well-known that in our country, particularly in North India, there has been a move in this direction for the last 1½ to 2 years and the Government of India Award in October 1954 was a step in this direction.

In case of the former procedure, the position is much simpler. A standard price of cane may be fixed for a standard quality ; for example, Rs. 1/7/- per maund for a recovery of 9.6%. The change in quality in this system would affect the price pro-rata. The Development Council for Sugar in its meeting on 9th August, 1954, proposed to appoint a committee to make proposals for introduction of a system of price for sugarcane on the basis of quality. It was proposed to adopt this as an experimental measure in one factory in West U. P. and another in Central U. P. in the season 1954-55. Due to certain difficulties this, however, has not been implemented.

In this paper, it is proposed to discuss only the latter aspect, i.e., linking price of cane with quality of cane, and no attempt will be made to touch the realization of sugar aspect, vis-a-vis, price of cane.

DIFFICULTIES IN THE WAY OF PAYMENT ON QUALITY BASIS

Before discussing any proposal for paying on the basis of quality, it would be helpful to recapitulate the difficulties apprehended in the adoption of such a system. These may be considered as under :-

(1) *Illiteracy*. In view of the illiteracy of the grower, it is hard to conceive his being agreeable to a system of sampling, determination of its quality in the laboratory, and payment on this basis. It would be safe to say that even in

West U. P., well over 90% of the growers will not be able to understand the system and, therefore, will not be agreeable to its adoption.

(2) *Small growers.* An average factory in West U.P. draws its requirements from 8,000 to 12,000 growers. The supplies are made very largely in bullock carts and each unit of sampling would be approximately one ton. For a thousand tons factory, this would work to 1,000 samples of cane to be drawn at gate and the out-lying road and rail centres,their transport to the factory and analysis. Although Dillewijn (1), (1952) has maintained that problem of large scale sampling in India involves difference in degree only, and is a matter of personnel and laboratory facilities, it may safely be said that the existing facilities are far too inadequate to venture such a large scale sampling system. It is obvious that there have to be government inspectors as well as factory representatives at various stages of sampling and analysis. The expenses of such an analysis may very roughly be put at well over pies six per maund.

(3) *Absence of reliable and suitable methods for assessing quality in small samples.* The unit of sampling in Queensland is 30 tons, and for purposes of quality, estimation of fibre and sucrose is done on these samples. Where as such a procedure could be satisfactorily handled with samples numbering 25/50 a day, the handling of a 1000 to 1,500 samples a day would obviously need a simpler, more reliable and fool proof method of assessing quality. Hand refractometers giving brix are not of much use for this purpose and there is no other handy and reliable method available for such a procedure.

In view of the above, it must be agreed that the difficulties in the way of assessment of quality of each lot of cane purchased by the sugar factory under the existing conditions are very great and may be described as insurmountable at the present moment.

FACTORS AFFECTING QUALITY

Failing a direct appraisal of quality and payment on this basis, we might look out for indirect measures of quality provided they are simple enough and are intelligible to the Indian grower.

The main factors that influence quality may be listed as under :

(1) *Variety.* It is agreed that of all the factors, variety is quite often the most significant. This is all the more so when the area is growing such diverse varieties as Cos. 321 (an early high-sugared variety) and Co.321 (a mid-season to late season, rather low-sugared variety). It would, therefore, appear to be correct to link quality, to a considerable extent with the nature of variety.

The idea is no novel one, for Dutt (2), (1950) pointed out that "it would be better, therefore, to fix price according to varieties and the month in which they are offered. In fixing the price to be paid, the crushing period may be divided

between the varieties of the locality according to their time of maturity ". In an earlier communique Dutt (3), (1947) advocated a large measure of premium for early high-sugared varieties and suggested the percentage of area under cane to be put under different varieties.

This principle has already been, more or less, accepted by the industry in West U.P. and premium is already being paid on early and mid-early varieties, namely Cos. 321 and Cos. 245.

(2) *Planting.* It is hardly necessary to say that ratoons mature earlier and their crushing in the early part of the season is an attempt against low recovery in the beginning of the season. This also helps the industry to start crushing earlier. The desirability of marshalling ratoons in early season is very well established. Differences in quality due to variety persist in ratoons also as has been pointed out by the author (4), (1954). Some typical results, in this connection, are given in Table I below :—

TABLE I

COMPARATIVE JUICE ANALYSIS OF RATOON AND PLANT

CANE OF PRINCIPAL VARIETIES

		Plant cane 24/1/1955			R atoon cane 22/11/1954		
Sl. No.	Variety	Brix	Pol	Purity	Brix	Pol	Purity
1.	Co. 312	16.36	12.59	78.48	15.81	11.99	75.72
2.	Cos. 321	19.06	16.82	88.22	18.65	15.52	85.76
3.	Cos. 245	19.21	16.45	86.00	18.44	14.62	79.33

In view of the fact that the ratoons have higher sugar content in the early period and the varietal differences persist in ratoons also, it is logical to suggest the following :—

(i) In the early period, i.e., till the end of December, the ratoons of the same variety should be paid higher than for its plant cane.

(ii) The different rate of payment for varieties should be applied in case of ratoons also.

(3) *Period.* In the typical climate of West U.P., ripening in sugar canes starts actively from October onwards. In case of ratoon cane, the process of ripening in early varieties may be said to be completed by the middle of November to end of December and in case of late to end of December or there about. In case of plant cane, the ripening continues in early varieties to the beginning or

middle of January and in case of late varieties to the beginning of March or middle of March. The above limits are only generalizations and variations are always expected between varieties and between years.

With the above pattern of ripening in cane, it appears logical to suggest a rise in price of cane with the advance in maturity; for example in case of plant cane of a late or mid-season variety like Co. 312, supplies made in early November should be taken at a discount whereas the supplies of this very variety if made in the end of March or beginning of April, may be taken even at premium. There is nothing novel about this suggestion either. Dutt (2), (1950) suggests that "in the beginning of the season normal prices should be offered for early high-sugared varieties but very low prices should be fixed for the mid-season canes so that the cultivators will be discouraged to offer the un-ripe mid-season cane in the early part of the crushing season". This appears to be the only practical way to make the grower supply cane on the basis of its maturity and a measure like this can effectively put a check on supplies of plant cane of Co. 312 and Co. 453 in early or middle of November.

On the basis of periodic maturity and with Cos. 321, Cos. 245, Co. 312 and Co. 453, as the main varieties of the area, the schedule of supply may be drawn as under :—

SCHEDULE OF SUPPLY

Sl. No.	Variety	Time of crushing Ratoon	Plant
1.	Cos. 321	November	3rd week of Nov. to 31st Jan.
2.	Cos. 245	3rd week of November onwards	3rd week of Jan. to end of Feb.
3.	Co. 312	beginning of December onwards	middle of February onwards
4.	Co. 453	middle of December onwards	beginning of March onwards

(4) *Staling.* Quite often the cause for low quality in supplies made to the mills, is heavy staling that the cane is subjected to. It is well-known that purity of cane juice can serve as index of staling. Wherever cases of heavy marked staling are noted, the factory may be authorised to draw samples in collaboration with the cane department representatives for determining the purity. The difference in purity of the sample and that of the average for the day may be used as the criterion for a discount in price. As an approximate measure, the percentage discount may be fixed at twice the drop in purity. It will be seen that on the basis of the usual formula for calculating available sugar, this suggested measure works out fairly satisfactory.

(5) *Attack of insect pests and diseases.* A crop that has been badly attacked by pests like pyrilla, borers or by diseases, is bound to be low in sugar. Such supplies can normally be detected at the time of their weighment, where the cases are isolated. These supplies may be sampled and paid for on the basis of such analysis with a view to encourage plant protection measures.

(6) *Lodging.* Quality is adversely effected by lodging. Lodged cane can easily be detected. Such supplies can easily be sampled and paid for at discount, if any.

The above list could be multiplied but for all practical purposes, the above factors may be said to be very largely responsible for the variation expected in cane quality and these may safely be taken as measures for the same.

On going through the above factors, it will be seen that factors listed in items No. 4, 5, and 6 are not usual and would vary from sample to sample.

PROPOSED SYSTEM

The first three factors enumerated above, namely, varieties, nature of planting and period, are applicable to all supplies and a system that could take cognisance of all the three factors should very largely be able to delineate the quality. For example, the price of cane may be fixed on the basis of its being plant or ratoon, and on the basis of its date of supply. According to this system, the price of ratoons in the early period would be higher than the plant cane, price of early varieties would be higher than late varieties, particularly in the early period, and the price in the early part of the season would be paid for at lower rates than when these varieties are ripe.

On a perusal of Table II, it will be seen that such a system of payment will serve the interest of the grower as also the industry. It would pay to the grower to supply early varieties in the beginning of the season and free his land for a second crop. The higher price that he tends to obtain from these early varieties in the early period is another big attraction. Supplies of mid-season cane will tend to be offered when they are ripe enough and as these give good ratoons the supply of good ratoon crop is also assured. Supplies of early plant varieties could also be justified in the beginning of the season, thus enabling these varieties to be raised only for plant crop and it will be seen that such a system will be conducive to a healthy crop in the area.

PRACTICAL DIFFICULTIES APPREHENDED FOR THE ADOPTION OF THE SCHEDULE

Besides the usual difficulties on the adoption of any new system, namely the need to train personnel and educate the concerned public, the following are expected to be the difficulties which will have to be tackled in advance before such a proposal could be implemented.

(1) *Trained personnel.* It will be seen that the price of the same variety in the early period varies significantly on the nature of its planting, i.e., whether it is classed as ratoon or plant. Whereas in majority of the cases supplies could be differentiated without any doubt, there are definite cases where differentiation is really difficult, if not impossible, on seeing the supplies of cane in the cart only. In all such cases, definite opinion could be given on tracing the suuplies to the fields. This would need necessary staff for this purpose. The need for such staff would, however, not be much because it is expected that not more than 10% of the supplies may require such a recourse.

(2) The personnels will have also to be trained in the identification of varieties. This, however, is not usually difficult.

(3) *Preparation of schedule of prices.* Figures in the schedule in Table II are based on results of mill-tests and the average recoveries for the period. The particular mill test figures are underlined. In case this system has to be adopted, a schedule of this type will have to be drawn up on the basis of mill tests in every week in respect of each variety and planting. This work can be entrusted to the Director, Sugarcane Research and these schedules may be drawn up for a number of factories with a more or less uniform climate and pattern of varietal distribution, as for instance, the seven factories in Meerut District could be covered by one schedule.

(4) *Variation from year to year.* As the quality of cane does vary from year to year, it would be helpful to draw up the schedule in view of the expected recoveries and not stick to one standard set of figures. This work again could be entrusted to the Director, Sugarcane Research with the collaboration of industry and the growers.

The system proposed is offered only as a basis of discussion. The figures given in the table are purely indicative of a policy or a line of thinking that might be helpful in this direction.

It is also necessary for me to add here that the views expressed in this paper are my own and do not necessarily reflect the views of the company, i.e., Daurala Sugar Works, Daurala.

SUMMARY

A system of linking price of cane with quality on the basis of its variety, nature of planting and the period of its supply, has been suggested. It has been pointed out that under the conditions obtainable in Western U.P., it is as yet not practicable to asses the quality for each lot of supplies made. Some difficulties expected in the system, are also out-lined.

TABLE II
INDICATIVE QUALITY-WISE CANE PRICE SCHEDULE

PERIOD	PLANT CANE				RATOON CANE			
	Co.312		Cos. 321		Co.312		Cos.321	
	Recovery	Rate	Recovery	Rate	Recovery	Rate	Recovery	Rate
		Rs. as. p.		Rs. as. p.		Rs. as. p.		Rs. as. p.
7/11	5.00	0 12 0	8.00	1 3 2	7.00	1 0 9	9.30	1 6 0
15/11	5.60	0 13 5	8.60	1 4 7	7.60	1 2 3	9.70	1 7 3
22/11	6.10	0 14 7	9.20	1 6 0	8.20	1 3 8	10.00	1 8 0
30/11	6.70	1 0 1	9.45	1 6 8	8.60	1 4 7	10.20	1 8 5
7/12	7.20	1 1 3	9.70	1 7 3	9.00	1 5 7	10.40	1 8 11
15/12	7.70	1 2 5	9.85	1 7 7	9.30	1 6 3	10.60	1 9 5
22/12	8.20	1 3 8	10.00	1 8 0	9.70	1 7 3	10.80	1 9 10
31/12	8.50	1 4 4	10.20	1 8 5	9.90	1 7 9	10.90	1 10 1
7/1	8.70	1 4 10	10.40	1 1 11	10.00	1 8 0	11.00	1 10 4
15/1	8.85	1 5 2	10.60	1 9 5	10.10	1 8 2	11.00	1 10 4
22/1	9.00	1 5 7	10.75	1 9 9	10.10	1 8 2	11.00	1 10 4
31/1	9.15	1 5 11	10.90	1 10 1	10.10	1 8 2	10.90	1 10 1
7/2	9.30	1 6 6	11.05	1 10 5	10.10	1 8 2	10.80	1 9 10
15/2	9.40	1 6 6	11.20	1 10 10	10.10	1 8 2	10.60	1 9 5
22/2	9.60	1 7 0	11.40	1 11 4	10.00	1 8 0	10.40	1 8 11
28/2	9.80	1 7 6	11.60	1 11 10	9.90	1 7 9	10.00	1 8 0
7/3	9.90	1 7 9	11.70	1 12 0	9.80	1 7 6	—	—
15/3	10.00	1 8 0	11.60	1 11 10	9.60	1 7 0	—	—
22/3	10.10	1 8 2	11.50	1 11 7	9.40	1 6 6	—	—
31/3	10.30	1 8 8	11.30	1 11 1	9.20	1 6 0	—	—

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REFERENCES

1. Dillewijn, C. Van. 1952. Improving India's sugar output-*Sugar* (November).
2. Dutt, N.L. 1950. Survey of Sugarcane Research and Development in India-*Published by Indian Central Sugarcane Committee*
3. Dutt, N. L. 1947. Sugarcane in India-Retrospect and Prospect-*Presidential Address to the Section of Agricultural Association, 34th. Indian Science Congress.*
4. Girdhari Lal. 1954. Need for varietal survey of ratoon canes in factory zones-*Proceedings of the Second Biennial Conference of Sugarcane Research and Development Work, I.C.S.C., New Delhi.*

The author presented the following paper

Paper

PAYMENT OF CANE ON QUALITY BASIS

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In a crop like sugarcane, the problems attendant on this aspect are different from others. The cultivator is mainly interested in yield per acre so long as the crop is paid for on the weight basis. The factory, on the other hand, is interested in cane of high sugar content irrespective of the acre yield. The two interests of the cultivator and the mill owner are different and may be even.

The present system of payment of cane on weight basis therefore needs modification as it provides no incentive to the cultivator to grow better varieties, improve agricultural practices, delivering cane immediately after harvest to avoid cane deterioration, whereas, in other sugar producing countries the payment is based not only on the weight of cane but on the percentage of the contained sugar. The general principle adopted in such countries is that the planter gets for his cane a certain proportion, varying from 50-70 percent of the sugar or the cost of the sugar that is manufactured from the same. The payment on quality basis is easily feasible in other sugar producing countries mainly because either the mill owners plant, cultivate and harvest their own cane or there are a few large estates which grow exclusively cane but do not own a factory. These cane estates sell their cane to a factory on agreement. The basis for the determination of the sucrose content of the cane for planters payment is the pol percent first expressed juice with a correction factor computed from the data of the previous crop. The system of payment of course varies from country to country. The Government of India, Ministry of Food and Agriculture, are considering the possibility of introducing the payment of cane price on sucrose content.

The question now arises as to what system is to be adopted in our country of small holdings The system followed in other cane growing countries can not be suitably applied in India. Various workers (1, 2, 3, 4, 5, 6, 7, 8 and 9) have suggested various views and also the members (10, 11, 12, 13 and 14) of the Development Council who examined the question of making payment for sugarcane on the basis of quality gave various suggestions but none of them has been considered as suitable to be adopted in our country as the interests of the grower and millowner are not reconciled. Before imposing this system, it is but necessary for the Government of India to lay down some specific methods by which the sucrose content of a cane variety can be culturally improved. The choice of cane varieties now-a-days does not rest with the cultivator as in chief producing states only the recommended varieties by the Government are cultivated. Unfortunately inspite of the considerable amount of research work that was carried out and is still being carried out in India and abroad, we are still not in a position to give any decisive advice for improving the quality. A few references of the work done in this respect are summarised just to throw some light on this point for giving advice to the cane growers. Das (15) found out heavy dressings of nitrogen induced vegetative growth at the cost of quality. Similar observations were made by Khanna and Prasad (16), Mukherjee (17), Rege and Sannabhadt (18), Paramanik and others (19). Contradictory results were often reported with potassium and phosphate fertilisers on the quality of cane. Khanna and Sen (20) in their studies of water logging observed that water logging upto 6-8 inches not only induced early maturity but also maintained juice quality so long as canes were within 6-8 inches.

Sen (21) pointed out that heavy dressing of manures supplemented with appropriate doses of water not only gives higher yield but also gives higher sucrose. The consumption of manures is correlated with the water supply. This view is amply substantiated from the different manurial schedule adopted in India and abroad. Amongst the chief sugar producing states in India, the recommended manurial dose of nitrogen in Bihar, Uttar Pradesh and Deccan is 60 lbs., 120 lbs. and 300 lbs. nitrogen per acre for canes of same duration. These wide differences cannot be accounted alone by the soil characters and climatic conditions. The irrigation facility in Bihar is meagre, whereas, in Uttar Pradesh 5-6 irrigations are often given to cane during summer and the cane lands of Deccan receive irrigation after every 10 days throughout the year. In spite of heavy dressings of N in Deccan for Eksali canes, the quality is found definitely superior to canes of Bihar and Uttar Pradesh. Similarly, in Cuba 1200 lbs. or 1800 lbs. of manures are applied in highly and very highly rain-fed areas respectively. Similar observations were made by Mohan Rao and others (22) but the level of irrigation depends on soil conditions and other edaphic characters. Further evidence is adduced (23) that carbohydrate (low molecular weight saccharides) content of the planted mother sett is one of the reasons for assimilating sucrose content of the new seedlings and the results indicated distinctively better juice quality compared to control, when planted setts were soaked in 30-35% molasses solution at pH 7·0 for 6-7 hours prior to planting under all other identical conditions. The effect of spraying 10 percent molasses solution mixed with lime at the rate of 10 lbs. per acre per application over the leaves at the age of three, five, six and eight months significantly indicated better sucrose at harvest (24). Alvarer and Alharlaha (25) observed similar observation with molasses spraying in South Africa. The spraying of hormones and fertilizers over the leaves are increasingly used but the results achieved in respect of quality are contradictory. Khanna, Chakravarti and Srivastava (26) observed 0·55 percent higher sugar recovery on spraying dichlorophenoxy acetic acid whereas, Sen and Bhattacharjee (loc.. cit.) or Mukherjee and Sen (27) could not observe any beneficial effect. Sen (28) recently observed that the balanced food of phosphoric acid of sugarcane plant is about one-third of the requirement of nitrogen.

The following recommendation of manurial dose may be made for the improvement of yield and sucrose content of sugarcane from the discussion of research workers.

1. Proper application of manurial dose with uniform distribution of water supply artificially.
2. Pre soaking the planting cane setts over night in 30-35 percent molasses solution at pH 7 0 and application of proper manurial dose at the time of planting, supplimented with uniform distribution of water supply and spraying 10 percent molasses solution mixed with lime at the rate of 10 lbs. per acre per application at the age of three, five, six and eight months.
3. Spraying hormones over the leaves in addition to the application of proper manurial dose along with uniform distribution of water supply.

The manurial dose and water supply will depend on rainfall, soil and other edaphic characteristics.

The real problem has not so far been touched and it is really a hard task to come to a concrete proposal which would satisfy the interest of both the millowners and the growers. This is particularly so in view of the fact that sub-tropical India characterised by the progressive ripening of cane from the beginning of November till the end of March (depending upon the nature and distribution of monsoon in the crop year and on set of hot weather in the following spring) the period covering almost the entire. crushing season. The sugar recovery % has been found to vary between 8·5 or 9.0 in November and 11.0 in mid Feb. to mid March in almost all the sugar factories in India. This characteristic behaviour stands as a great disadvantage to the grower, if payment of cane is strictly followed by sucrose content. The canes harvested in the early (November-December) or in the late season (April-May) would give poorer recovery compared to canes crushed in Feb.-March, inspite of the fact that these canes were superior to Feb.-March cane which could be verified if examined in one particular time. The reason is that in the early part of the season, the cane would not mature and at the fag end of the season the deterioration would set in. Therefore, the grower who labours hard and operates all modern technique for growing his cane gets lesser price than the neighbour who grows cane without any operation of the modern technique by the supply of canes at the fag end of the season.

Panje (loc. cit.) due to this variability in juice quality has suggested to make the payment on date-bound basis. He recommended lower price for canes entering the mill in early December or late March-April, compared to canes crushed in February-March, the optimum sugar, recovery period. By this suggestion, the millowner is no doubt in the advantageous position but the grower suffers. The grower who supplies cane earlier can, however, utilise his field for some other crop; but the one who supplies late suffers in addition from agricultural operation difficulties.

Attempt is now made to give some concrete suggestions for the payment of cane price on quality basis having taken into consideration the interests of sugarcane growers and sugar manufacturers. Khanna and Sen (29) have shown that the juice quality survey of all the plots (30,000 plots) in the reserved area of a sugar factory in Bihar could be completed at a non-recurring expenditure of Rs. 20,000/- and recurring expenditure of Rs. 6,000/- within 15 days.

This survey can however be completed at a lower cost of Rs. 6,000/- in all including a non-recurring expenditure of Rs. 2,000/- and at a shorter period within 7 days according to the method suggested by Sen (30). The calculation and tabulation of the data in succession of maturity have also greatly been curtailed by using puncturing needles provided with reservoirs.

Khanna and Sen (31) for Bihar and Sen for Hyderabad—Deccan have prepared a table on the basis of Statistical calculation with the past ten years data, through which the recovery percent in the mill may be forecasted within an error of ± 0.3 percent from either middle internodal brix of the standing cane or from the brix or pol% of the primary juice of the mill. This error ±0·3 percent can be easily reduced to ±0.1 percent if a similar table is prepared with the factory data individually of the past five or six years. The table thus provided for each factory will afford prediction of probable sugar recovery in the mill from the average brix or preferably from pol value of the day, which will assist in the assessment of the cane price on quality basis.

The two extreme brix limits of juice from sugarcane in a factory reserved area when examined within a week often indicate a difference of 10 brix. If the canes are supplied according to the schedule worked out by actual survey just 7-10 days prior to the actual crush in the factory, the brix variations of canes entering the mill in a day would not exceed 0.5 percent. This implies, that canes supplied in a day as per schedule all contain almost the same sucrose, the difficulty of fixing the cane price in India due to small holdings may thus be obviated. Assuming the cane entering the mill every day is of the same sucrose content, the cane price may be either fixed on the pol percent primary juice or on recovery basis. The average brix or pol percent juice can be worked out by hourly samples analysis and recovery may be predicted according to the table worked out on factory-wise basis, which is likely to indicate values correct upto ±0.1 percent. This prediction can be very well verified by actual stock taking after a week or so. At present 140 sugar factories are working in India and the table of these 140 factories can be easily worked out within six months with the help of a dozen computors, after the receipt of the required data, in this connection from all factories.

Mid January to end of March is the optimum recovery period. Growers supplying canes during this period are likely to get more price if the payment is made on sucrose content basis, than growers supplying canes in early or late crushing season. A little higher percentage of profit on the sugar produced should be fixed up for these growers (who receive challans to supply canes early or late of the season) to counter balance their cane losses. Mill owners would definitely get higher recovery in the early season and higher over-all recovery, on the basis of cane supply according to surveyed schedule than at random supply, therefore, they would not murmur to pay the price as suggested.

Assuming the cane price fixed by the Government of India is roughly Rs. 1/7/- a maund, the price of 100 maunds canes calculates to Rs 143/12/- considering the average sugar recovery in India being 9·98 percent. The price therefore, of 9·98 maunds of sugar @ Rs. 29/- a maund calculates to Rs. 289/4/-. 50% of the final product is roughly the price of sugar cane crushed, on the present market basis. The fixation on percentage basis is to be modified, this scale has been just suggested on the assumption of cane price and sugar produced.

Assuming 50 percent of the product is the cane price, then a sliding rule for fixing the cane price may be adjusted to make up the losses of the growers due to early or late supply. The following scale is recommended.

1. Nov.—Dec. 55 percent of the sugar produced.
2. Jan.—March 50 percent of the sugar produced.
3. April—May 55 percent of the sugar produced.

Inspite of lower recovery in April/May the concession has been given for the growers experiencing agricultural operation difficulties after harvest. This system of fixing the cane price will initiate quality consciousness to the growers and will produce more sugar and more dividents.

To make this scheme workable and success, it is but necessary to have the full support of Government of India and an Act may be enforced for supplying canes in succession of ripening, this will involve a great National Savings in total production of sugar and rich dividents.

It may of course so happen that after the survey there may be a sudden catastrophe, e.g., frost, earthquake, cyclones etc. These may cause damage to the cane and canes may deteriorate and the scheduled programme may not yield the objectives. In such cases, one has to deviate from the schedule and arrangement of early supply of damaged canes should be made. It has been observed by Khanna and Sen (loc. cit.) that canes deteriorate very rapidly soon after the recede of water from the water logged plots. It is advisable to issue challans first to these plots on a top priority basis.

SUMMARY

1. The survey of the entire plots (30,000) under cane in a reserved area of a sugar factory by the puncturing needle provided with a reservoir, can be done within a week at a nominal cost of in all Rs. 6,000/-.
2. Survey should be started only a fortnight before the date of crush of the factory.
3. Due to supply of canes according to the schedule on the basis of ripening, canes of almost of the same sucrose content will be crushed every day.
4. Payment of cane price may be fixed according to recovery percent of the day.
5. The recovery percent table should be prepared factory-wise according to the method of Khanna and Sen or Sen.
6. The sliding scale of payment has been suggested on the basis of the present cane price fixed by the Government of India.
   During, Nov —Dec. 55% of the total sugar produced,
   ,, Jan.—March 50% of the total sugar produced,
   and during April-May 55% of the total sugar produced,
   in the mill, is the price of the cane crushed.
7. The growers producing better quality of cane will derive more benefits and this will make the grower quality conscientious.
8. Canes under water logged area or canes affected by frost or cyclones should be crushed first in order to derive maximum benefits for both growers and millowners.

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REFERENCES

1. Avice, J. R. and Serge Staub, G.J.B. 1943. *South African Journal,* December Issue p. 589-595.
2. Walawalkar, D. G. 1936. *Fifth Ann. Conv. S. T. Assoc., India* p. 237-41.
3. Desai, M. H. 1937. *Sixth Ann. Conv. S.T. Assoc., India* p. 11-23.
4. *Tenth Ann. Conv. S. T. Assoc., India* 1941 p. 71.

5. Dutt, N. L. 1949. *Eighteenth Ann. Conv. S. T. Assoc., India* p. 100-103.
6. Panje, R. R. 1950. *Nineteenth Ann. Conv. S. T. Assoc., India* p. 27-38.
7. Aiyar, K. V. Gopala. 1950. *Ann. Conv S. T. Assoc., India* p. 255-264.
8. Colin, W. Waddell. 1952. *I. S J.* p. 310.
9. Singh, Harbans Lal. 1954. *Second Biennial Sugarcane Conf. Jullundur.*
10. Directorate of Sugar and Vanaspati (Payment of cane price on the basis of its sugar content, Development Council for Sugar Industry at its meeting, 1955).
11. Caws, A.
12. Khanna, K. L.
13. Puri, D. D.
14. Narang, D. R.
15. Das, U. K. 1942. *Hawaii Planters Record.*
16. Khanna, K. L. and Prasad, S. N. 1950. *Annual Report of Central Sugarcane Research Station, Pusa.*
17. Mukherjee, B. K. and Verma Gyanendra. 1950. *19th Ann. Conv. S. T. Assoc. India* p. 46-69.
18. Rege, R. D. and Sannabhadt, S. K. 1940. *Ninth Ann. Conv. S. T. Assoc. India* p. 71-77.
19. Paramanik, B. N., Rao, B. B. and Lal, J. B. 1937. *Sixth Ann. Conv. S. T. Assoc. India* p. 177-87.
20. Khanna, K. L. and Sen, S. C. 1952. *First Biennial Sugarcane Conf. Coimbatore,* p. 61-64.
21. Sen, S. C. 1952. *Annual Report, Central Sugarcane Research Station, Pusa.*
22. Mohan Rao, N. V., Thirumula Rao, W. and Narasimha Rao, G. 1954. *23rd Ann. Conv. S. T. Assoc. India* p. 14-25.
23. Sen, S. C. 1952. *Jour. and Proc. Inst. Chemist, India,* 24 p. 119-131.
24. Sen, S. C. and Bhattacharjee, H. 1944. *23rd Ann. Conv. S. T. Assoc. India.* p. 99-103.
25. Alvarer and Alharlaha. 1954. *South African Sugar Journal.*
26. Khanna, K. L., Chakravarti, A and Srivastava. 1953. *Indian Sugar,* July issue p. 171.
27. Mukherjee, B. K. and Sen, S. C. (Unpublished).
28. Sen, S. C. 1955. *Jour. of the Scientific Soc.,* H.B.T.I. & N.S.I. Kanpur
29. Khanna, K. L. and Sen, S. C. 1953. *Twenty Second Ann. Conv. S. T. Assoc., India* p. 134-141.
30. Sen, S. C. 1956. *Proc. 9th Congress I.S S.C.T.* p. 389.
31. Khanna, K. L. and Sen, S. C. 1937-50. *Annual Report of the Central Sugarcane Research Station, Pusa.*

Mr R. R. Panje presented the following paper.

Paper

A NOTE ON PAYMENT FOR SUGARCANE ON THE BASIS OF ITS JUICE QUALITY IN INDIA

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The principal considerations in the evolution of a system of payments for sugarcane on the basis of juice quality are :—

1. The method of estimation of juice-quality
2. Methods of organization and execution of the system selected for payment on juice-quality basis, and
3. The respective titles of the cane supplier and sugar manufacturer to share in the increased income from improved juice-quality and in the profits from the sale of sugar.

Before considering the problem as it affects conditions in Indian sugar factories, the systems prevalent* in other cane-growing countries may be briefly examined. It is true that the most important difficulty that has to be solved in India does not exist in most of the foreign countries ; viz., that of paying individually a very large number of suppliers who make up the crush of a single day. Yet, the experience of other countries would be useful and it would be possible to adapt some of the procedures to suit the conditions in our country.

Java is one of those countries where, the factories could enter into agreements with large plantations for the supply of cane. Naturally the problem of enforcement and control did not arise. The rate of payment was based on the polarization of the first expressed juice, with a correction factor for each variety mainly based on its fibre content. The title of the supplier extended to half the profits from the sale of sugar, but the supplier was also liable to bear half the losses. The important features of the Java system were assessment of juice-quality by pol with a correction factor, profit-sharing and formal agreements between grower and manufacturer.

In Mauritius, the special feature of the system is the conduct of a cane-test, somewhat similar to the mill tests conducted by our cane research stations. The cane supplied in this test is assumed to be representative of the bulk supply made by the grower, and the extractable sugar from this test sample is determined through a series of estimations ranging from brix of crusher juice to bagasse pol, fibre in cane and bagasse, and the purities of mixed juice and last mill juice. The grower gets the value of 2/3 of the sugar computed to have

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* Vide "Methods of Payment for Cane in Different Countries and the Method of Payment suggested for adoption in India" by Shri K. V. Gopala Aiyar. 19th Proc. of Sug. Techn. Association of India, p. 255. The information given above, however, is in many cases slightly out of date, as systems of payment have been considerably modified in some of the countries in recent years.

been made from his cane on the basis of the test-figures. This system is somewhat unique, where attention is paid to the estimation of sugar recovery rather than to the sampling of the raw material.

In Louisiana, the method of determination of the share of the grower differs from place to place. The growers' cane is sampled from the wagons as they arrive and the sample is crushed in a laboratory mill. Certain apparently arbitrary, but presumably well-based corrections are applied to the laboratory-mill figures. Payment is based on pol by laboratory analysis only, and no account is taken of the other factors that affect the recovery of sugar. It is to be presumed that these are allowed for in the summary correction factor applied to the lab-mill figures. The schedule of payment names cane of a certain quality as 100% standard cane. For cane of this quality, the grower gets paid approximately at the rate of one dollar per ton for every cent in the prevailing price per lb. of sugar. For every 0·1% sucrose difference in favour of the cane supplied, the quality index increases by 1 unit over the 100% (standard). On this basis, if the quality of the "standard" cane is fixed at 10% recovery and the cane supplied by a grower is of standard quality, the grower gets 50% of the value of the sugar made from it; and for any improvement over the standard also, he gets the same 50% benefit. This means that the factory keeps apart of the benefit from improved juice quality. Also, the rate of payment viz., $ 1 per ton per c itself varies on a sliding scale such that when the price of sugar falls below 3½ cents per lb., the grower is at a slightly greater disadvantage than the manufacturer, whereas when prices are higher he gets a slightly bigger benefit of the increase. These figures are of course on the pre-war level.

The principal features of this somewhat complex and variable Louisiana system is the unusual simplicity of the sampling system for cane, the lab mill analysis as the basis of payment, and the variability in the growers' share of the profits. Whether, all the complexity and schedules notwithstanding, the payments are based on a correct estimate of the cane quality and whether the sliding scales are equitable, can be decided only with a more intimate knowledge of the conditions affecting the industry in Louisiana ; under our conditions, lab-mill analysis of 3-4 stalks of cane would probably not be considered a very reliable system of sampling.

It is not surprising that in the only other country where cane is grown and supplied to factories by small peasants and farmers, namely Cuba, the raw material should be paid for by weight alone and no account should be taken of its juice quality. One may also take note of the fact that under these conditions, in Cuba also, the quality of cane supplied is not high, for the grower naturally does not concern himself with the sugar content of his cane ; in fact, it is stated that with the effect of quotas on sugar production, the system there actually "acts as a direct stimulus to the production of cane with low-juice-quality."

In Puerto Rico, the colonos are not as small growers as in Cuba, and it is therefore possible for factories to estimate the juice-quality of individual lots of cane supplied by them. Here again, simple sucrose % juice value is adopted to represent sucrose recovered, a rough-and-ready index, quite suitable where too much variation in cane does not exist. The cane supplier apparently shares in the profits from the sale of sugar.

In South Africa, the basis for calculation of the quality of cane is the sucrose % of the crusher juice which is multiplied by the Java Ratio to get the sucrose % cane which again is multiplied by an efficiency factor to arrive at the sugar recovery. The value of cane is determined by the division of the price at mill value of 96° sugar in the proportion of 64·3 percent to cane and 35·7 percent to sugar.

Of special interest to our country is the system in vogue in Queensland ; here, the formula used for calculating the sugar recovery, known there as the C.C.S. formula, and in India (in a slightly modified form) as "Srivastava's formula" is comparatively simple, although it calls for determination of fibre % cane in addition to brix and sucrose content. Juice samples are analysed and fibre determined by a Government Check Chemist for every 30 tons of cane crushed. The sugar extractable from the cane supplied is then calculated applying the C.C.S. formula. The payment for cane is on the basis of the C.C.S. In many of the mill districts, a scheme called the Relative Percentage System is in vogue. Under this scheme, the average cane price is worked out for the whole season and the cane supplier receives payment either at this price rate each week, or at a proportionately higher or lower rate according as his cane quality is equal, superior or inferior to the average quality for that week. Another special feature of the Queensland system is that the supplier is paid at a fixed and presumed efficiency rate of sugar extraction, whatever may be the actual rate of extraction by the factory. This gives the factory the benefit of its own improvements in the processing of sugar.

METHOD OF ESTIMATION OF JUICE QUALITY

In deciding the method of estimation of juice-quality under Indian conditions, emphasis has necessarily to be firstly on speed and simplicity of procedure both for sampling the raw material and the determination of quality ; and secondly, on the equity of the formulae adopted. It will be readily conceded by all who have experience of it, that sampling of cane is difficult, uncertain, laborious as well as inefficient at its best ; it cannot be therefore advocated under any circumstances for the object in view. On the other hand, sampling at the juice-stage has all the advantages, including the reliability of a well-mixed sample and the facility of sub-sampling ; further, juice unlike cane lends itself well to the use of mechanical devices. Crusher juice would be the best stage for sampling in the milling train, and the simplest formula for assay would be the Winter-Carp duly adjusted for our conditions in the light of the past 25 years' experience in cane milling in different parts of India. The Winter-Carp formula takes into account the effect of fibre-in-cane at a fixed value and admits of modifications necessitated by changes in fibre when necessary. The C.C.S. formula is definitely better, but the difficulty in adopting it is that it involves a fibre determination ; the latter is somewhat time-consuming, and is more liable to errors than juice-pol. Brix alone would be the quickest determination, but it is not a sufficiently accurate indication of recoverable sugar. Although Winter-Carp does not actually predict the yield of sugar, for a quick estimate with fair accuracy, it is unexcelled.

As regards considerations of equity, in so far as it concerns the method of analysis, once the ratios and constants of the formula are carefully and fairly decided, there need be no further difficulty, or at any rate, no occasion for a daily difference of opinion or a break-down of the system. The spade work of fixing the constants in initial stages would, however, have to be done after very thorough surveys of cane quality, fibre and recoverable sugar, for admittedly fibre value is a factor of great importance and has to be taken into account in fixing the constants ; due to this the formulae will differ from region to region. A change in the varietal composition will also involve slight readjustments, but these can be mutually agreed upon at the start, in close consulation with research stations and technologists and with the help of adequate data from milling tests.

Needless to say, the juice-quality determinations at the crusher-stage have to be done by Government-paid Chemical Assistants (3 per factory i.e., one for each 8-hour shift) stationed at the factory. Stationing of chemical staff by Government is not unusual in industrial establishments and this should present no serious difficulties of any kind.

METHOD OF ORGANIZATION AND EXECUTION

In regard to payments, our chief difficulty is the large number of suppliers concerned in a day's supply. Augmentation of gate supplies by rail-borne outstation cane is an additional complication. Nor is the difficulty merely one of numbers ; it is one of sampling as well ; for the cane delivered by different growers gets mixed up in the hopper to a considerable extent before it is crushed. The only way to overcome this difficulty is to assay samples from larger quantity of cane, and the only manner in which this can be done is to group the suppliers and arrange their supplies in such a way that all growers of one group bring their cane at the same time. Mixing of successive lots of cane in the hopper can be avoided with a minimum of attention. Although to the extent the suppliers are grouped, this method falls short of the ideal, it is certainly a vast improvement over the present system which takes nothing into account except the dead weight of cane ; and it is definitely in the direction of rationalization and equity.

Since under the Winter-Carp formula payment has to be based on polarization and brix of juice, it would be possible to assay only about 3 samples per hour. In 20 minutes at full crushing in a 1,000-ton factory, about 15 tons of cane will pass through the crusher and this will be 8 to 10 cartloads. Thus the juice-quality estimation made on one sample will determine the price to be paid to about 10 cultivators. This fixes the size of the suppliers' groups to about 10. It should not be difficult to organise supplies in such a fashion that cane is delivered by successive groups of about 10 growers each. In factories with larger capacities, the groups will have to be larger.

The first criticism of the suggestion for grouping the suppliers would probably be that by grouping, the supplier with a better-quality cane would be put to loss while the poor-quality supplier would undeservedly benefit at his expense ; the answer to this is that this is so in all co-operative and joint efforts between people -- it has to be so till the scheme adjusts itself and people learn how to work it. In any case when the better-juice-quality grower finds his income affected by the company he keeps, he will take care to choose his co-suppliers more carefully in the next season.

A more important objection to the grouping system is that the estimation of juice-quality made at the crusher stage can be employed, if at all, only for gate-cane, and is of no use in respect of cane delivered at weighment centres. Actually, however, the group-payment system can well be extended to include outstation cane too. The grouping here would be by the wagon-load and the hopper has to be loaded exclusively from one wagon at a time ; only the transport of wagons should be quick and very regular.

In bringing into effect grouped supplies, a certain amount of planning and prior-organization would be necessary. Village groups are likely to be the best in every way. At first, there may be many objections on the part of some growers to pool their cane with that of others ; where this objection is reasonable, e.g., when it is based on, say, variety-difference, it can be easily avoided by advance planning by the groups at the time of planting. Other objections not so well based will gradually disappear with the promotion of a sense of mutual trust and joint obligation.

A very important contribution to this whole scheme would be the provision of quick and efficient transport. If cane from different growers is pooled in the village itself, it would save much difficulty.

TITLES OF GROWER AND SUPPLIER

One of the most important points to be decided in respect of increased income through improved juice-quality is whether a standard should be adopted for calculation what may be called a "quality-bonus", or whether the entire value of the payment for the cane should be linked to the juice-quality estimate. The latter method is in vogue in Java, Puerto Rico, Hawaii and Mauritius whereas in Louisiana and Queensland the grower has a "standard" or "average" quality to go by. This "Standard" does not really make any difference to payments, except where the income from the improvement in quality over the standard is entirely credited to the grower. For even though the "standard" or "average" is recognised in Louisiana, the system does not credit the entire proceeds of the improvement in juice-quality to the grower ; the factory keeps out of it the same share as it does out of the bulk processing. In Queensland, on the other hand, the principle adopted by the Central Cane Price Board is that the miller is to benefit to the full extent by any increase in factory efficiency in excess of 90 and the grower to obtain the full benefit or bear the loss of any increase or decrease over the value 12 for C.C.S. according to their formula. This system appears to be not only the most equitable, but also the most progressive, as it contains in itself independent incentives to improvement of production.

Under our conditions, the proper course would be to assume the present structure between cane costs and manufacturing costs and the cost of production of sugar as having been established more or less on an equitable basis (or alternatively to arrive at an agreed rate of sharing) and then fix the schedule of payments for improved recovery on a "quality bonus" basis ; this quality bonus should be the entire income from the presumed increase in the output of sugar as calculated by the Winter-Corp or other formula, less small incidental charges such as extra cost of centrifuging, drying, bagging, bags and transport which the factory has perforce to incur as a result of the extra sugar produced. Indeed considering the need for improving the juice-quality and the advisability of placing the entire system on a progressive basis with regard to juice-quality, such a "quality bonus" arrangement involving maximum possible payment to the grower is not only sound from the point of view of equity, but is also the least that can be done to put the industry on a progressive basis.

Under this scheme ; the average price of cane for the whole season is calculated taking into account the accepted cane costs and manufacturing costs, and the recovery obtainable. The season is divided into, say, weekly periods and the average quality of the cane is worked out for each week as also for the entire season. Every grower or group of growers whose cane, delivered in any one week, is upto the average quality of all cane delivered during that week receives the average price of the whole season. This price corresponds to what is now the "minimum price of cane". It is calculated as follows :

Suppose the season's average quality of cane (C.C S.%) and recovery in a factory are 11% and 10% respectively. If Rs. 20/- is taken as the net ex-factory price of sugar per maund after deducting excise duty, taxes, etc., ⅔rd as the share of the grower and 90% as the co-efficient of efficiency, the average price of cane for the season would be—

$$\text{Rs. } \frac{20 \times 11 \times 0{\cdot}9 \times 2}{100 \times 3} \text{ or Rs. 1-5-2}$$

This is the average price of cane to be paid for all cane having an "average periodical quality" (C.C.S.%) during the whole season.

The average periodical quality varies during the season somewhat as follows :

1st week December	9·20
2nd week December	9·50
3rd week December	9·80
4th week December	10·15
1st week January	10·40
2nd week January	10·70

and so on.

Cane having a sugar content above the average of the week in which it is delivered for crushing will be paid for at a proportionately higher rate and cane falling below the "average periodical quality" at a proportionately lower rate. The "quality bonus" will be the entire value of the additional sugar produced due to better juice quality, less incidental costs. Thus the price will be linked to normal progress of maturity of cane. If this is not done, the supplies in early season will be seriously jeopardised.

The quality bonus and discount are calculated as follows :

If the incidental cost borne by the factories due to the extra sugar produced is Re. 1/- per maund, the unit price for every unit increase or decrease in quality of the cane of the individual group of growers over the average quality during the period, which should be added to or substracted from the average price of cane for the season will be Rs. (20—1) 0·009, or 2·74 annas, when the ex-factory price of sugar, less taxes, is Rs. 20/-.

The crediting of the entire net proceeds of sugar produced as a result of improved cane-quality to the grower is an important principle, which should not be overlooked or modified. There need be no grievance either, since the principle is to ‘ give everyone his due". For just as increase in output of sugar brought about as a result of improvement in the juice-quality of cane is not an item for the factory to share in, similarly an increase in sugar-yield affected through improved manufacturing technique is not an appropriate profit for the grower to share in. The actual quantity of sugar recovered by the factory therefore need find no place in the formulae of payments to the grower. This system of independent incentive has the advantage of forcing the less efficient factories to come upto the minimum standard instead of wasting national wealth by inefficient methods ; it would also give the more progressive ones their due, and encourage them to further progress. Care should of course be taken not to fix the first co-efficient in the Winter-Carp formula too low, lest the below-par factories stagnate in their present efficiences. Fortunately, the working data in most factories, as at present shown, speak well of their boiling and milling efficiencies, and factors, one for each varietal-climatic tract, based on the average working efficiency of all the factories in the area should be quite satisfactory for basing the payment-formulae upon in that area.

Finally, there is the question of net profit sharing. Normally the question of the grower's sharing the profits or losses accruing to the manufacturer should not have come into the consideration of problem of payment on juice-quality basis, but it so happens that in most countries including Louisiana, Java, etc., the cane grower's income is linked directly to sugar prices. There is no reason why the grower should not be a co-sharer in the entire-sugar-transaction ; though we in India have been used to regarding the grower and manufacturer as independent, and to accepting that once the factory-owner purchases the cane and pays off the grower, the sugar is his to do what he likes with. One may be equally right in considering that it is the grower who produces the sugar and sells it in the market, and that the manufacturer is merely a processing agent, paid for making sugar out of the grower's cane at so-much per ton.

The difficulty in this is not one of the principle but one of practice. An additional factor for selling-price of sugar can certainly be fitted into the schedule based on juice-quality, but there may be difficulty in respect of payments. While cane is sold during only 3 months in the year, sugar is sold throughout the year. The question naturally arises which price of sugar is to be taken into account for proportionate sharing with the grower ? The prevalent sugar price at the time of supply of cane was once tried to be linked with cane price in U. P. and Bihar, but this had to be given up ; for the sugar price generally remains low during the crushing season and rises in the off-season. The whole year's average would be reasonable, but this means serious deferment of payments. We have now an expanding economy and a rising market for sugar, and grower's share can be made good even as deferred payments, but the problem is to make adjustments to the debit of the grower in a falling market. Refund from the grower can be avoided only by making partial payments in cash for cane in anticipation of losses, but this is a proposition to which no grower would easily agree.

Under the circumstances, it would perhaps be in keeping with our past policies to assure a fair price to the grower linked to the weekly average juice-quality, and fix a schedule for a quality bonus (or penalty) for every plus (or minus) unit in his juice quality. As said before, in this, care should be taken to ensure that the grower gets the full share of the income from the increased output attributable to his improved juice-quality, so that above the figure corresponding to the average recovery, he gets all the income, less incidental charges. The question of profit-sharing need not arise now, since the immediate need of the country is the stabilization and a gradual, orderly reduction in prices of commodities, and this is far more important than procuring for the grower a share in sugar profits. This would be practically needlessly inviting the grower to join the speculation business in the sugar market, which the grower, already exasperated with the weather-and-crop risks on his investments, would perhaps be in no mood to enter. Perhaps, he would be only too glad to get a steady payment for his produce consistently with its quality. It would be much better to control the sugar price according to a reasonable price-structure and to plan a reduction in the price of sugar over a period of years, rather than find formulae for apportioning between the grower and the factory-owner the profits or losses arising out of sugar sales in the open market.

Mr. M. Lakshmikantham presented the following paper.

Paper

ON FIXING CANE PRICES

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INTRODUCTION

Fixation of cane prices equitably is a problem of great magnitude in a country like India, if statutory action is contemplated on an all India basis. Even though a large part of the cane produced in India is crushed for jaggery manufacture, quite a considerable quantity (20-25%) is supplied to sugar factories for white sugar manufacture. Unlike in some of the other sugar producing countries, the number of cane suppliers involved is large and costs of cane production vary widely in the different states. Hence fixation of a common price for the whole of India satisfying a majority of growers as well as the factory owners is extremely difficult.

Payment of cane on quality basis is an unexceptionable principle. But where large number of cane suppliers as in India is involved, evolution of a workable basis for price fixation appears apparently impracticable.

It has to be admitted that except in an 'adhoc' manner, when some higher price was paid in certain seasons to a few varieties (considered richer than the normally supplied canes) or long duration crops (adsali) that facilitate commencement of crushing early, no systematic and specific attempts seem to have been made to ensure supply of rich canes for crushing by paying appropriate premiums. A plea is made in this paper to make the cultivators quality conscious by payment of suitable 'bonus', and certain steps have been suggested for adoption towards this end. The conditions obtaining in the Andhra State form the main basis of the observations made in this paper.

REVIEW OF LITERATURE ON CANE PRICE FIXATION

The methods of cane price fixation in different countries were reviewed by Spencer and Meade 1945(1). Lakshmikantham 1948(2), Gopala Iyer 1950(3), and others. Paboa and Davila 1950(4), reported that the percentage share of the cane supplier in the quantity of 96° sugar produced increased from 63·5 to 67·5 when the sugar yield percent cane increased from 9% to 14·50% in Puerto Rico. The share of the miller decreased to the extent that of the cane grower increased. According to Locsin 1953(5), the percentage yield of raw sugar to each colono in this country, is determined by analysing crusher juice samples continuously. "In Philippines payment for cane is based on a division of the sugar produced between planter and miller on 63 : 37 basis. Continuous crusher juice first expressed samples are taken and analysed for pol and purity. Every week the actual sugar production is correlated with calculated production and planters' share determined. From the analysis of first expressed juice a fixed table of recoveries is worked out, based on 94 mill extraction, 34 gravity purity of molasses, 96·5° pol of sugar and 93·5 Java Ratio. In Louisiana the value of cane is directly related to price of raw sugar. The cane purchase contract defines a range in the sucrose content of the cane within which one ton of net actual cane, equals one standard ton. Generally one sucrose sample is taken for each 50 tons of cane delivered. Each sample consists of 3 to 12 stalks. In Cuba, mills pay cane in percentage of 96° sugar, regardless of cane quality. The juice is continuously sampled on predetermined lots of the grower's weekly deliveries in Queensland, fibre and C.C.S. are estimated and cane is paid on the basis of C.C.S. percent. Full details of the procedure adopted in recent years in the making of a price scale for payment of cane in this country were described by Macgibbon 1951(6). To make the calculation of C.C.S. more accurate Kerr 1952(7), suggested installation of juice weighing scales in all mills. According to him the total weight of cane sugar and impurities taken into the factory can then be assessed accurately and so the true C C.S. in cane.

The methods of payment adopted in Cuba (flat rate) and Queensland (based on C.C.S. % cane) may be characterised as the simplest and most rational respectively. The case of India is somewhat similar to that of Cuba in this respect. Cane price is being fixed on a flat rate, in both the countries. But while the flat price is a pre-determined percentage of 96° sugar on the weight of cane in Cuba, no apparent link is discernible between cane price and quality of cane or price of sugar in India.

The disadvantages of fixing a flat price "when the same price is fixed for wood and water as for sucrose' are obvious. Any system based on juice analysis is superior to a system based on flat price regardless of cane quality. But as Spencer and Meade put it " it is doubtful whether complicated methods of calculation result in a more equitable distribution than do the simple systems which have been worked out through an economic custom". Gandhi 1945(8), detailed the various steps taken in India for statutory fixation of cane prices by the Central and State Governments. Till 1934, the price of cane was fixed on demand and supply and there was no legislation fixing the minimum price of cane. The Sugar Technologist to the Imperial Council of Agricultural Research suggested, towards the end of 1933, that the price per maund of cane should be equal to half the cost of sugar made from it. A statutory irreducible minimum price was fixed for the first time in 1937-38 in the U. P. and Bihar. Two years afterwards U. P. and Bihar decided to fix the minimum price based on fortnightly sugar prices. But this policy was short lived and was changed from 1940-41 to non-varying minimum prices. In subsequent years other provinces like Madras, Mysore and Hyderabad fixed minimum price for sugarcane. It will be evident that, but for the formula suggested by the I.C.A.R. there had been no attempts to correlate quality of cane with its price. During 1948-49 season the South Indian

Sugar Mills Association drew up a memorandum suggesting fixation of a basic minimum cane price and giving a share in surplus profits realised by millers when sugar prices ruled high. This formula popularly known as 'SISMA' formula introduces indirectly a premium in the price paid to the cane supplier. As per this, the price payable for cane by any factory ranges between 55% to 70% of the net price of sugar when the price of the later varies from Rs. 440/- to Rs. 940/- per ton. The return to the agriculturist improves by 3 percent for each slab above Rs. 440/- of sugar price. By dividing the share of the net sugar price to the agriculturist with the number of tons of cane used in the production of one ton of sugar, the price per ton of cane is worked out. Actual application of this formula for payment of cane price was tried on an agreed basis between the cane growers and factory owners for only one year during 1952-53 in the Madras State.

In recent years the Government of India have taken up the fixation of minimum cane price and the basis on which prices are being fixed, have not been clearly indicated. The minimum is being announced two seasons in advance to put the cane supplier as also the manufacturer-wise about the possible returns they may expect in the coming season. During 1954 a formula was evolved, at the instance of the Government of India, based on the principle that the cane growers should get the same percentage of the net price of sugar as is the percentage of the cost of cane to the cost of production of sugar excluding taxes. This formula is in the first instance to be applied for payment of cane crushed in 1953-54 season. According to this formula the percentage share of the net price of sugar to cane growers ranges between 53% in East U.P. and North Bihar, to 60% in West U.P. and Bombay The share of the growers as per this formula is found to be much lower than what the cane growers are reported to be getting in countries like Puerto Rico and Philippines. It has also been noted that the cane growers of the Andhra state realised invariably lower prices than what they would have got according to SISMA formula.

SPECIAL FEATURES OF THE INDIAN SUGAR INDUSTRY IN REGARD TO CANE PRICE FIXATION

Since cane holdings are small, the number of cane suppliers in this country is, as already mentioned, very high. Estimation of quality of cane supplied by individual ryots is therefore difficult. Another peculiar feature of this country is the vital influence of jaggery prices on the cane supply to sugar factories. In years of high gur prices factories are starved for cane and have an uneconomic crushing season. Duration of crushing, thus assumes unusual importance in this country with regard to cane price fixation unlike in other countries. Under the existing conditions it is not possible to reckon without it.

According to the latest Tariff Board Report of 1950(9), on the sugar industry, Panje suggested date bound variation in cane price payment in the interests of lengthening the duration of crushing. It is claimed that the scheme provides for variation in cane supply according to demand and supply at the different parts of the crushing season. As per this, during the early part of the season when gur price is high, even though the sucrose content is low, the scale of payment should start with a moderately high price and slowly increase at regulated interval so as to reach the highest level at the peak of the season. In the later part of the season, when the sucrose content goes down and when cultivator is anxious to clear the field, the price will be slightly lower than the peak level. It is suggested that the scale of variation of price over successive intervals of time may be so drawn up that the average of the prices paid will be approximately the same as the minimum price paid by the Government. No provision is made in this scheme, for encouraging supply of rich canes nor will be cane suppliers have a share in the surplus profits derived by millers when sugar prices soar high.

A proposal to link duration af crush with payment of bonus as per SISMA formula, was first mooted by the Sugarcane Specialist, Anakapalle, by circularising all the sugar mills in composite Madras State in 1953. M/s Parry & Co., propounded a modification of the SISMA formula recently, apparantly based on this suggestion. They proposed payment of full additional price according to SISMA formula (which they termed as bonus) only when a factory crushed to its full rated capacity for over 70% af the normal season. According to them normal season is to be taken as 120 days of working. The rate of bonus is to be proportionately reduced when the duration of the crush is shorter, and completely eliminated, when it is less than 50% of the economic crush.

SUGGESTIONS FOR CANE PRICE FIXATION

Basic minimum price. The Indian Tariff Board (1950) suggested that besides cost of cultivation (a) estimated return to the grower if he converts his cane into gur, (b) quality of cane, (c) probable estimated return to the grower from alternative crops, (d) parity prices of important articles of consumption for the cane grower, such as food grains, should be taken into account while fixing prices of cane. During the period 1933-36 the Imperial (now Indian) Council of Agricultural Research sought to estimate the cost of production of sugarcane in the sugarcane tracts in India directly. Village investigators were stationed in select villages and they noted the labour employed and cash expended in raising sugarcane in select holdings. The statistics collected have been published. These do not seem to satisfy the present statistical standards. A scheme of work is now again in progress for collection of data on cost of cultivation of sugarcane in factory areas of select states. The nature of work in this scheme seems to be identical with that carried out previously. Field investigators have been employed to collect the data on the basis of objective observations. The selection of village holdings, however, had been done according to the stratified random sampling method. How far the statistics of production collected in this scheme will satisfy the cane cultivators as basis for assessing cost of production, remains to be seen.

In order to improve accuracy in maintenance of accounts, it seems desirable to entrust this work to Agricultural graduates of the rank of Assistants and not to the village or field investigators. This scheme should be worked on a permanent basis since cost of production changes from year to year. The fields or villages may be changed to satisfy the statistical standards. Apart from the actual cost of cultivation, other items of expenditure that are to be included in the cost structure of sugarcane, such as repairs and renewals etc., have also got to be worked out each year to arrive at the basic minimum price. Information on the parity prices of commodities needed by the cane cultivator as also the returns he gets by taking to alternate cropping or converting his cane into gur has also to be gathered by the investigator. The principles that should govern the relationship between these items of expenditure and the actual cost of cultivation have got to be established in consultation with economists. If agricultural graduates are employed in the collection of basic data they will be able to furnish reliable information that facilitates working out these principles. The basic minimum price thus worked out in a year will be applicable to the next year. This basic minimum should not be fixed on an all India basis. It has to be only on a State level.

SHARE OF INCREASED PROFITS TO BE PASSED ON TO GROWERS

The attempts made from time to time by the Sugar Mills Association, individuals or Government to enunciate the principles of profit sharing between the mills and the cane suppliers have been briefly described in the foregoing pages. The original SISMA formula favours indirectly supply of quality cane. But it encourages, the millers and the growers to bargain for exhorbitant sugar prices because the share of the profit, especially that of growers progressively increases with increase in sugar price. The formula suggested recently by the Government of India does not seem to benefit the cane suppliers of this part of the country (Andhra State) for, the price as worked out in certain factory areas according to this formula was, lower than even the statutory minimum price by about one rupee per ton. Hence a modified formula laying emphasis on the quality of sugarcane is suggested and described in the sequel.

When the sugar recovery percentage is 9% or below it, the minimum bonus as proposed by M/S Parry & Co., may be paid. For every slab of 0.5% increase in sugar recovery 5% increase in the proposed bonus is suggested when the duration of crush is over 50% of the normal. Details of the modified formula are embodied in Table I.

TABLE I

FORMULA FOR DETERMINING THE AMOUNT OF BONUS (EXTRA* OVER MINIMUM PRICE TO BE PAID FOR CANE) IN RELATION TO DURATION OF CRUSH AND PERCENTAGE RECOVERY OF SUGAR

Quantity of actual cane crushed as a percentage of normal crush	Percentage of bonus to be paid at different levels of sugar recovery			
	9.0% and below	9.50%	10.00%	10.50% and above
upto 50%	10	10	10	10
51%—55%	20	25	30	35
56%—60%	40	45	50	55
61%—65%	60	65	70	75
66%—70%	80	85	90	95
over 70%	100	105	110	115

* The extra price or bonus is to be arrived at according to the SISMA formula.

Assuming the gross price per ton of sugar to be Rs. 850/- and the statutory minimum cane price as Rs. 1/7/0 per maund the extra amount payable per ton of cane for different recoveries and durations of crush has been worked out and presented in Table II.

TABLE II

EXTRA AMOUNT PAYABLE PER TON OF CANE FOR DIFFERENT DURATIONS OF CRUSH

Duration of crush	Amount of bonus payable as per revised formula per ton of cane at different recoveries			
	9% and below	9.5%	10·00%	10.5% and above
upto 50%	0.1001	0.3278	0.5553	0.7828
51—55%	0.2002	0.8195	1.6659	2.7398
56—60%	0.4004	1.4751	2.7765	4.3054
61—65%	0.6006	2.1307	3.8871	5.8710
66—70%	0.8008	2.7863	4.9977	7.4366
Over 70%	1.001	3·4419	6.1083	9.0022

N.B.—Gross price of sugar — Rs. 850/- per ton
Minimum price of cane — Rs. 1-7-0 per maund
(Rs. 39.130 per ton)
Excise duty — Rs. 112.5 per ton
Sales tax — Rs. 11.523 per ton
Sales commission — Rs. 7.375 per ton

The increased monetory benefit to the sugar factories due to higher recovery has been worked out with reference to a 600 tons factory for different durations of crush and the figures are furnished in Table III.

TABLE III

QUANTITY OF EXTRA SUGAR MADE DUE TO HIGHER SUGAR RECOVERY AND THE EXTRA NET PROFIT MADE DUE TO INCREASED PRODUCTION OF SUGAR

Percentage of crush	Quantity of cane crushed Tons	Quantity of sugar made in tons at recoveries				Additional quantity over 9% recovery due to increase in recovery Tons			Gross price of increased quantity of sugar made at higher recoveries at Rs. 850/- per ton			Extra profit made by the factories		
		9%	9.5%	10%	10·5%	9.5%	10%	10.5%	9.5%	10%	10.5%	9.5%	10.0%	10.5%
									Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
50%	36,000	3,240	3,420	3,600	3,780	180	360	540	1,53,000	3,06,000	4,59,000	1,17,151	2,34,309	3,51,467
55%	39,600	3,564	3,762	3,960	4,158	198	396	594	1,68,300	3,36,600	5,04,900	1,13,359	2,17,724	3,13,081
60%	43,200	3,888	4,104	4,320	4,536	216	432	648	1,83,600	3,67,200	5,50,800	1,06,305	2,00,816	2,86,500
65%	46,800	4,212	4,446	4,680	4,914	234	468	702	1,98,900	3,97,800	5,96,700	91,344	1,72,098	2,42,204
70%	50,400	4,536	4,788	5,040	5,292	252	504	756	2,14,200	4,28,400	6,42,600	75,419	1,39,452	1,92,020
100%	72,000	6,480	6,840	7,200	7,560	360	720	1,080	3,06,000	6,12,060	9,18,000	74,952	1,33,729	1,68,005

Taking the lowest increase of 0·5% recovery and a minimum crush of 50% of the normal or economic crush, the distinct advantage to the factories in encouraging quality will be evident from the following figures.

Value of extra sugar made due to 0·5% increase in recovery over 9% at 50% crush	Rs. 1,53,000
Less	
(1) Additional bonus that has to be paid on cane crushed in 60 days (50% normal crush) 600 × 60 tons = 36,000 tons @ Rs. 0.3278–0.1001 per ton	Rs. 8,197
(2) Excise duty, sales tax and sales commission on 180 tons of sugar	Rs. 23,652
(3) Additional expenditure in handling etc., of 180 tons of extra sugar made due to increased recovery and allowing for any incidental expenditure (assumed)	Rs. 4,000
Total deduction	Rs. 35,849

The net additional profit to the miller will thus be about Rs. 1,17,000/- for ½% increase in recovery over 9% even with only 50% of the normal crush.

ENCOURAGING QUALITY IN INDIVIDUAL HOLDINGS

These things apart, if sugar production is to be cheapened no stone should be left unturned to make the cane suppliers quality conscious as emphasised at the outset. This consciousness has to be brought about only by providing additional inducement to individual suppliers of rich cane in the form of extra payment apart from the general benefit that accrues due to payment as per the formula suggested above. For this, there is need to estimate the quality of cane separately supplied by individual cultivators. Even though the problem at first sight appears stupendous, it seems capable of solution.

Full details in respect of the cane crops in the reserved area of each factory should be in the possession of the respective factory authorities. Harvest programme has to be based on certain accepted general principles. Ratoons have to be cut first followed by plant crops. Ratoons of early maturing varieties, plots that were ratooned earlier, plots that were waterlogged or that do not command adequate water supply late in the season, have to be given priority. For plant crops, date of planting, nature of variety and level of manuring are important criteria that should govern the issue of cutting orders. A quality survey of all the fields in the reserved area of each factory has got to be conducted by means of hand refractometers in December. This should guide harvest control.

A cart load of cane in this State (Andhra) weighs about a ton. Each cane grower has to supply a minimum of two tons of cane every time. Then it is possible to arrange for continuous sampling of juices by instituting a sampling device like the Sivyer Sampler, or by employing human labour. It has been reported that the automatic method of sampling has been perfected by means of a modern mechanism installed at Victoria Mill in Queensland recently (10). "It consists of a juice collecting tray and pipe through which the juice is pumped to a series of containers in the form of segments mounted on a circular table in the laboratory. When there are two tandems, two such tables are installed. Juice analyses are made by the shift chemist. The accuracy of the system depends on accurate timing which is accomplished by the operation of a Strugnell Wheel. On the edge surface of the wheel, spaced holes accommodate pins which are inserted to show the end of a sample and the commencement of the next sample, the space between pins representing the neutral or the flushing period. As the carrier moves upward the wheel revolves and as the end of the sample passes through the rollers, the pins denoting the end of that sample operate a switch on the motor. This moves the sample can into its neutral position and at the same time cuts off the flow of juice. Then as the next sample is passing the rollers, the next pin touches the control switch which moves the next sampling can into position, turns on the juice flow and starts the motor again which draws the juice to the vessel". Wherever there is no provision for electrical operation of this automatic sampling mechanism, it is possible to engage persons for juice sampling by suitable arrangements to mark the beginning and end of crushing of every parcel of cane dumped into the carrier. A carrier supervisor should note the names of the individual cane suppliers in the order in which their cane is loaded into the carrier. There should be a separate person for signalling the juice sampler with regard to commencement and closure of crushing of cane from individual suppliers.

Certain practical considerations as detailed below have to be taken into account while devising means to analyse canes supplied by individual growers in small lots.

1. Cane is not put into the carrier directly from the cart or lorry at times. It is stocked, when a breakdown occurs, the stocks accumulate and it is impossible to stock cane got by each individual separately.
2. When cane is supplied in the cart loads, the number of samples to be analysed will be very high in the case of plants with large crushing capacities
3. When cane is brought in rail wagons from out stations analysis of cane belonging to individuals is not possible.

Under these circumstances when uniform conditions of cane supply do not obtain automatic juice sampling methods will not be of much avail. Human labour may be employed for sampling and the following procedure adopted in working out the scheme.

Two tons has to be the minimum limit for each individual supplier per day in the case of factories crushing about 500 tons per day. When the capacity is higher the limit has to be increased proportionately in the interests of convenience. For a thousand ton plant, it may be 4 tons (to last for about 5 minutes crushing). In the case of rail cane each wagon should be arranged to be filled by cane belonging to two neighbouring ryots who grow the same variety and whose soil and cultivation conditions are as far as possible similar. The analysis of composite juice sample from the canes in the wagon has to be made applicable to both the ryots. The issue of cutting orders has to be so arranged that one acre of produce belonging to an individual is sent to the factory in a maximum period of 15 days, supply being continuous till the field is cleared. The number of samples to be analysed may be limited to four per acre from the same field and juice sampling may be done only when cane is directly unloaded on to the carrier without stacking. Care has to be taken to see that four samples of the required size are got from each acre of sugarcane any time before it is completely harvested and their percent pol is to be estimated in the manner described below.

The Java Ratio calculated for a whole day of crushing may be taken as applicable to all the individual parcels of cane, for calculating their pol reading. Since pol percent crusher juice is estimated, the pol percent cane can be arrived at by multiplying this with Java Ratio in respect of each parcel of cane. The average pol percent cane for each fortnight will be worked out and cane parcels that recorded a substantially higher pol reading (say more than 1%) than this average will be paid a premium.

Pol percent cane may also be estimated by adopting a suitable equation such as the one recently suggested by Ramanayya and Ramachandramurthy 1954(11), in which refractometric brix of primary juice is used as an index of pol in cane. According to these authors this equation will be as follows :

$$Y = 0{\cdot}05\,x + 2{\cdot}335$$

where Y = pol % cane and x = refractometric brix. The limits of pol reading which earn a premium may be fixed with reference to the average quality of cane usually crushed in any particular factory each fortnight. Even though this is an approximate way of determining cane quality, it is expected that the emphasis on the quality of raw material will be increased and the 'atmosphere' will change for the better. There is no need for introducing penalties for poorer quality canes because better quality is being paid a premium. Penalties tend to defeat the purpose of improvement in quality.

The financial implications of estimating quality of cane supplied in two tons (or more) lots each time was worked out in one instance in the case of a factory of 500 tons crushing capacity. The scheme was worked for about a week employing human labour. It seemed possible to sample juices, estimate pol and work out extra price etc., by spending about Rs. 6,000/- on the organization in a season of 120 days crushing even when all the cane lots supplied by each individual were sampled. To instil confidence in the minds of the cane suppliers, juice analysis has to be done by Government employees, and the system of calculation may also be scrutinized by the Inspectors of Factories. As compared to the profit that accrues by improvement in sugar recovery, the amount spent in estimating the cane quality has to be considered negligible (Table III).

This extra payment to individual suppliers for quality has to be, in addition to the bonus proposed to be paid for passing on surplus profits, due to enhanced sugar prices and general improvement in sugar recovery.

The top limit of the share of cane suppliers in the net price of sugar actually realised by millers, (excluding excise duty and direct taxes) may be kept at 70% taking into consideration both the basic price as also extra bonus offered by the factory owners. Since this is the maximum limit actually offered by the millers in the SISMA formula, it is expected it will be acceptable to them. Premium offered for quality cane supply to individual ryots, has to be paid by the factories in their enlightened self interest over and above this top limit, if necessary.

If this offer is backed by well planned cane development work in the factory reserved areas it will go a long way in steadily improving cane quality. Provision of material aids such as irrigation facilities, manures (in time) and implements is the best way of popularising cane development and stepping up yields of rich canes in any locality. It has to be remembered, that sugar is manufactured in the field and only extracted in a factory.

SUMMARY

Sugarcane is best paid on quality basis. Improvement in cane quality can be ensured only by payment of inducement to individual cane growers for supplying canes of better quality.

By paying attention to cane development work, cultivation of good quality sugarcane has to be encouraged in each factory reserved area. This work has to be carried on a planned basis. For this, complete information on the cultivation details of individual holdings has to be gathered. Wherever necessary, material aids in the form of fertilizers, irrigation facilities etc., have to be given to the cultivators by the factory authorities. Harvest control has to be instituted based on a quality survey of individual fields.

The basic price has to be fixed by recording actual observations on cultivators' holdings selected as per stratified random sampling method. The cost of cultivation, reasonable margin of profit, parity prices of other commodities needed by the cane grower, return to him when cane is converted into gur should also be taken into consideration while fixing this price. It should be only on a State level and Agricultural graduates should be entrusted with this work which should be a permanent feature.

Part of the extra profits realised by millers has to be passed on to the growers, depending upon the sugar recovery and duration of cane crushing. A formula linking duration of crush and percent sugar recovery has been proposed. It is suggested that the maximum share of the growers in the net price of sugar realised by millers may be kept at 70%.

A scheme for payment of premium to individual growers based on the quality of cane supplied has been suggested. The need for emphasis on the

quality of cane at every stage in deciding the basis for cane price payment is indicated.

ACKNOWLEDGEMENT

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REFERENCES

1. Spencer, G. L. and Meade, G. P. 1945. *Cane Sugar Handbook.* A manual for cane sugar manufacturers and their chemists.
2. Lakshmikantham, M. 1948. On fixing sugarcane prices. *Indian Sugar 11*, (6).
3. Gopala Iyer, K. V. 1950. Modes of payment of cane in different countries and the method of payment suggested for adoption in India. *Proc.* 19*th Annual Convention of Sug. Tech. Assoc. Ind.* 255-264.
4. Paboa, H. E. and Davila, F.S. 1950. Factory efficiency a dilemma to the mill operator in Puerto Rico, *Sugar* 45 (10) 31.
5. Locsin, C. 1953. Marketing of sugarcane. *Sugar Jour.* August 53.
6. Macgibbon, J. M. 1951. In the making of a price scale for payment of cane. *Proc. Queensland Soc. Sug. Tech.*
7. Kerr, H. W. 1952. Co-efficient of work. *Proc. Queensland Soc. Sug. Tech. 19th Conf.* p 21-31 *Extract Int. Sug. Jour.* Sept. 52.
8. Gandhi, M. P 1945. *The Indian Sugar Industry Annual.*
9. Report of the Indian Tariff Board on the continuance of protection to the Sugar Industry, 1950.
10. Anonymus. 1954. Automatic juice sampling devices. *Australian Sug. Jour.* 45 (11), 717 *Extract Int. Sug. Jour.* Jan.' 55 p. 17,18.
11. Ramanayya, S. V. and Ramachandramurthy, M. S. 1954. Refractometric brix of primary juice as an index of pol in cane. *Ind. Sugar, 4* (6) 277-278.

The author presented the following paper.

Paper

THE PROBLEM OF CANE PRICE IN INDIA

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INTRODUCTION

Sugarcane cultivation has a stronghold on the agricultural economy of the Indian ryot and the sugar industry is the second biggest national industry. This industry received tariff protection from 1932 and its expansion was made easy by the introduction of Co. canes into cultivation. The raw material for the industry is cultivated and supplied by small agriculturists who needed price guarantees from Government. The fixation of minimum price for sugarcane was first on state level in 1935 and from 1951 it is done by the Central Government. The fixation of minimum price naturally led to investigations on cost of cultivation of sugarcane and cost of manufacture of sugar, in order to allow reasonable margin of profit to the two partners of the sugar industry. While the Srivastava scale was recognised as the basis for the cost of manufacture, the cost of cultivation of cane could not be arrived at with reasonable accuracy (1). The practice of arriving at cane price from the sugar price minus the cost of manufacture of sugar is placing the cart before the horse. The productive efficiencies of the soil and the cultivator vary so widely that the direct enquiry method of assessing cost of cane cultivation led to no useful results in the past in India. The fixation of miuimum price under statute, therefore placed the two partners of the industry in competition to boost prices and demand larger margin of profits and this is now in conflict with the policy of Government of India to bring down sugar price.

An ideal cane price must leave sufficient margin of profit to the industry for renewals and expansion, it should also allow sufficient margin of profit to the cultivator and be flexible to the individual level in order to encourage increased production per acre of better quality canes.

REVIEW

The sugar consumer is interested in having cheap sugar. The comparative prices in different countries (2), are indicated in Figure 1. The cost of sugar in India is not so high as it is believed to be.

The minimum price for cane was first fixed in Uttar Pradesh and Bihar States in 1934-35 and it was varied every fortnight with selling price of sugar. In 1937-38 an irreducible minimum price was fixed for the entire season. The Mysore State fixed minimum price in 1936 and the Madras State in 1938-39. A sliding scale of cane price was fixed in 1939-40 in Uttar Pradesh and Bihar, but it was soon given up. In 1942, attempts were made to pay higher prices for exotic varieties as an incentive for quality and this was linked to selling price of sugar. In Madras, one of the progressive sugar factories paid on the basis of quality as judged from 'gur' recovery percent and later, bonus was paid for better varieties of canes. When statutory price was fixed in Madras, it was varied with the crushing capacity of the factory unit and for some time the "freight advantage" which represents the freight on sugar from the surplus sub-tropical zone to the deficit Madras zone, was added on to cane prices. When the Central Government took over the subject of cane price, variable cane price was first adopted in different states and later a uniform flat minimum price was adopted for all states. The break up of sugar price and average cost for cultivation of sugarcane are furnished in Tables I and II (Figure 2.)

TABLE I

COST OF PRODUCTION OF SUGAR

	Rs. as. p.	% to total price of sugar	Rs. as. p.	% to total price of sugar	Rs. as. p.	% to total price of sugar	Rs. as. p.	% to total price of sugar
Price of cane	16 4 0	59 64	16 4 0	60 00	17 8 0	61.0	13 2 0	52·0
Transport of cane	0 3 1		0 5 3		0 5 3		0 5 3	
Co-operative Society's Commission	0 5 3		0 6 9		0 6 9		0 7 6	
Provincial Government Cess	1 7 3	16.89	1 14 0	16.0	1 14 0	16.0	1 14 0	23·0
Excise Duty	2 9 6		2 12 1		2 12 1		3 12 0	
Salaries and Wages	2 11 9	9.74	3 12 10	13.0	3 12 10	13.0	3 9 4	14·0
Manufacturing charges (Less Molassess realisation)	2 7 4	10 53	1 13 6	-	—	--	1 0 6	—
Net profit (Est. by Government)	0 14 6	3 20	0 14 9	3.0	0 14 9	3·0	1 8 0	-
Approximate Income Tax	0 11 3	—	---	—	-	—	—	—
Packing Bags	0 8 1	-	—	—	–	—	...	
	28 2 0		28 8 0		29 12 0		27 0 0	--

In order to assess costs, a scheme for direct investigation by enquiry into cost of cultivation was initiated in States and the Srivastava formula was sought to be revised by Dr. Narayanaswamy Naidu Committee.

Apart from cost of production, cane price involves the question of quality of cane and sharing the benefits of the industry by the cane supplier. In 1934, the sugar technologists suggested a simple formula for cane price.

$$C = \frac{S \times P}{200}$$

C = Cane price in annas per maund

S = Extraction of sugar percent

P = Price of sugar in annas per maund

Panje (4) recommended a date-bound variation, according to which the cane price will be low for early supply and increase for mid and mid-late supply. A formula that linked cane price with quality as judged by fortnightly mill tests and average price of sugar in the last season was suggested by Gopala Iyer (5). The Indian Tariff Board suggested six criteria for arriving at cane price but no practical formula was suggested integrating the factors (1). But the formula that has been actually adopted is the SISMA formula which passed on 70 percent down to 55 percent of net sugar price to the grower with a fall of 3% for every fall of Rs. 100/- from Rs. 940/- per ton of sugar. This formula is even now adopted by a group of sugar factories in Madras and probably it is the first

TABLE II

AVERAGE COST OF CULTIVATION OF SUGARCANE PER ACRE UNDER VARIOUS HEADS DURING 1948-49

State	Cultural Operation						Manuring	Percentage over total cost	Irrigation	Percentage over total cost	Other charges (including rent)	Percentage over total cost	Total*	Average yield of cane per acre in maunds	Average cost per maund including profit
	Preparatory tillage	Percentage over total cost	Interculture and propping	Percentage over total cost	Harvesting and clearance	Percentage over total cost									
	Rs.		Rs.		Rs.		Rs.		Rs.		Rs.		Rs.		Rs. a. p.
Western U.P.	72	12.06	102	17.09	46	7.69	103	17.25	40	6.70	54	9.04	597	490	1 4 0
Bihar	52	9.17	28	4.94	49	7.72	61	10.77	45	7.94	152	26.82	567	380	1 7 10
Madras	37	3.27	338	29.92	158	14.01	137	12.16	84	7.84	256	22.66	1110	1053	1 1 2
Bombay	58	5.04	73	6.34	265	...	618	53.66	123	10.60	115	9.98	1152	1120	1 0 6
East Punjab	56	11.89	30	6.37	12	2.55	64	13.59	15	3.18	210	44.69	471	350	1 5 6

*Certain minor items of cultivation omitted.

instance of a practical step in the midst of suggestions. There are certain practical difficulties in the adoption of this formula in all factories. Stepping up growers' share with increase in sugar price is obviously wrong when the objective of Government of India is to bring down sugar price (6). The Government of India evolved a formula in 1953.

$$\text{Minimum cane price} = \frac{X}{100} \times \frac{P - (\text{taxes} + \text{Sales commission} + d)}{\text{Quantity of cane required for one maund of sugar}}$$

X = Percentage share of net price payable as cane price

P — Average price of sugar

d = Allowance for duration of season

This formula introduced a variable percentage share to growers in different regions and also involved an arbitrary factor 'd'. A suggestion was made that assessment of quality of cane of individual supplies will only involve analysis of large number of samples and this should not prove difficult.

An ideal formula should be simple to be understood by small cultivators and should offer incentive for increased production of quality canes and leave room for expansion of the industry.

SUGGESTION

The individual stalks of clumps are variable in weight and quality. Sampling a few canes from each cart or lorry load will prove difficult. When the interests of the cane supplier and the factory occupier are in conflict, sampling may become biased.

The average holding under sugarcane is 2 to 5 acres and five hundred to one thousand growers supply cane every day to a factory. The cane yield being low in the sub-tropical belt, a sugar factory has to deal with 10 to 20 thousand acres for the season. The assessment of quality of individual supplies at the cane carrier is not feasible due to at least the personal bias of the sampling staff. The assessment of quality in the field is less useful due to the factors that may come in from the time of harvest to the time of supply in the factory yard.

The judgment of quality on individual level is therefore to be ruled out at present. This could be done by grouping the suppliers on (i) geographical regional basis or (ii) supply time basis. The groups may be kept small or large according to local factors.

(i) *Spatial groups* :—The factory supply area may be divided into convenient number of regions keeping each region as homogeneous as possible. Distance from the factory and transport facilities have to be considered in demarcating the regions. The supply from each region is to be regulated so that the factory may crush the canes from a region for a minimum of one or two shifts (6 to 12 hours) in a day. The primary juice at the mill may be tested for assessment of quality. Cane prices may be decided for each zone either for the whole season or for each supply concerned. This system has the advantage of locating the bad regions which could be pulled up in the coming seasons.

(ii) *Time groups* :—Where spatial groups could not be formed for any reason, time groups may be adopted. The Primary juice may be analysed for every one or two hour intervals for assessment of quality. For corresponding time units, the list of suppliers and quantity supplied may be drawn up. The cane supply cannot be grouped into homogeneous units of suppliers or regions. This time group may be adopted as a first step in a phased programme and is to be adopted where spatial grouping is not feasible.

(iii) *Cane delivery* :—The sugar factories issue cutting orders for supply of cane. Normally this should be based on the maturity test on the crop in the field. The use of hand refractometers had not been very useful under field conditions. The cane delivery should be decided on the basis of (i) variety (ii) plant or ratoon (iii) date of planting or ratooning.

Schedules for cane cutting may be drawn up on the above criteria and in special cases small mill tests may be conducted to alter the schedule. Such harvest control is already in vogue in the sugar factories of Madras State.

(iv) *Percentage share* :—The percentage share of cane price on the gross selling price of sugar ex-factory varied from 55 to 59 percent in the past. This percentage cannot be fixed on any scientific basis. The two basic factors, cost of cane and cost of manufacture of sugar are highly variable and the former should be the basis for minimum price and the latter for ceiling price. The percentage also should be varied with the sugar recovery percent in order to offer incentive for production of good quality canes. The following percentages are suggested (6).

Average sugar recovery percent	Percentage share to grower on net sale price of sugar, (ex-factory)
8.5	65
9.0	66
9.5	67
10.0	68
10.5	69

(v) *Sugar price* :—The selling price of sugar can be ascertained from the books of the sugar factory, or assessed from market quotations. In the managing agency system under company law, it is difficult to note the correct selling price, as there is scope for low selling price ex-factory, in order to corner the profits by the managing agents. An independent agency for assessing market price is needed and it should be made independent of the influence of the interested parties.

(vi) *Price Board* :—Constitution of a price board for each sugar factory or region is needed. It should have two agencies (i) an agency for assessing quality of cane on spatial or time zone (ii) an agency to assess the selling price of sugar. Based on the above two sets of data, the price board may work out cost of cane from the formula furnished in table.

(vii) *Cane supply* :—This will decide the length of crushing season and the incidence of overhead charges on manufacturing and total cost. Gur manufacture is a disturbing factor and possibly it could not be banned in a factory zone. The only way to tackle the problem is to register and bond canes on a three years or five years basis with penal clauses for failure to supply cane. The factory should also plough down part of its profits in cane development work in its own area.

(viii) *Research* :—Any price fixing formula should aim at keeping up or increasing net profit per unit for production and at the same time bring down the total cost to the sugar consumer. Increasing the efficiencies of production in the field and the factory are the means to achieve the objectives. Recently it was pointed out that increased production of sugar per acre in Hawaii was achieved through research (7). New varieties contributed to the increased yield by 40-45 percent, manures by 15-20 percent, irrigation by 20-25 percent and control of pests by 10-15 percent. Therefore any price fixing formula must set apart sufficient funds for research and development activities.

SUMMARY

The yield attribute varies from zone to zone and similarly costs. While

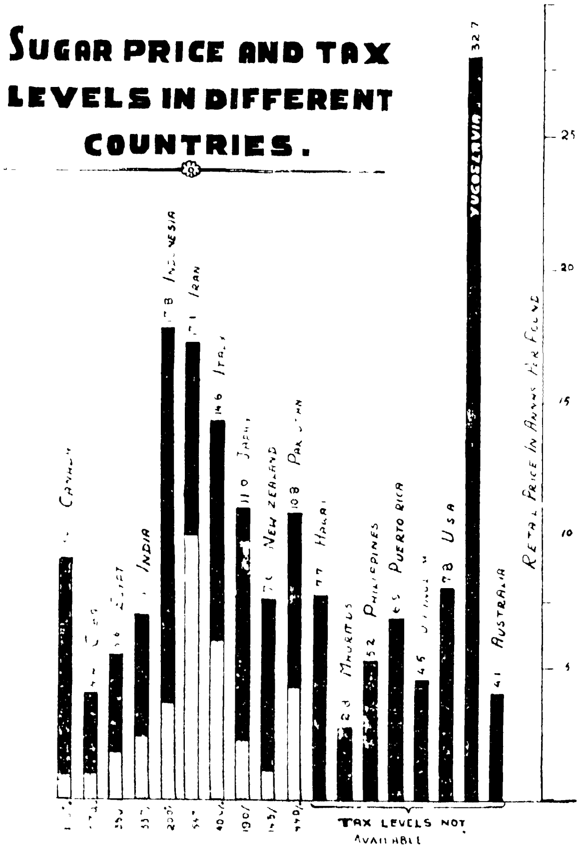

Fig. 1.

manure forms bulk of total cost in Bombay, propping in Andhra, land rental and irrigation in Madras, it is difficult to aim at uniform cane prices in India.

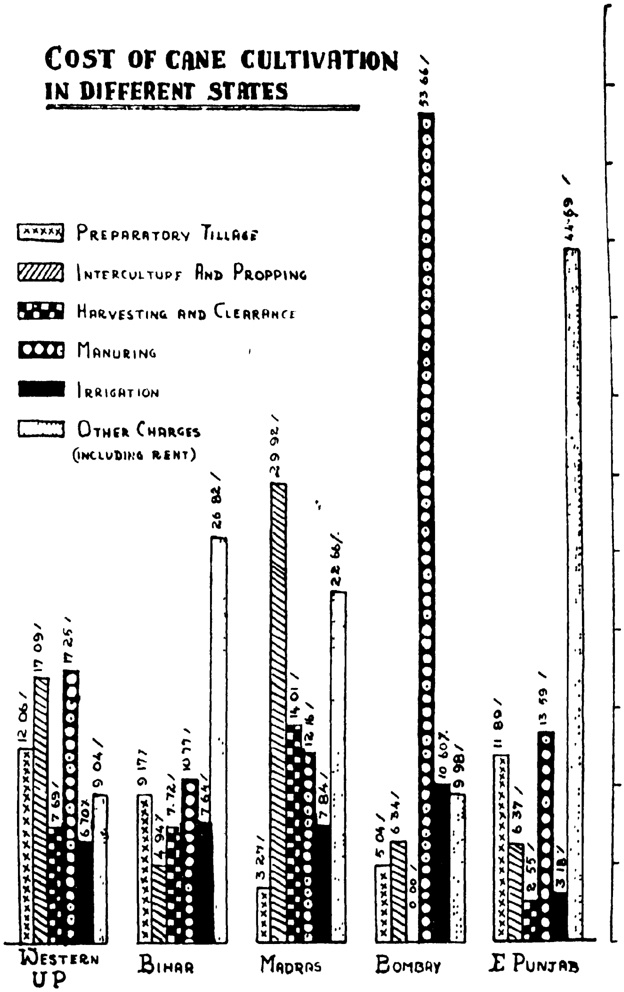

Fig. 2.

Due to possible bias in sampling, quality of individual supplies could not be assessed at the carrier. Payment for cane on flat basis is obviously a wrong step. Assessing the actual quantity of sugar delivered by each supplier is not possible. Hence the assessment of quality of cane by analysing the primary juice is the only feasible step. . The cane supplier can get group incentive either on regional basis or supply-time basis. This will involve a date-cum, quality-cum regional basis and not a uniform price for all regions. The percentage share to cane supplier cannot be decided on any scientific basis and is therefore to be negotiated. An independent agency to assess quality and another agency for assessing net selling price of sugar are to be constituted under a cane price board for each factory or region. Sufficient funds must be set apart for research and development.

REFERENCES

1. *Report of Tariff Board on Protection to Sugar Industry in India*, 1950.
2. *Indian Sugar Manual*. 1952. Published by Sugar Technologists Association of India, Kanpur.
3. Gandhi, M.P. 1954. *The Indian Sugar Industry Annual for 1953-54.*
4. Panje, R.R. 1950. *Nineteenth Proceedings of the Sugar Technologists Association of India.*
5. Gopala Iyer, K.V. 1950. *Nineteenth proceedings of the Sugar Technologists Association of India* p. 255.
6. Parthasarathy, S.V. 1954. *Twenty-third Proceedings of Sugar Technologists Association of India.*
7. Baver, L.D. 1954 *Proc. I.S.S.C.T.* p. 56.

The author presented the following paper.

Paper

THE DETERMINATION OF CERTAIN QUALITIES OF INDIVIDUAL CONSIGNMENTS OF SUGAR CANE

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INTRODUCTION

The problem of assessing the value of cane as bought by millers from growers has been studied in many countries. Generally speaking one may say that the value of cane depends

(a) on its sucrose content
(b) on the purity of the juice extracted from the cane
(c) on its fibre percentage.

In some countries the price paid for cane by millers is based on these three variables ; in South Africa the price is based on its sucrose content only. Although the latter system has many advantages, not taking into account the fibre content of the cane—as influenced by the presence of trash—has been felt to be a major disadvantage of the present system, for milling results are affected when cane containing an excessive quantity of trash has to be crushed and processed.

In South Africa the sucrose content of individual consignments of cane is found by multiplying the pol of the first expressed (crusher) juice from each consignment by the so-called Java Ratio.

The Java Ratio is a factor which is determined once a week by every mill and is applied to all consignments crushed during that period. The Sugar Act defines the Java Ratio as

> " Weight of sucrose in cane crushed during the period divided by the summation of the products of the weight of each consignment multiplied by the polarization of the crusher juice of such consignment in respect of the same period ".

The weight of the sucrose in the cane crushed in one week is found by adding to the weight of the sucrose in mixed juice produced during that week the weight of the pol in bagasse produced in the same period.

In mixed juice sucrose is determined by the double polarization method (Jackson and Gillis No. 4 method), in crusher juice the polarization only is assessed.

The main advantage of the Natal method of determining the sucrose content of individual consignments is its simplicity. It is realised, however, that the average weekly Java Ratio is not necessarily equal to the true pol % crusher juice-to-sucrose % cane-ratio pertaining to each consignment to which the weekly figure is applied and it is appreciated that the main factor affecting the difference between the average Java Ratio and the true ratio is the fibre content of the consignment (1).

Serious attempts have been made in the past to improve the Java Ratio method by developing a method of testing consignments of cane by taking and analysing representative cane samples but these attempts have not been successful (2).

Recently the subject was again recommended for further study and an investigation is now being carried out by the Sugar Milling Research Institute, which, however, aims further than just at developing a new routine method for cane analysis.

SUB-DIVISION OF INVESTIGATION

If a consignment of cane of, for example, 30 tons has to be tested by direct analysis the first problem is to assess the weight of the sample required and then to decide where and how to take the sample.

The second problem is how to disintegrate the sample in such a way that a sub-sample suitable for direct analysis can be taken.

The third problem is to analyse the sub-sample for the qualities about which information is desired.

As an introduction to the study of the composition of consignments of cane as they arrive at the carrier, it was decided to study the sub-sampling and subsequent analysis of the sub-sample of samples of cane cut from experimental fields, and weighing up to 100-150 lbs.

ANALYSIS OF SUB-SAMPLE

How such rather large samples were disintegrated and mixed will be described further on; it suffices here to say that the procedure allows a representative sub-sample of finely shredded cane, weighing 600 gm., to be taken. Since data for fibre % cane, sucrose % cane and purity of the juice in cane were required it was necessary to extract the 600 gm. sub-sample with water and to analyse the extract. In the first place it had to be decided whether the hot or the cold method of extraction would be followed, the cold method to be executed in a high speed mechanical extractor.

Mainly in order to reduce the time required for extraction, the cold method was selected and a high speed extractor as described by Mahon (3) was built (r. p. m. of the two four-bladed knives approx. 6,900).

The critical factor in *any method of extraction* is the even distribution of the solutes over the extract. Cold extraction will give low results if not all cells of the cane are ruptured. Hot extraction on the other hand will give low results if, due to lack of circulation in the digester, not all cane particles are properly leeched by the boiling water.

In both methods a pre-determined weight of shredded cane is extracted with a pre-determined weight of water. Complete extraction is attained when all the juice in the sample is homogeneously mixed with the added water, and the weight of the extract is then equal to the combined weights of water and juice. If it is assumed that cane consists of fibre plus absolute juice, the weight of the juice in the sample can be found by determining fibre in a parallel sample of the shredded cane. The weight of the extract can now be calculated and after determining the sucrose content of the extract sucrose % cane can be found.

The assumption that cane consists of fibre plus absolute juice is, however, not generally considered to be correct. The alternative theory maintains that cane consists, in addition to fibre, of juice which is available for extraction after the cells have been ruptured, and a certain amount of water which is " chemically" bound to the fibre and will not mix with the extract. According to the advocates of the latter theory, cane consists of fibre, undiluted juice and brix-free water, and if it is assumed that the latter theory is correct, the extract of the sucrose determination will consist of the added water plus undiluted juice. In this case the weight of the extract differs from the weight of the extract calculated according to the absolute juice theory by the weight of the brix-free water.

Consequently sucrose % cane calculated on the basis of the absolute juice theory will be higher than when calculated on the basis of the undiluted juice theory. The magnitude of the difference can be gauged when we know how much water is " chemically " bound to fibre.

Unfortunately this quantity is not known. It is true that the Milling Control Reports of some countries show data for brix-free water % fibre in bagasse, but these data are calculated on the basis of certain assumptions which may not be quite correct. Moreover all kinds of errors normally made in assessing the basic data on which the calculation of brix-free water % fibre is based have their effect on the final figure. For this reason the brix-free water % fibre data of the normal Milling Control Reports cannot be considered to be sufficiently correct to be used in the sucrose % cane determination and the possible existence of brix-free water is therefore generally ignored when sucrose % cane, or sucrose % bagasse is determined by extracting a sample and analysing the extract.

In the present investigation it is also assumed that the weight of the extract can be found by adding the weight of the added water to the weight of the absolute juice in the sample.

N. B. According to Natal Milling Control Reports, brix-free water % fibre in bagasse averages about 25 (Java: 23). If the Natal figure is assumed to be correct and also applicable to cane, taking into account brix-free water in the calculation of the sucrose % cane data of our investigation, would result in data which are approx. 1.2% lower than when brix-free water is not taken into account.

The complete analytical procedure is described in Appendix I. Sucrose in the extract was determined by the chemical method in which the reducing sugar content before and after inversion was measured by the Luff-Schoorl method (4). This method was thought to be more accurate when applied to the rather dilute extract (approx. 5° Brix) than the usual Jackson and Gillis method and moreover provided also data for the reducing sugar content of the cane.

SUB-SAMPLING TECHNIQUE

The problem of how to obtain a representative sub-sample was solved as follows. By using a simple hand-operated chaff-cutter the sample of cane, weighing more than 100 lbs., is cut up in cylindrical sections or chips of about 1″ length. This operation does not take more than 20 minutes and could be speeded up by driving the cutter mechanically. Separate tests showed that loss of weight due to evaporation during this period is negligible under our conditions of work. This completely cut up sample is then well mixed for three minutes in a mixing barrel* from which, after mixing, 10 lbs. of chips are extracted by hand. These sections are then placed in a Waddell shredder (5) and disintegrated. This operation takes 45 seconds, after which a 600 gm. sub-sample of finely shredded cane can be taken from the contents of the shredder for further analysis.

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* The "Tumbling Barrel" consists of a barrel with the hinged lid and balanced with a shaft so placed as to give eccentric rotation, so that besides rotation there is also a lateral displacement.

Capacity—100 lbs. of clean cane cut in chaff-cutter. The sample is "tumbled" for 3 mins. (approx. 50 turns), the speed of rotation being kept slow to avoid separation by centrifugal action.

TIME REQUIRED FOR COMPLETE EXTRACTION

The first point investigated concerned the period of time required to obtain a constant sucrose percentage of the extract. In two tests, A and B, the following data were obtained.

Period	Sucrose % Extract A	 B
After 10 minutes	3.96	3.38
,, 15 ,,	3.92	3.41
,, 20 ,,	3.98	3.40
,, 25 ,,	3.97	3.40
,, 30 ,,	3.97	—

The above data suggest that 15 minutes are required for complete extraction.

REPRODUCIBILITY OF RESULTS

To judge the reproducibility of the extraction and the subsequent analysis of the extracts, nine tests were carried out in each of which a large sample of cane was cut up in the chaff-cutter and 10 lbs. sample of the sections was shredded in the Waddell shredder in the usual way.

Then from the Waddell shredder 4 parallel samples of shredded cane were taken and separately analysed as described in Appendix I.

Results were :

Test No.					
1.	Fibre % cane	13.09	12.91	13.08	13.06
	Sucrose % cane	16.08	16.19	16.18	15.67
	Red. sug. % cane	0.068	0 068	0.071	0.078
	Purity	93.3	93.9	93.9	91.0
2.	Fibre % cane	13.22	13.16	13.06	13.13
	Sucrose % cane	14.65	14.49	14.09	14.49
	Red. sug. % cane	0.371	0.405	0.405	0.438
	Purity	88.6	87.6	85.1	87.6
3.	Fibre % cane	15.21	15.12	14.61	15.15
	Sucrose % cane	13.86	13.17	13.62	13.60
	Red. sug. % cane	0 034	0.034	0.067	0.067
	Purity	91·8	91.8	90.0	90.0
4.	Fibre % cane	13.65	13.49	13.79	13.52
	Sucrose % cane	14.33	14.62	14.16	14.00
	Red. sug. % cane	0.172	0 172	0.179	0.213
	Purity	93.8	91.4	90.9	87.4
5.	Fibre % cane	13.47	13.68	13.45	13.68
	Sucrose % cane	13.80	14.07	14.04	14.06
	Red. sug. % cane	0.135	0.145	0.155	0.169
	Purity	83.1	88.9	87.8	89.4
6.	Fibre % cane	17.32	17.54	17.33	17.32
	Sucrose % cane	11.25	11.67	12.14	12.11
	Red. sug. % cane	0.10	0.13	0.10	0.10
	Purity	81.7	83.3	85.4	84.2
7.	Fibre % cane	15.32	15.26	15.22	15.28
	Sucrose % cane	10.33	10.14	10.07	10.07
	Red. sug. % cane	0.17	0.17	0.17	0.20
	Purity	69.4	68.6	69.2	68.8
8.	Fibre % cane	15.03	15.27	15.18	15.12
	Sucrose % cane	13.47	13.63	13.77	13.74
	Red. sug. % cane	0.10	0.10	0.17	0.14
	Purity	87.7	89.7	88.9	89.7
9.	Fibre % cane	15.54	16.04	15 91	15.91
	Sucrose % cane	13.45	13.22	13.23	13.23
	Red. sug. % cane	0.17	0.17	0.17	0.17
	Purity	88.1	87.8	88.0	87.6

To gauge the dispersion of the results of each analysis, the standard deviation was calculated for each set of 4 data, using the formula $S = \frac{\sqrt{\Sigma(x-\bar{x})^2}}{n-1}$ and also the coefficient of variation $C.\ V. = 100\ \frac{S}{X}$.

The mean results of each test and the corresponding coefficients of variation are shown in Table I. The coefficients of variation of the nine tests varied markedly and to calculate an average value for each component the nine coefficients were squared, added, divided by 9 and from the 9 quotients the square roots were taken.

TABLE I

DISPERSION OF RESULTS OF ANALYSIS

No. of test	Fibre % cane		Sucrose % cane		Red. sug. % cane		Purity of extract	
	Mean	Coeffic. of variation	Mean	Coeffic. of variation	Mean	Coeffic. of variation	Mean	Coeffic. of variation
1	13.04	0.64	16.03	1.53	0.071	5.63	93.02	1.49
2	13.14	0.51	14.43	1.65	0.405	6.91	87.22	1.70
3	15.02	1.84	13.74	1.07	0.505	3.76	90.90	1.01
4	13.61	0.97	14.21	1.13	0.184	10.86	90.87	2.90
5	13.57	1.07	13.99	0.91	0.151	9.27	87.30	3.29
6	17.38	0.62	11.79	3.57	0.108	22.22	83.65	1.86
7	15.27	0.28	10.15	1.21	0.178	10.67	69.00	0.54
8	15.15	0.67	13.65	1.00	0.120	18.33	89.00	1.06
9	15.85	1.36	13.28	0.84	0.170	0.00	87.88	0.25
Mean	14.67	0.99	13.47	1.64	0.213	11.7	86.54	1.84

Apparently the percentage error of the fibre percentage is smallest, the percentage error of the sucrose percentage is slightly smaller than that of the purity, and the percentage error of the reducing sugar percentage is largest due to the low reducing sugar content of the cane.

In a second set of tests the parallel samples were not taken from the shredded cane as was done in the first set, but one step back, i.e., from the chips obtained from the chaff cutter after they had been properly mixed in the mixing barrel. In this case the dispersion of the results was expected to be larger, due to shredded cane being more finely divided and hence a more suitable material for sub-sampling than cane which had passed the chaff cutter only. Both in the first and second sets of tests clean stalks were passed through the chaff-cutter. The weight of the samples being passed through the chaff-cutter in the second test was 70-100 lbs.; in each of the five tests 4 parallel samples were taken.

TABLE II

DISPERSION OF RESULTS OF ANALYSIS

No. of test	Fibre % cane		Sucrose % cane		Red. sug. % cane		Purity of extract	
	Mean	Coeffic. of variation	Mean	Coeffic. of variation	Mean	Coeffic. of variation	Mean	Coeffic. of variation
1	15.38	1.51	12 52	0.59	0.23	14.34	86 3	0.21
2	16.17	0 43	12.36	2.40	0.83	10.84	84.7	1.51
3	15.38	2.61	13.06	1.22	0.42	13.57	86.4	0.60
4	15.22	0.95	11.51	0.83	0.31	5.48	84.0	0.34
5	15.40	0.67	11.57	1.64	0.30	0.00	85.2	0.31
Mean	15.51	1.46	12 20	1.48	0.42	10.4	85.3	0.76

Rather unexpectedly the scatter of the percentages of sucrose and reducing sugars were found to be slightly smaller, of the purities markedly smaller, and of the percentages of fibre somewhat bigger than those of the tests reported on in Table I.

The general conclusion is that a sub-sample taken from the chips is on the whole just as characteristic for the cane sample as a sub-sample taken from the contents of the Waddell shredder.

COMPARISON OF THE PRESENT FIBRE PERCENTAGES WITH THOSE OBTAINED BY THE QUEENSLAND METHOD

In tests Nos. 6 and 7 of the first set (Table I), the chips from which the sample for the Waddell shredder had been taken were passed through a laboratory mill and the fibre percentage was determined following the Queensland method as described by O'Connor (6).

The following data were obtained :

	Present Method	Queensland Method
Test No. 6	17.38%	17.06%
Test No. 7	15.27%	14.75%

The small differences are probably due to certain solids, which are not attacked by cold water, being dissolved by the action of boiling water in the Queensland Method. The agreement between the results of the two methods is, however, satisfactory.

COMPARISON OF PRESENT RESULTS WITH THOSE OF OTHER METHODS

In this part of the investigation the results of the present method of analysis were compared with those of the conventional method in which cane is passed through a small mill and bagasse and juice are analysed separately.

100 lbs. samples of cane were cut in the chaff-cutter and the chips were well mixed. Then 50 lbs. sub-samples for extraction in the laboratory mill

(18″×24″) were taken and 10 lbs. sub-samples for analysis by the present method, as described before.

A. *Mill Extraction*: About 10 lbs. of the chips from the chaff cutter were fed through the mill twice to " fill " the mill with bagasse and juice. The juice and bagasse obtained were discarded.

The 50 lbs. sample was next passed through twice, the juice and bagasse weighed and the loss corrected in proportion to the respective weights.

The juice was analysed for brix, reducing sugars and sucrose (chemically, by the Luff-Schoorl method).

The bagasse was mixed and a 6 lbs. sample withdrawn for shredding in the Waddell shredder.

The shredded bagasse was analysed for:

(a) moisture: weighing out 1,000 g. and drying to a constant weight.

(b) sucrose, brix and reducing sugars:

  (i) by weighing out 520 g. and extracting with 3,980 ml. water plus 20 ml. 10% sodium carbonate solution at boiling point for one hour.

  (ii) by weighing out 300 g. and extracting in the high speed extractor with 1,500 ml. water and 5 ml. sodium carbonate for 15 minutes.

(c) fibre:

  (i) from dry matter in bagasse and refractometer brix of juice extracted in the mill.

  (ii) from the high speed extractor results.

B. *High Speed Extractor*: The 10 lbs. sample was disintegrated in the Waddell shredder and 600 g. of the shredded cane analysed using the high speed extractor.

In all seven tests were carried out, the results of which are given in Table III.

CONCLUSIONS FROM TABLE III

To obtain a better insight into the discrepancies of the results of the three methods, as shown in the separate tests, the results of the seven tests were averaged. The means obtained in this way are shown in the last line of Table III.

Fibre: The mean of the results of method B agree quite satisfactorily with those of method A-c-ii. Those of method A-c-i are on the average 3.8% lower than the mean of the results of method B and A-c-ii, not unlikely due to more " dry matter " being dissolved by the action of the boiling water.

Sucrose: Method A-b-i is the conventional method of analysing cane samples. Unfortunately the result of method A-b-ii in the 5th test is so much lower than those of method A-b-i and B that some operational error must be suspected. For this reason the results of test No. 5 have been excluded from the means reported in the bottom line of the Table. The means from the remaining 6 tests indicate that Method A-b-i gives results which are—in respect of sucrose—on the average 1.2% higher than those of Method B. The mean results of method A-b-ii and B agree very well.

TABLE III

COMPARISON OF RESULTS OF DIFFERENT METHODS OF TESTING

No. of test	Fibre % cane				Sucrose % cane				Red. sug. % cane				Brix % cane				Purity of juice in cane			
	A-c-ii	A-c-i	B	Mean	A-b-ii	A-b-i	B	Mean	A-b-ii	A-b-i	B	Mean	A-b-ii	A-b-i	B	Mean	A-b-ii	A-b-i	B	Mean
1	14.99	14.50	15.60	15.03	12.42	12.75	12.30	12.49	0.62	0.53	0.44	0.53	14.73	15.75	14.55	15.01	84.32	80.95	84.54	83.27
2	15.97	15.23	16.13	15.78	11.22	11.35	10.91	11.16	0.62	0.50	0.50	0.54	13.25	13.41	13.15	13.27	84.68	84.64	82.97	84.10
3	15.68	15.10	15.47	15.42	12.29	12.37	12.44	12.37	0.61	0.49	0.47	0.52	14.54	14.93	14.65	14.71	84.53	82.85	84.91	84.10
4	15.32	14.70	15.33	15.12	12.30	12.63	12.48	12.48	0.67	0.63	0.54	0.61	14.53	14.97	14.66	14.72	84.65	84.50	85.13	84.76
5	14.36	14.49	15.47	14.94	(10.41)	12.27	12.01	(11.56)	0.51	0.49	0.44	0.48	14.41	14.67	14.19	14.42	(80.15)	83.64	84.64	(82.81)
6	15.31	14.11	14.61	14.68	13.84	13.88	13.75	13.82	0.29	0.32	0.24	0.28	15.96	16.34	15.84	16.05	86.70	84.90	86.80	86.10
7	12.62	12.70	12.67	12.66	15.49	15.39	15.52	15.47	0.14	0.14	0.10	0.13	17.88	17.83	18.73	18.15	86.60	86.30	82.90	85.30
Mean	14.89	14.40	15.04	14.80	12.92*	13.06*	12.90*	12.96*	0.49	0.44	0.39	0.44	15.04	15.41	15.11	15.19	85.24*	84.02*	84.54*	84.60*

*Test No. 5 excluded.

A-c-ii = mill extraction, brix in bagasse from high speed extractor results.
A-c-i = ,, ,, ,, ,, ,, ,, dry matter in bagasse, and refractometer brix of juice extracted in the mill.
A-b-ii = ,, ,, bagasse extracted in high speed extractor.
A-b-i = ,, ,, ,, ,, ,, boiling water.
B =cane samples extracted in high speed extractor.

Reducing Sugars: Method B tends to give results which are lower than those of methods A-b-i and A-b-ii.

Brix:—The slightly higher results of method A-b-i may be due to more solids being dissolved in the hot digestion process.

Purity of Juice: The effect of the lower sucrose percentages obtained by method B is outweighed by the lower brix figures of method A-b-i, resulting in a slightly higher average purity for method B, which, however, is somewhat lower than the average purity obtained by method A-b-ii. The results of Test No. 5 have again been omitted from the means.

Summarising, it is concluded that although the results of the three methods show a fairly satisfactory agreement, the tests should be continued in an endeavour to find the cause of the small discrepancies.

ANALYSIS OF PARALLEL SAMPLES OF CANE CUT FROM ONE FIELD

The method of analysing cane samples by cold extraction in a high speed extractor as described above was applied to parallel samples of cane cut from a field of about one acre. The area was approximately square.

Each sample was taken by walking through a pair of lines and taking a stick at random every few yards. Only sticks obviously unsuitable for milling and which would not normally go to the mill, were discarded. The procedure was repeated after skipping a few lines throughout the field, and the total weight of the sample was approximately 150 lbs.

A second and a third sample were taken in a similar manner, and four different fields were sampled in this way. The samples were cut up in the chaff cutter, as described above, and from the chips obtained two sub-samples were taken and analysed separately. The results are shown in Table IV.

TABLE IV

ANALYSIS OF CANE FROM FOUR FIELDS

Field	Sample	Fibre % cane			Sucrose % cane			Red. sug. % cane			Purity of juice		
		a	b	Mean	a	b	Mean	a	b	Mean	a	b	Mean
A	I	16.32	15.41	15.87	11.27	11.73	11.50	0.70	0.56	0.63	81.9	84.3	83.1
	II	14.97	15.34	15.16	11.01	11.16	11.09	0.63	0.63	0.63	81.4	83.0	82.2
	III	14.84	15.13	14.99	11.47	11.13	11.30	0.53	0.63	0.58	83.7	83.1	83.4
	Mean	—	—	15.34	—	—	11.30	—	—	0.61	—	—	82.9
B	I	15.44	16.60	16.02	13.51	13.50	13.51	0.31	0.31	0.31	88.6	89.4	89.0
	II	15.60	15.20	15.40	13.64	13.34	13.48	0.31	0.38	0.35	89.3	88.3	88.8
	III	16.59	15.06	15.83	13.33	13.41	13.37	0.38	0.42	0.40	86.7	86.4	86.6
	Mean	—	—	15.75	—	—	13.46	—	—	0.35	—	—	88.1
C	I	13.50	12.62	13.06	15.35	15.45	15.40	0.17	0.23	0.20	90.2	89.0	89.6
	II	13.35	13.48	13.42	15.42	15.35	15.39	0.23	0.17	0.20	89.0	89.2	89.1
	III	17.48	16.58	17.03	15.30	15.40	15.35	0.17	0.17	0.17	93.2	92.4	92.8
	Mean	—	—	14.50	—	—	15.38	—	—	0.19	—	—	90.5
D	I	14.64	13.51	14.08	14.62	14.66	14.64	0.37	0.44	0.41	88.9	89.0	88.9
	II	13.95	13.93	13.94	14.98	14.75	14.87	0.44	0.47	0.46	88.7	88.0	88.4
	III	15.04	13.71	14.38	14.56	14.86	14.71	0.43	0.44	0.44	88.2	88.8	88.5
	Mean	—	—	14.13	—	—	14.74	—	—	0.43	—	—	88.6

By an analysis of variation the following co-efficients of variation were found:

Particulars	Fibre	Sucrose	Reducing Sugars	Purity
within pairs	4.22%	1.17%	11.29%	0.08%
within fields	7.02%	0.39%	—	0.13%

The fibre determination was apparently less accurate than would have been expected from the results reported in Tables I and II. This may have been due to the fact that the samples taken from the fields, A, B, C and D were much more trashy than the clean stalks which provided the data of Table I and II. This may also explain the differences between the fibre percentages of the three samples from each field.

The results of the sucrose determinations in Table IV on the other hand were slightly more accurate than those in Tables I and II and the sucrose contents of three parallel samples from each field agreed very well.

The relative inaccuracy of the reducing sugar determination is again reflected in the high co-efficient of variation within pairs. The purities agreed very well, both within pairs and within fileds.

SUMMARY

A method is described of disintegrating and sub-sampling samples of cane of 100-150 lbs. and of analysing the sub-sample by extraction in a high speed extractor, the extract being tested for sucrose and reducing sugars by the Luff-Schoorl method. The reproducibility of the results has been studied, and the results of the present method have been compared with those of the more conventional method of testing cane.

Finally the method of analysis has been applied to parallel samples of cane taken from one field and the results have been analysed statistically.

The investigation is being continued by analysing chip samples taken from the left and right hand sides respectively of the cane carrier after the cane has passed two sets of knives.

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REFERENCES

1. Christianson, W. O. 1947. Correlation and its application to certain problems in the sugar industry. *Proc. S.A.S.T.A. Congress*, p. 80.
2. Moberly, G. S. 1949. Summary of experiments conducted with a cane sampling machine, *Proc. S.A.S.T.A. Congress*, p. 53.
3. Mahon, H. I. 1953. Sugar Losses, Field to Factory. *Reports of the Hawaiian Sugar Technologists, 12th Annual Meetings,* 1953, p. 66, 1954, ibid, p. 107.
4. Douwes Dekker, K. 1950. The Luff-Schoorl method for determination of reducing sugars in juices, molasses and sugar. *S.A. Sugar Jnl.* 34, 157.
5. Waddell, C. W. 1953. Effective fibre detrmination in sugar cane. *Proc. 8th I.S.S.C.T. Congress*, p. 828.
6. O'Connor, B. 1954. The determination of fibre in sugar cane. *Communications from the Sugar Milling Research Institute*, No. 24.

APPENDIX I

ANALYTICAL PROCEDURE

(1) From the contents of the Waddell shredder 600 gms. are weighed into a ½ gallon glass bell jar and the lid screwed firmly into place.

(2) 1,500 gms. water are weighed out and 5 ml. of 10% sodium carbonate added.

(3) The cleaned and dried high speed extractor is fitted into the drive assembly and a copper, rectangular bottomed funnel is placed into the opening.

(4) The 600 gms. of shredded cane and the 1,500 ml. of water to which 5 ml. 10% Na_2CO_3 (anhydrous) have been added, are wholly transferred into the extractor. The lid with gasket is then bolted into place and a breather tube of glass fitted tightly into the opening provided.

(5) The extractor is set in operation for 15 minutes (an automatic time switch stops the motors at the end of this period).

(6) The extractor is then removed and cooled for 5 mins. in the cooling bath.

(7) The extractor is then dried externally and placed on the wooden stand provided. The top and breather tube being carefully removed to avoid loss of the fibrous material.

(8) A small portion of the extract is passed through a large filter funnel provided with a removable copper residue collector fitted with 200 mesh copper gauze screen. The filter is placed on a conical flask. The screen, the funnel and two conical flasks are rinsed with the filtrate and the filtrate is discarded. This is repeated.

(9) The balance of the extract and fibrous residue is transferred to the filter screen. 300 ml. of the filtrate thus collected is transferred to a small conical flask after first rinsing out the flask with two small portions of extract and discarding the extract each time. The flask is firmly sealed with a rubber stopper and cooled in running water preparatory to the Luff-Schoorl determination.

(10) The remaining filtrate is used to transfer all remaining residue from the extractor, lid and gasket, and breather tube, on to the filter screen.

(11) To determine moisture in bagasse samples an electrically heated P.O.J.-type drier, with three bronze cannisters, is used. The cannisters have a capacity of 1 kg. of bagasse. During the operations (1)—(10) the drier has been in operation at 115°C. for at least one hour in order to dry the empty cannisters placed on the apparatus. The bottom cannister is removed and tare weighed to 0.5 g. weight (while hot).

(12) The lid of the cannister is then removed and the fibrous residue on the screen is transferred by hand into the cannister after first squeezing out well the extract. The filtrate is used to transfer remaining residue on the hands back to the filter screen. In this way all the residue is placed in the cannister.

(13) The lid of the cannister is replaced and the cannister and contents immediately reweighed to ½ gram. The nett weight of contents being noted.

(14) The cannister is placed on top of the two remaining cannisters, on the drier. The thermostat being checked that it is operating at 115°C. and the air draught through the three heating elements is adjusted to give a maximum draught without causing a drop in temperature when the thermostat is in the " on " position.

(15) The process is repeated for the next sample and just before placing the cannister with the second sample on top of the two cannisters, the 1st sample is taken off the drier, the lid removed and the lumps of fibrous residue broken up and rubbed by hand and evenly distributed over the bottom of the cannister—a bristle brush is used to transfer any residue from the hands into the cannister.

(16) The cannister with sample No. 1 is placed in the middle position on the drier and sample No. 2 is then placed on top of the 1st cannister. (It should be noted that when removing and replacing cannisters on the drier, the air current should be reduced to a minimum to avoid possible loss of the dried residue). Approx. 20-30 minutes should elapse for pre-drying before breaking and rubbing the lumps of residue, for should the mass be too moist, a portion of the concentrated, brix-containing extract may be removed on the hands and if dried too thoroughly before rubbing, difficulty may be experienced in breaking up the fibre.

(17) When the above process is repeated, sample No. 1 will be at the bottom position of the 3 cannisters on the drier and after 1¼-1½ hours of total drying, cannister No. 1 with contents is reweighed to ½ gm. and the weight of the contents noted. This is repeated at ¼ hr. intervals until constant weight is obtained. Constant weight is usually obtained after 1½-1¾ hours of total drying.

(18) Cannister No. 1 is then emptied of contents, brushed out and re-tared (while hot) ready for the next sample. (It should be noted that on re-taring, the weight rarely differs by more than ½ gm. and is usually the same as the original weight).

(19) The conical flask with 300 ml. extract is cooled in running water. This sample will contain up to 5% sucrose and 0.2% reducing sugars.

(20) 50 ml. of the extract is pipetted into a 100 ml. graduated flask, 4 ml. of 10% neutral lead acetate solution added and the volume made up to 100 ml. with distilled water. After shaking, the solution is filtered. The first few ml. of filtrate are discarded and the second few ml. returned to the filter paper (100 ml. of the filtrate contain approx. 2,500 mg. sucrose and 100 mg. reducing sugars).

(21) 50 ml. of the filtrate from (20) is pipetted into a 100 ml. graduated flask and one ml. sodium phosphate-potassium oxalate solution is added, and the volume made up to 100 ml. with distilled water. Shake and filter; the first few ml. of filtrate being discarded and the second few ml. returned to the filter paper (100 ml. of the filtrate contain approx. 1,250 mg. sucrose and 50 mg. reducing sugars).

(22) 25 ml. of the filtrate from (21) is pipetted into a 250 ml. conical flask containing 25ml. of the Luff-Schoorl solution and the reducing sugar content determined immediately (Solution contains approx. 310 mg. sucrose and 12 mg. reducing sugars).

(23) 20 ml. of the filtrate from (21) is pipetted into a 200 ml. graduated flask and 10 ml. HCl (1:1 v/v) and 50 ml. distilled water added. The solution is heated in a water bath to 67°C.-70°C. in 5 mins. and kept at that temperature for 5 mins. and then cooled in running water. The solution is then neutralised with a 20% NaOH solution, and cooled in running water. When cool, the solution is made up to 200 ml. with distilled water (200 ml. contain approx. 270 mg. reducing sugars).

(24) 25. ml. of the solution from (23) is pipetted into a 250 ml. conical flask containing 25 ml. of the Luff-Schoorl solution and the reducing sugar content determined immediately (Solution contains approx. 34 mg. reducing sugars).

(25) The apparent density of the extract is determined using a specific gravity bottle placed in a constant temperature bath at 20°C. (sp. g. 20/20). From the (apparent) density at 20 °C., the brix is found using Table XXVII of Spencer and Meade-Cane Sugar Handbook.

CALCULATIONS

If mg. reducing sugars found in titration before inversion $= r_1$ and mg. reducing sugars found in titration after inversion $= r_2$, then reducing sugars % extract (before inversion) $= 16/1000 \times r_1/\text{density}$, and reducing sugars % extract (after inversion) $= 16/100 \times r_2/\text{density}$.

Terming these percentages R_1 and R_2 respectively, sucrose % extract $= S_1 = 0.95\ (R_2 - R_1)$. The density here is the weight of one ml. of the extract at the ambient temperature and is found from Table XVI of the book by P. Honig—Principles of Sugar Technology.

Terming the weight of the wet residue from the high speed extractor W gms., and the weight of the dry residue D, also the brix of the extract Bx_1 and the fibre % cane = F, we find that

$$F = 1/6\ D—(W—D)\frac{Bx_1}{100—Bx_1}$$

and, similarly, that

Sucrose % cane $= S = S_1\ (3.5083—0.01\ F)$
Red. sug. % cane $= R = R_1\ (3.5083—0.01\ F)$
Brix % cane $= Bx = Bx_1\ (3.5083—0.01\ F)$
Purity of juice in cane $= 100\ S/Bx$*

EXAMPLE OF CALCULATION

	W (g.)	D (g.)	Bx_1 (%)	R_1 (%)	S_1 (%)	F (%)	R (%)	S (%)	Bx (%)	Purity
A_1	510.5	115.0	5.17	0.133	4.49	15.57	0.45	15.05	17.38	86.8
A_2	512.0	113.5	5.19	0.145	4.46	15.28	0.49	14.97	17.42	85.9
A_3	514.0	109.5	5.24	0.143	4.53	14.52	0.48	15.23	17.62	86.4
A_4	480.5	109.0	5.25	0.142	4.54	14.73	0.48	15.26	17.64	86.5

*In these calculations the weight of the added $Na_2\ Co_3$ is neglected.

In the absence of the author the paper was taken as read.

Paper

A UNIVERSAL EQUATION FOR INDICATED AVAILABLE SUGAR IN CANE

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Determination of available sugar in cane from brix and pol of primary juice is an important feature of systems in present use for cane purchase, factory control and research. Availability of a simple method for making routine sugar yield calculations is especially important in agronomic research where numerous determinations of indicated sugar yield are required for proper analysis and interpretation of experimental results. As reported in earlier publications (2, 4), the formula for available sugar as calculated from primary juice analyses developed at the Houma, Louisiana, Station (U.S.D.A.) has been simplified to the equation :

$S' = Sx—By,$

where, S' = Pounds of 96° sugar per ton of cane
S = Pol of primary juice
B = Brix of primary juice

Factors x and y are determined empirically from results of small-scale milling tests with extraction of sucrose ordinarily ranging from 92 to 94 percent.

Basic equations are :

$$x = 21.5017\ C$$
$$y = 6.2383\ C$$

An earlier report (4) gives the derivation of constants 21.5017 and 6.2383. The value of C (varietal correction factor) for any given variety integrates the combined effects of varietal normal juice extraction and sucrose (pol) reduction factor in relation to corresponding values observed in parallel tests of the control variety, Co. 281 (1). Normal juice extraction is based on brix at a constant reduction factor of 0.985.

An important practical advantage of the simplified formula is the ease and rapidity with which routine calculations can be made and checked. Brix and pol of primary juice are linear functions of available sugar. Use of the derived term purity in a recovery formula as is often done necessitates an additional calculation and complicates unnecessarily the mechanics of routine calculation by introducing a non-linear term in the equation. The purpose of this paper is (1) to show how representative sugar yield formulas can be resolved to terms of the simplified equation, and (2) to compare the effects of differences in underlying assumptions on the pattern of this expression. Two formulas in addition to above mentioned Houma Station factors have been selected for comparison and conversion to the simplified recovery equation, viz., the C. C. S. Formula of Australia (5) and the recently reported SE formula of Reunion (6). All are based on brix and pol of primary juice and make direct or indirect adjustments for fibre in cane.

HOUMA STATION FACTORS

In yield calculations according to the Houma Station method, the equation $S' = 21.5017\ S - 6.2383\ B$ applies to Co. 281 and other varieties of correction group 1.00. As mentioned earlier, S' = pounds of 96° Sugar per ton of cane. With S'' = yield of 96° sugar percent cane, the equation becomes

$$S'' = \left(\frac{21.5017}{20}\ S\right) - \left(\frac{6.2383}{20}\ B\right) = (1.0751\ S) - (0.3119\ B)$$

Applying the latter equation to the primary analysis brix 17.00, pol 15, for the purpose of illustration, we have

$$S'' = (15 \times 1.0751) - (17 \times 0.3119) = 10.8242.$$

The Houma Station equation does not make a specific correction for fibre content of cane but it is recognized that varietal correction factors as determined reflect in a large measure varietal differences in fibre content. Determination of fibre in cane readily lends itself to the procedure followed in making varietal milling tests and is regularly done as a matter of course. Therefore, extensive data on comparative varietal fibre content have been accumulated over the years. A recent report gives comparative fibre content and varietal correction factor as observed in extensive milling tests of 49 varieties at the Houma Station and discusses the relationship between the two values (3). For the purpose of comparison, the average fibre content 12.41% observed with the control variety Co. 281 will serve to relate the Houma Station recovery equation to above-mentioned C.C.S. and SE formulas.

THE C. C. S. FORMULA (Queensland)

The equation for this formula is given as

$$\text{C.C.S.} = \frac{3S}{2}\left(1 - \frac{5+F}{100}\right) - \frac{B}{2}\left(1 - \frac{3+F}{100}\right) \text{ in which}$$

C.C.S. = Commercial Cane Sugar
S = Pol of primary juice
B = Brix of primary juice
F = Fibre percent cane

It can be shown that the above equation may be resolved to

C.C.S. = (S x — B y) in which
x = 1.425 — 1.5 f
y = 0.485 — 0.5 f
(f = ratio of fibre to cane)

The simplest way to calculate constants for x and y equations as given above is as follows :

Analysis of Primary juice		C. C. S. as per original formula	
Brix	Pol	At fibre in cane = 14%	At fibre in cane = 15%
15	12	8.355	8.250
16	12	7.940	7.840
16	13	9.155	9.040

(I) At fibre in cane = 14%
x = 9.155 — 7.940 = 1.215
y = 8.355 — 7.940 = 0.415

(II) At fibre in cane = 15%
x = 9.040 — 7.840 = 1.200
y = 8.250 — 7.840 = 0.410

(III) Decrease in x for 1% increase in fibre = 0.015
0.015 x 100 = 1.5 (coefficient of f for x on unit basis)
Decrease in y for 1% increase in fibre = 0.005
0.005 x 100 = 0.5 (coefficient of f for y on unit basis)

(IV) 1.215 + 0.14 (1.5) = 1.425 = x at zero fibre
0.415 + 0.14 (0.5) = 0.485 = y at zero fibre

At the base value of 12.41% fibre in cane (ratio of fibre to cane = 0.1241), as observed in Houma extraction tests,

$x = 1.23885$

$y = 0.42295$

Applying the above to the primary juice analysis of brix 17, pol 15, cited earlier, we have

$$\text{C.C.S.} = (15 \times 1.23885) - (17 \times 0.42295) = 11.3926$$

For comparison

$$\text{C.C.S.} = \frac{45}{2}\left(1 - \frac{17.41}{100}\right) - \frac{17}{2}\left(1 - \frac{15.41}{100}\right)$$

$$\text{C.C.S.} = (22.5 \times 0.8259) - 8.5\,(0.8459) = 11.3926$$

THE SE FORMULA OF REUNION

Hugot in recent paper (6) shows the basic derivation of the following equation for recoverable sugar according to the formula for determining cane quality recently adopted in Reunion :

$$SE = K \cdot B_1\left(\frac{P_1 - 30}{100}\right)(1 - 1.4f), \text{ in which}$$

SE = Recoverable sugar (sucre extractible) basis : 97°

B_1 = Brix of crusher juice

P_1 = Purity of crusher juice

f = Parts of fibre per part of cane (ratio of fibre to cane)

K = Factory co-efficient, ranging from a minimum of 1.2 to a maximum of 1.3

Terms of the simplified equation as based on the SE formula would be as follows :

$x = K\,(1 - 1.4f)$

$y = K\,(0.30 - 0.42f)$

At $K = 1.25$ the mid point in range of factory co-efficient and with fibre % cane = 12.41 ($f = 0.1241$)

$x = 1.032825$

$y = 0.309848$

With a primary juice analysis of brix 17 and pol 15 as taken in the earlier example, the equation

$$SE = (Sx - By)$$

$$SE = (15 \times 1.032825) - 17 \times 0.309848 = 10.2250$$

Determined as per the original equation

$$SE = K \cdot B_1\left(\frac{P_1 - 30}{100}\right)(1 - 1.4f)$$

$$SE = 1.25 \times 17 \times 0.582353 \times 0.82626 = 10.2250$$

Thus, at the same primary juice analysis of brix 17, pol 15 and at the same fibre content of cane we get the following values for available sugar according to the different formulas :

Available 96° sugar Houma Station factors = 10.8242
SE (97° sugar) Reunion formula with K = 1.25 = 10.2250
C.C.S. (recoverable sucrose) Queensland = 11.3926

Observed differences are due in minor part to differences in pol value of the assumed end product, but as will be shown later are largely the result of differences in basic premises upon which the separate formulas are predicted.

Values of x and y for each of the 3 different systems, rounded to the nearest 0.0001 at the fibre level corresponding to varietal correction factor 1.00 of the Houma Station equation, are as follows :

System (Basis, yield % cane)	x	y
Available 96° sugar, Houma Station	1.0751	0.3119
SE, 97° sugar, Reunion	1.0328	0.3098
C.C.S. Available Sucrose, Queensland	1.2388	0.4229

EFFECT OF FIBRE AT FIXED VALUES OF BRIX AND POL

Varietal correction factors determined according to the Houma Station system on 49 varieties and corresponding values of fibre % cane given in a previous publication (3) Table III were grouped so as to give average differences of approximately 1.0 in fibre percent cane and the average varietal correction factor value of each group was determined. These together with calculated values of x and y are given in Table I.

TABLE I

AVERAGE VALUES OF VARIETAL CORRECTION FACTOR AND OF x AND y FOR GROUPS OF VARIETIES ASSEMBLED ACCORDING TO FIBRE % CANE AS BASED ON HOUMA STATION MILLING RESULTS

Group	Average Fibre%Cane	Average Varietal Correction Factor (C)	Houma Station Equation x = 1.0751 C	 y = 0.3119 C
1	15.34	0.9378	1.0082	0.2925
2	14.36	0.9670	1.0396	0.3016
3	13.24	0.9855	1.0595	0.3074
4*	12.41	1.0000	1.0751	0.3119
5	11.59	1.0263	1.1034	0.3201
6	10.63	1.0480	1.1267	0.3269

*Control Variety Co. 281.

Using group averages of fibre % cane as a basis, values of x and y as applying (a) to the C. C. S. formula and (b) to the SE formula may be calculated as follows, for groups representing the two extremes in fibre content.

Group	Fibre % Cane	C. C. S. Equation x= 1.125—1.5f	C. C. S. Equation y= 0.485—0.5f	SE Equation at K=1.25 x= K (1.0—1.4f)	SE Equation at K=1.25 y= K (0.3—0.42f)
6	10.63	1.26555	0.43185	1.06397	0.319192
1	15.34	1.19490	0.40830	0.98155	0.294465

By applying the appropriate x and y factors in each case to the analysis of brix 17, pol 15, we get the following yield values illustrating the effect of a given change in fibre at fixed values of brix and pol with each of the 3 formulas.

Fibre % Cane	Yield of sugar % cane Houma Staion factors adjusted for V.C.F. Basis : 96° sugar	Yield of sugar % cane SE Formula at K = 1.25 Basis : 97° sugar	Yield of sugar % cane C.C.S. Formula Basis : Recovered sucrose
10.63	11.343	10.533	11.642
15.34	10.150	9.717	10.982
Difference+4 71	—1.193	0.816	—0.660

It is not the purpose of this paper to analyse differences between provisions of the 3 formulas in minute details, but it may be shown that computed reductions in available sugar cited above reveal gross differences of fundamental importance. In the case of the C.C.S. formula the reduction of 0.660 reflects largely the incidental decrease in juice content of the cane since nearly complete extraction of sucrose is assumed. With the SE formula the decrease of 0.816 combines effects of reduction in juice content and a flat 5% loss of sucrose in bagasse. Finally, the drop of 1.193 in available sugar indicated by the Houma Station equation reflects the sum of empirically determined reductions due to (1) decreased juice content of cane, (2) loss of sucrose in bagasse which presumably increases with increased fibre in cane, and (3) change in the relation of primary juice to normal (absolute) juice, with a change in fibre content of cane. The latter is considered of special interest since it is ordinarily disregarded in formulas for determination of available sugar.

The significance of varietal differences in sucrose reduction as a factor in the available sugar equation has been shown in a recent publication (1). Results of milling tests supplying the previously cited fibre data (3) were examined for the relationship between fibre % cane and sucrose (pol) reduction factor. From results presented in the following tabulation it is possible to assess the effect and importance of sucrose reduction factor on decrement in available sugar associated with increase in fibre % cane.

Group	Average Fibre % Cane	Average reduction factor to convert pol of primary juice to pol of normal juice
1	15.34	0.9696
2	14.36	0.9729
3	13.24	0.9737
4 (CK)	12.41	0.9720
5	11.59	0.9774
6	10.63	0.9793

It is obvious from the above that the magnitude of sucrose (pol) reduction factor bore a consistent inverse relation to fibre % cane. The correlation coefficient of —0.893 ±0.091 is statistically significant. From the regression coefficient of sucrose reduction factor (R), on fibre % cane (F); (b_{RF}) = —0.00183, it may be shown that there was a predictable decrease of 0.00862 in sucrose reduction factor with an increase in fibre % cane of 4.71 covered by the range under consideration. At the assumed value of 15 for pol of primary juice this would account for a difference of 0.1293 in pol of normal (absolute) juice, and according to the Houma Station equation a decrease of 0.146 in available 96° sugar % cane.

Thus, the previously mentioned total decrease of 1.193 in available sugar % cane according to the Houma Station equation may be regarded as comprising 1.047 representing direct effects of increased fibre content (reduction in quantity of juice in cane plus loss of sucrose in added bagasse), and 0.146 representing indirect effects associated with a concomitant change in composition of normal (absolute) juice in relation to that of primary juice. Figure 1 gives the reduction in available sugar % cane converted to the basis of 96° with an increase of 4.71 in fibre % cane according to each of the 3 formulas. It is obvious that the Houma Station equation places a greater and presumably more realistic penalty on fibre than does either one of the other two expressions. A comparatively large reduction in available sugar based on actual extraction is attributed to direct effects of fibre. In addition, a substantial correction is made for a significantly changed relation of primary juice composition to that of normal (absolute) juice. It is considered pertinent to mention here that evidence of a consistent change in sucrose reduction factor with a change in fibre percent cane presented above is based on 424 pairs of observations on as many different lots of cane. From these extensive data the order of decrease in sucrose reduction factor associated with a given increase in fibre percent cane could be measured with good statistical precision. However, because of unavoidable experimental variations and also because of possible variety effect irrespective of fibre content, it cannot be expected that individual determinations or averages based on much smaller numbers will show similar consistency.

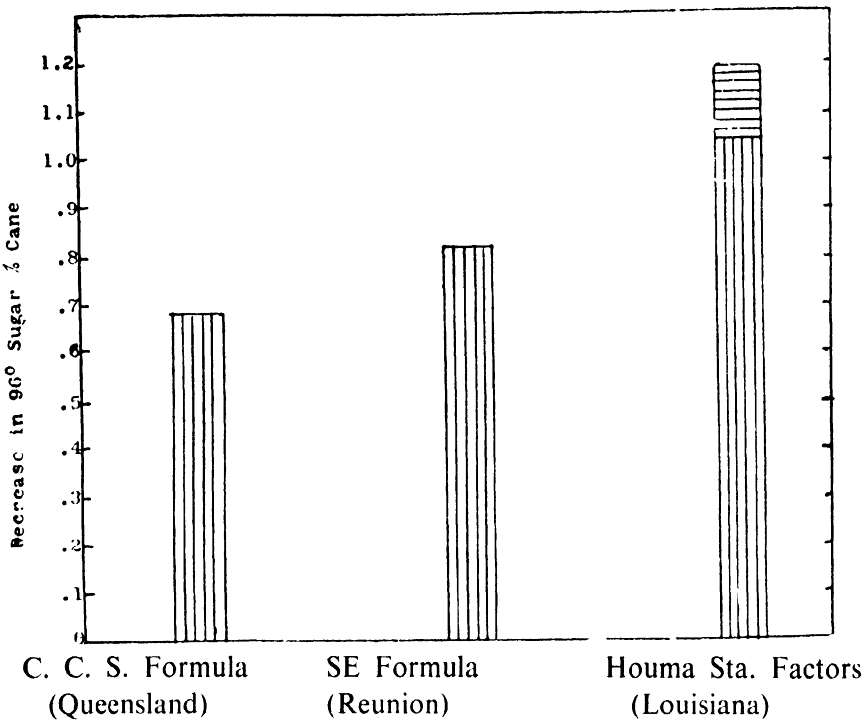

Fig. I. Reduction in indicated available 96° sugar % cane with an increase of 4.71 in fibre % cane according to each of 3 formulas. Primary juice: Brix = 17; pol = 15.

▥ = Reduction due to lowered juice content of cane and loss of sucrose in bagasse (direct effects).

▤ = Reduction due to concomitant change in relation of normal (absolute) juice to primary juice (indirect effect).

It is recognized of course that, strictly speaking, factors for recoverable sugar-developed from studies at Houma must be considered as characterizing a specific set of experimental conditions. However, it is considered worthy of note that: (1) the 49 varieties included in the study consisted of species hybrids of the general type in present world culture, (2) the range in the fibre % cane from 10.63 to 15.34 is representative of present day mill-cane, and (3) the level of sucrose extraction ranging from 92 to 94 percent is fairly typical of a reasonably efficient level of mill performance. Therefore, trends observed, especially with regard to the demonstrated association between fibre % cane and sucrose (pol) reduction factor, are considered of more than casual interest and significance.

DISCUSSION OF RESULTS

The Houma Station equation for available sugar, in contrast with the C. C. S. and SE formulas, uses actual extraction instead of fibre content as a criterion in evaluating variety effect on milling results as integrated in the term varietal correction factor. However, as indicated by data given in Table I, there is a very close negative relation between fibre % cane and varietal correction factor. The correlation co-efficient of —0.994 ± 0.006 is highly significant. The following tabulation compares varietal correction factor values determined (1) according to the Houma Station procedure and (2) from the regression equation. In the latter case the varietal correction factor was taken as 1.000 at the base value of 12.41% fibre in cane. Adjustments in V. C. F. Values were made for departure in fibre % cane from 12.41 on the basis of the linear regression of Varietal Correction Factor (C) on fibre % cane (F) at the computed value of b_{CF} = —0.0226462.

Variety group	Fibre % Cane	Varietal correction factor according to Houma Station method on the basis of Actual Milling Results	Varietal correction factor according to The regression equation applied to fibre
1	15.34	0.9378	0.9336
2	14.36	0.9670	0.9558
3	13.24	0.9855	0.9812
4	12.41	1.0000	1.0000
5	11.59	1.0263	1.0186
6	10.63	1.0480	1.0403

Thus, it is seen that a reasonably accurate varietal correction factor may be computed from results of fibre analyses and information already accumulated from results of experimental milling tests. The value of such at system in lieu of additional extraction measurements would obviously depend on the ease and accuracy in measuring comparative varietal fibre content. Where experimental facilities for high-level extraction are available, it is cosidered preferable to base the adjustment for variety effect on actual extraction measurements and to use comparative fibre data incidentally obtained as supplementary evidence.

It has been shown how basic provision of each of 3 formulas for available sugar in cane can be resolved to the simple equation S″ = (Sx)—(By) in which S″ = yield of sugar % cane, S = pol of primary juice, B = Brix of primary juice, and x and y are calculated factors. The expression as adjusted reflects combined effects of prevailing or assumed milling and fabrication efficiency with due allowance for fibre content of cane. The calculation can be made quickly in a single operation with any modern calculating machine but features of automatic positive and negative multiplication are especially useful in the operation.

The simplified equation has been found a particularly valuable tool in agronomic research requiring numerous routine determinations of available sugar from results of primary juice analyses. In such cases it is not customary to make individual fibre determinations. Ordinarily a uniform value of fibre in cane or conversely of normal (absolute) juice extraction is assumed in the case of an experiment confined to a single variety. Where varietal differences are involved, adjustments if any are customarily generalized. In any case, the combined effects of basic assumptions can be accurately integrated in values of x and y of the simplified equation. Calculation of available sugar by means of such factors applied directly to brix and pol of primary juice has been found much more satisfactory than determination by use of yield tables. Yield tabulations covering the usual range of the 3 basic variables in terms of actual analyses are lengthy and cumbersome to use. Interpolations required with abbreviated tables of greater intervals between ultimate units are time consuming and can be another source of errors.

Calculations to determine purchase value of cane in accordance with such formulas C. C. S. and SE where individual fibre determinations are made can probably be expedited by use of the Sx—By formula. It would be a simple matter to construct a table giving x and y values at different values of fibre % cane. Available sugar for any analysis of primary juice could then be computed quickly by use of the appropriate x and y values in the simplified equation.

The author has not had any experience in factory control but it is believed that a considerable saving in time could be realized and greater accuracy achieved by use of the simplified equation in many of the routine calculations in factory laboratories.

SUMMARY

The equation $S'' = (Sx) - (By)$ permits the determination of available sugar % cane (S'') from pol (S) and Brix (B) of primary juice in a very simple operation especially well suited to mechanical calculation. Derivations of x and y integrating combined effects of extraction and final recovery provisions of each of 3 formulas are illustrated ; at 12.41 fibre percent cane, values of x and y are as follows :

Formula	x	y
SE (Reunion, at K 1.25)	1.0328	0.3098
Houma Station (Louisiana)	1.0751	0.3119
C. C. S. (Queensland)	1.2388	0.4229

The simplified equation has proved especially useful in agronomic research and would probably expedite routine calculations of available sugar in determining the market value of mill cane. It may also have an important application in some of the calculations for factory control.

In results of experimental milling tests the composition of normal (absolute) juice in relation to that of primary juice changed significantly with a change in fibre % cane. This has been generally overlooked as a factor in the formulation of equations for determining available sugar from analyses of primary juice.

REFERENCES

1. Arceneaux, G. and Hebert, L. P. 1954. Calculation of sugar production from sugarcane variety tests. *Sugar, 49,* No. 12 : 50-52.
2. Arceneaux, G. and Roberts, B. S. 1954. Simplification of conventional sugar recovery formulas. *Sugar, 49,* No. 3 : 59-62.
3. Arceneaux,G. 1953. Some neglected aspects of experimental procedure in making comparative tests of sugarcane varieties. *Proc. 8th Congress I.S.S.C.T.* p. 430-440.
4. Arceneaux, G. 1935. A simplified method of making theoretical yield calculations in accordance with the Winter-Carp-Geerligs formula. *Int. Sug. Jour. 37.* 264-265.
5. Hughes, C. G. 1949. The production and testing of sugarcane seedlings. Page 67, *Techn. Com. No. 2, Dept. of Agr. Queensland,* 69 p. illus.
6. Hugot, E. 1955. Cane payment on quality basis-an extractable sugar formula in Reunion. *Int. Sug. Jour. 57.* 187-190.

DISCUSSION

The Chairman requested the delegates to give their views on the subject in the light of the system of cane payment adopted in their countries.

Mr. J. D. R. St. Antoine said that in Mauritius cane from estates and from independent planters was analysed at the mill for brix and apparent purity of first expressed juice and fibre in cane. First expressed juice was converted to absolute juice by a factor and the estimated recoverable sugar in cane calculated by the S. J. M. formula using a standard Boiling House Recovery. Two thirds of this sugar value goes to the grower and one third to the miller. The grower also gets one third share of molasses. Mauritius has many small cane growers. About half the cane comes from the factory estates ; one quarter from large growers and one quarter from growers with less than about 10 acres of land. It was impossible to individually sample the very small deliveries and groups are formed to ensure deliveries of not less than 10 minutes crushing time, only among the extremely small suppliers. The cane payment system is controlled by a Central Board with a magistrate for Chairman, two millers' representatives, two large growers' representatives (1 vote) and two small growers' representatives (1 vote). This Board regulates its own procedure ; has power to fine, to control stale or dirty cane, and control the assignment of land for cane growing. Growers are bound each year by a contract. He recognised that India's extremely large number of very small cane suppliers presents a dificult, but not an impossible cane payment problem. He suggested that all large cane farms should be given a separate test to start with.

Mr. D. R. Narang (India) said that the sugar industry of India is spread over a sub-continent with very greatly varying conditions. Most factories in the Deccan area have their own farms ; their soils differ widely from light to heavy type ; some 30 irrigations are given to each cane crop ; 400 to 450 lbs. nitrogen per acre are applied and yields are seldom less than 50 tons cane per acre. In Bihar and U. P. there are no cane farms and cane is supplied by a large number of growers up to 25000 in number, some of them owning less than an acre. Some factories crush for 90 days while others for 200 days. It is hard to see how a uniform price of cane can equitably apply to all these widely varying conditions. Does any one know of one fool proof cane payment system that can be applied to all these widely differing conditions ?

Mr. A. Constandse (India) said that the main difficulty confronting payment on quality basis is the extremely small deliveries, in some areas the average size of cane farms being 0.8 acre ; 22% of the cane supply comes from hundreds of different rail and road loading centres many miles from the factory. Cane is frequently stale and its fibre content varies widely.

Mr. K. L. Khanna (India) drew attention to a natural gift formed in the fact that cane ripens fairly uniformly as the season progresses and the sugar content rises, as a rule, fairly steadily from November to March. It may only be necessary to determine quality once during the season to predict the best harvesting schedule for each farm.

Mr. D.D. Puri (India) stated that the preharvest survey suggested by Mr. Khanna would present an impossible administrative task and a very large number of disputes may follow over harvesting schedules. Determination of a fair price for cane involved consideration of question such as the basis of the price to be on predicted or actual recovery ; assumed or actual price of sugar ; should the price of cane be regulated by mill efficiency ; and should the price of cane rise and fall with the progress of season. If growers are paid a low price early in the season, they will be tempted to divert cane to Gur production. Late in the season the recovery is higher, but the land has been occupied by the crop longer, more water used and tops less useful for fodder. Under group payments, incentive to the individual farmer is defeated.

Mr. R. Gonzalez Rivera (Cuba) said that in his country each mill pays the growers collectively a price per ton of cane according to the over all recovery and price of sugar for the mill for the season, but with the exception of two factories each grower in any one mill area gets the same flat rate regardless of individual cane quality. Growers supplying 5000 short tons of cane or less receive 50% of the raw sugar value; between 5000 and 7000 tons, 49.5%and over 7000 tons, 49%. At two of the mills, each rail road car is sampled at the first roller and the growers price adjusted individually. This has resulted in an increased quality of cane at these paticular mills since the growers became quality minded. The yield of cane per acre in Cuba is low, but the average quality is fairly high. This may be partly due to the fact that severe crop restrictions have encouraged the growing of many ratoon crops, often as many as eight. He thanked Mr. W. E. Dickinson for assistance in preparing data on this subject and expressed the view that this Symposium of Cane Payment Systems was bringing forward many helpful ideas for all delegates.

Dr. G. A. W. Wagenaar (Java) stated that about one third of Java's cane supply came from small individual cane growers and the number was rapidly increasing. The law provides for sampling of first expressed juice from individual cane deliveries. Recoverable sugar content is estimated by the formula: S—0.4 (B—S) where, S and B represent % Pol and Brix in first expressed juice. This rendement multiplied by tons cane and sugar price and by a factor worked out for each mill gives the cane payment for each grower.

Mr. E. T. Infante (Philippines) said that about 99% of cane crushed in the Philippines is supplied by independent farmers, who have their deliveries sampled for % Pol and Brix of first expressed juice. From this, the piculs sugar per ton cane is estimated from simple tables adjusted to the actual factory bagged sugar at the end of each cane payment period, and the grower divides the raw sugar in the bag calculated from his cane with the miller. Growers get 60 to 65% and the millers get 40-35% according to various long term contracts. A minimum factory performance has now been included in the new contracts. One of the large mills, for example, crushing 8500 metric tons per 24 hours has over 3000 growers. A strict control of daily cane deliveries is maintained through the distribution of empty cars on the milling company's own railroads.

Mr. Alfonso G. Gallardo (Mexico) stated that even though every country had a number of peculiarities which differed from the others, there were some general principles that might be considered in any system intended to pay for sugar cane by quality. These were that :—

(i) the system should be as simple as possible and with convenient provisions to permit future improvements,

(ii) the small farmers should be arranged in groups of similar quality as nearly as can be found. Individual payment is impracticable for very small growers,

(iii) the only practical and satisfactory way for the analysis of sugar cane is the sampling of factory first expressed juice. The analysis of a few stalks is objectionable for the growers and for the factory,

(iv) there should be some practical way to take into account the mill extraction or fibre content of any particular sample in the calculation of recoverable sugar. Two canes with equal sucrose and purity of juice have different values for percentage of fibre. Direct analysis for fibre might be troublesome ,

(v) the fairest payment system is to share the sugar recovered between the cane grower and the factory on the basis of general yield of the whole crop and ' relative percentage' for each run to equitable regulated harvesting schedules ,

(vi) there should be a minimum price of cane based on the minimum share at the price of the sugar fixed by the Government, and increasing percentages for additional recoveries at the real selling price of sugar,

(vii) it should be provided, in connection with the theoretical calculation of recoverable sugar to reduce to the real recovery and to consider other pertinent circumstances (milling days, frosts, cyclones etc.) and

(viii) the payment for quality should be complimented with a comprehensive extension and demonstration service, and with more extensive financial facilities to carry out this work.

PROGRAMME PLENARY SESSIONS

I.S.S.C.T. 9TH CONGRESS PROGRAMME

(Including Tours)

Friday, 6th January, 1956

Formal enrolment of delegates at Taj Mahal Hotel, Bombay, on arrival up to and including 6th January, 1956. Those, who did not join at Bombay, were enrolled at the place they joined the tour or finally at the Central Hall of the Parliament House, New Delhi.

Welcome by the Union Minister for Agriculture in Sri Cowasji Jehangir Hall.

Reception by the Deccan Sugar Technologists' Association at Green Hotel.

Reception by the Governor of Bombay State, at Raj Bhawan.

Dinner by Deccan Sugar Factories' Association at Cricket Club of India.

Saturday, 7th January

Visit to Ellora Caves.

Visit to Ajanta Caves.

Sunday, 8th January

Field delegates visit sugarcane farm and factory delegates the factory of the Godavari Sugar Mills Ltd., Kanhegaon and study the working of Saha-Jain Process of Cane Juice Clarification.

Field delegates visit sugarcane farms and factory delegates the sugar factory of the Maharashtra Sugar Mills Ltd., Tilaknagar.

Field delegates visit sugarcane farm of Belapur Sugar Co. Ltd., Harigaon and factory delegates the factory.

Cultural Programme.

Monday, 9th January

Factory delegates visit Walchandnagar Sugar Factory, Walchandnagar.

Field delegates visit Sugarcane Research Station, Padegaon.

All delegates visit Dairy, Distillery and other Industries at Walchandnagar.

Field delegates visit the factory farms of the Walchandnagar Sugar Factory.

Cultural Programme.

Tuesday, 10th January

Visit to Humpi Ruins.

Wednesday, 11th January

Visit to Raman Research Institute and Indian Institute of Science, Bangalore and attendance at a lecture by Sir C. V. Raman.

Sight-seeing in Bangalore.

Witness a programme of Indian dance by Prof. U.S. Krishna Rao and party.

Cocktail Party by South Indian Sugar Mills' Association at West End Hotel.

Thursday, 12th January

Visit to the Industrial Show Room and Spun Silk Mills at Chennapatna.

Field delegates visit the sugarcane farm and factory delegates the Sugar Factory and Allied Industries of the Mandya Sugar Mills Ltd., Mandya.

Visit to the historical monuments at Seringapatam on way to Mysore.

Visit to Brindavan Gardens, Mysore.

Friday, 13th January

Visit to Prospect Tea Estate and Government Quinine Factory enroute to Ootacamund.

Toda dance on the lawns of Savoy Hotel, Ootacamund.

Cinema Show in the Assembly Room.

Saturday, 14th January

Visit to Sims Park enroute to Coimbatore.

Visit to Sugarcane Breeding Institute, Coimbatore.

Visit to Handloom Weaver's Colony.

Cultural Programme.

Sunday, 15th January

Visit to Kapaleeshwar Temple, Mylapore and the Theosophical Society, Adyar, Madras State.

Swimming at Gymkhana Club, Mahabalipuram.

Monday, 16th January

Field delegates visit the farm and factory delegates the Sugar Factory and Allied Industries of M/S. K.C.P. Ltd., Vuyyuru.

Tuesday, 17th January

Cocktail Party by Lala Karam Chand Thapar at Calcutta.

Wednesday, 18th January

Visit to Dakshineswar, Belur Math, Jain Temple and Botanical Gardens, Calcutta.

Visit to Museum.

Tea by Shri S. S. Kanoria.

Cocktail Party and Dinner by Shri S. P. Jain.

Thursday, 19th January

Some of the delegates visit Sugarcane Research Station, Pusa. Other delegates visit Texmaco, Jute Mills and Centres of Handicrafts etc., and also visit Fort William.

Cocktail Party by Shri B. P. Kedia.

Friday, 20th January

Visit to Sugar factory, Farm and other Industries at Dalmianagar.

Saturday, 21st January

Visit to Indian Institute of Sugarcane Research, Lucknow.
Visit to Imambaras.
Reception by Governor of U.P.

Sunday, 22nd January

Visit to The Botanical Gardens and other places of interest around Lucknow.
Visit to U. P. Governments' Handicraft Emporium.
Reception by Cane Union Federation.
Cultural Programme.
Dinner by the Indian Sugar Mills Association, U. P. Branch.

Monday, 23rd January

Visit to National Sugar Institute, Kanpur.
Luncheon by Shri M. R. Jaipuria.
Field delegates visit Government Agricultural College, Kanpur; factory delegates visit Experimental Factory of N.S.I., to witness trials of Prof. Ghosh's Electrical Process of Juice Clarification.
Tea at Kamla Retreat by Shri Padmapat Singhania.
Dinner by M/S. Begg. Sutherland & Co. Ltd.

Tuesday, 24th January

Visit to Sugarcane Research Station, Shahjahanpur and a Khandsari factory.
Field delegates visit the farm of M/S. Hindustan Sugar Mills, Golagokarannath and factory delegates the sugar factory.
Visit to Rosa Sugar Works and Distillery, Rosa.

Wednesday, 25th January

First Plenary Session in the Central Hall of the Parliament House, New Delhi.
Inaugaration by the Union Minister for Food and Agriculture.
General Chairman's Address.
Thanks by the General Vice-Chairman.
Official Photograph.
General Chairman declares First Business Session open.
Special Committee Business.
Visit to places of historical interest around Delhi.
Cocktail Party by Indian Sugar Mills Association at Imperial Hotel.

Thursday, 26th January

Witnessing the Ceremonial Parade on the Indian Republic Day.
Visit to Places of historical interest around Delhi.
'At Home' by the President of India at Rashtrapati Bhawan.
Seeing illuminations.

Friday, 27th January

Sectional Meetings in the Committee Rooms of the Parliament House.

Witnessing a programme of Indian Folk Dances.

Saturday, 28th January

Sectional Meetings in the Committee Rooms of the Parliament House.

Visit to Indian Agricultural Research Institute, and National Physical Laboratory, New Delhi.

Cocktail Party by Lala Charat Ram of M/S. Delhi Cloth & General Mills Co. Ltd.

Sunday, 29th January

Visit to historical monuments at Sikandara enroute to Agra.

Visit to Taj Mahal, the Fort at Agra and monuments at Fatehpur Sikri.

Monday, 30th January

Sectional Meetings and Symposia in the Committee Rooms of the Parliament House.

Tuesday, 31st January

Sectional Meetings and Symposia in the Committee Rooms of the Parliament House.

Visit to Sri Ram Institute of Industrial Research and the Indian Standards Institution.

Tea by Sri Ram Institute of Industrial Research.

Wednesday, 1st February

Sectional Meetings and Symposia in the Committee Rooms of the Parliament House.

Reception by the Union Minister for Food and Agriculture at Rashtrapati Bhawan.

Thursday, 2nd February

Second Plenary Session.
Resolutions.
Place of Next Congress.
Election of Officers.
Other Business.
Valedictory Dinner at Hotel Imperial.

FIRST PLENARY SESSION

OFFICIAL OPENING CEREMONY AND FIRST PLENARY SESSION HELD AT THE CENTRAL HALL OF THE PARLIAMENT HOUSE, NEW DELHI, INDIA

Wednesday, 25th January, 1956, 10-30 A.M.

The Ninth Congress was officially inaugurated by Shri A. P. Jain, Minister for Food and Agriculture, Government of India. The General Chairman (Mr. D.R. Narang) welcomed the Hon'ble Minister and requested him to open the Congress, the first of its kind to be held in India.

INAUGURAL ADDRESS

I am grateful to you for having afforded my country the opportunity to play the host to the Ninth Congress of the International Society of Sugarcane Technologists. International gatherings of scientists and technologists like the one which I have the honour to inaugurate, not only provide venue for exchange of knowledge and collection of information and thereby enable the world to increase the collective prosperity and to add to the common welfare but they also help to bring the different people together, understand their history and culture and create a climate congenial for co-existence. You must be aware that since the Independence, we have in our humble way been busy in helping to create better understanding between different nations of the world so that their cumulative energy may be applied for the betterment of the lot of humanity instead of destroying one another. For that reason also, I extend to you a most hearty welcome.

You have been going round our country for the last fortnight and a little more and during this period you have seen some places of historical and cultural importance. You have also seen some temples and a bit of our social, religious and cultural life in cities and villages. You have already come across a cross-section of our sugar industry and what we are doing in our fields and factories and various research and technological institutions. While we are proud of our past and historical monuments like Ajanta and Ellora, our hopes and inspirations lie in India of the future which we are trying to re-build on the twin principles of peace and prosperity. It is fortunate that your visit to this ancient town has synchronized with our Republic Day and tomorrow you will be witnessing our celebrations and share our happiness and joy on the great occasion.

We are, at present, engaged in the gigantic task of effecting an alround progress in the agricultural, industrial and other fields of economic activities through successive Five-Year National Development Plans of which the first one is now drawing to a close. We are on the threshold of the Second Five Year Plan which lays emphasis on the development of large-scale and heavy industries. Sugar industry, which is the second largest industry in the country finds an important place in our planning. The production capacity of the industry is proposed to be raised by over 50 percent during the coming five years. It is, therefore, all the more gratifying to have amidst us at this juncture of India's resurgence of industrial progress, many distinguished and renowned sugar technologists and sugarcane experts from various parts of the world. I have no doubt that we will profit immensely by the free and frank exchange of technical information and knowledge between experts of international repute during this Session. Science and technology know no national barriers or political boundaries. It is this branch of human knowledge and pursuit which is truly international and it is in the sharing of knowledge and experience between the nations of the world and in their application for the common good of mankind, that real human progress and happiness lie. I am highly gratified to learn that your Society contributed much to the technological and scientific advancement of sugar industry all over the world both in the field and the factory. India too has benefited through participation with your great Association and I hope that our connections will become even more intimate.

As you know, sugarcane has been grown in India from times immemorial. The earliest unmistakable record of sugarcane is found in the great book of Hindus-the 'Atharva Veda '-believed to have been compiled several thousand years ago. Some, therefore, and I believe rightly, regard India as the original home of sugarcane. It is grown throughout the length and breadth of the sub-continent and occupies an important position in the economy of the Indian peasant. In many parts, it is the principal or one of the principal crops which the cultivator grows for obtaining his cash requirements. It is grown on small farms operated mainly by the labour of the farmer's family and the livestock owned by him. Ordinarily, a portion of the farmer's holding is put under this crop depending upon the pattern of crop rotation and the subsistence requirements of the grower. Nearly 3/5th of the annual produce from 4 million acres under sugarcane is converted by the growers into gur (whole juice solidified) and khand (made by indigenous process) right in the heart of rural India on a cottage industry scale. The primitive open pan factory is a feature and an event in the rather uneventful life of the village. It becomes a rendezvous of the village and the young and old folks are often seen hovering around it. I wonder if you had the occasion to witness this happy sight during the course of your tour.

The white sugar industry in India is of recent origin. It was established only after 1932 when the industry was granted tariff protection. From a mere 29 factories in the pre-protection days the units in the industry had risen to 134 in 1936-37 and the production of white crystal sugar had gone up ten-fold. Even so, our modern sugar mills consume a surprisingly small portion of our total sugarcane-not more than one quarter.

World War II brought in its wake an era of control over production, distribution and price of foodstuffs. Sugar was accordingly rationed all over the country and it was only in 1952 that we could remove ·restrictions on the price and distribution of this commodity. The removal of controls brought about an unexpected situation. The annual consumption of white sugar which had averaged round about one million tons in the years of control suddenly jumped up by 80 percent in the free market conditions. We were compelled to take recourse to imports of sugar on a large-scale. Simultaneously, the Government also decided to increase the production capacity of the industry not only to equate the immediate and increased demand but also to provide for the prospective increase due to rise in the standard of living and the growth of population. During the next five years, our consumption of white sugar is estimated to rise to 2.25 million tons and we have decided to raise our production capacity to 2.5 million tons as against the present capacity of 1.6 million tons in 161 units. We have already issued licences for the establishment of 39 factories and expansion in 44 existing units and more licences are in the process of being issued.

The big development programme on which we have embarked is a challenge to the intellect and ingenuity of the Indian Sugar Technologists and the resources of the industry. I trust they will rise to the occasion and continue to carry on a relentless struggle both in the field and the factory. They will, I hope, bring down the price of sugar which, unfortunately, remains substantially higher as compared with that of other producing countries.

Sugar industry in India is a fine example of a regulated industry. The price of sugarcane supplied to the factories is fixed by law after taking into account the cost of production and other relevant factors. The wages and other amenities of labour are regulated by the labour laws of the land. The industrialist is allowed a reasonable margin of profit and allowances for depreciation and replacement in determining the fair sale price of sugar. Any profits in excess of the fair price is equitably distributed between the cane-grower and the factory owner. In human affairs where there are conflicting interests, while it may not be possible to establish a perfect harmony the sugar industry in India has, on the whole, functioned peacefully. Occasional disputes between the mill-owner and the cane-grower and the mill-owner and the labour have arisen but the atmosphere generally is permeated with a sense of peace and co-operation. The system of fixing the minimum price of sugarcane has given ample protection to millions of petty cane-growers whose interests no Welfare State can afford to overlook. Over a major part of the country, we have developed a net work of Co-operative Societies which enter into contract with the mills for the supply of adequate quantities of sugarcane and in their turn, the Co-operative Societies make contracts with individual growers. Thus the factory is guaranteed adequate supply on the one hand and the cane-grower an assured market on the other. We have gone ahead another stage and more than 50 percent of the new factories which we have licensed have been organised on the Co-operative basis. This is an important development in our food-processing industries and the success of this pattern will give us both experience and courage to go ahead.

Another main problem confronting us is the low yield of sugarcane, the average for the whole country being 13 tons per acre, although yields of 40 tons are quite common in Bombay, Deccan and other parts of South India. The average sugar percent cane for the whole country works out to about 12.4 percent and sugar recovery to about 10 percent. We are taking adequate steps to increase both. The Sugarcane Breeding Institute, Coimbatore, the Indian Sugarcane Research Institute, Lucknow, the Indian Central Sugarcane Committee and numerous Regional Research Stations are constant endeavouring to evolve better varieties and improve upon cultivation practices. The Coimbatore Cane Breeding Institute is engaged on a Saccharum Spontaneum Expedition Scheme under which that Institute is collecting various forms of wild Saccharum Spontaneum from all over the country and abroad and is assessing their value as parent stock in the breeding work. I need hardly tell you that it was the Coimbatore Institute which started crossing the wild Saccharum with noble canes, a practice which has contributed so much to the success of the Coimbatore canes. Where large number of small and unsophisticated peasants are involved, the process of introducing better technique and improved method takes time but we are determined to wage a total war to improve the lot of sugarcane grower by organising the grower's Co-operative Societies, developmental projects and the like. Apart from the major irrigation projects which will supply irrigation to large areas, we are sinking large number of tubewells in the sugarcane growing areas for increasing irrigation facilities. These efforts of ours have already begun to bear fruit and we expect that the all-India average yield per acre would during the next five years increase by 50 percent.

The Government of India have recently established a Development Council for Sugar to promote the development of industry on sound lines. The technological aspects of the industry are being looked after by the National Sugar Institute at Kanpur. Besides training technologists and giving advice to factories on technical problems, the Institute has been engaged in research on the process of sugar manufacture and utilization of bye-products of the industry. It has evolved an improved sulphitation process which yields sugar of a quality comparable to the carbonation process. I am told that you have already seen this process at work on a commercial scale at Kanhegaon. We are very keen to develop industries which may utilize the bye-products of sugar factories. We have, therefore, invited foreign experts to help us in the formulation of schemes for the proper utilization of bagasse. We hope that soon it will be possible for us to set up more industries which derive their raw materials from the bye-products of sugarcane.

In spite of numerous developmental programmes, our sugar industry has been suffering from periodical cycles of under and over production. The quantity of sugarcane available to the factories varies widely from year to year depending upon the vagaries of nature and the relative price which the grower is able to realize from the sale of his crop to factories and by converting it into Gur. Government are considering measures to stabilise production, arrange for the fair return to the cane-grower and equitable distribution of surplus profits between the farmer and the factory. We would like to correlate cane prices with its quality in order to provide an incentive for growing better quality cane. In order to study the organization of sugar industry, the inter-relation between the cane-grower and the factory, the method of the fixation of cane-price and the system of sugar distribution, we sent abroad a delegation to Australia and Indonesia which has submitted its report and soon we hope to take decisions with a view to benefit from the knowledge and experience thus gained. In solving our problems, I hope, your deliberations will also be helpful to us.

I would not like to encroach any more upon your time as you will soon set about on the more serious business of the Congress that is consideration and the discussion of Scientific Papers. I am greatly impressed by the long list and variety of scientific papers which cover numerous aspects and probably all the important problems of sugarcane culture, sugar manufacture, utilization of by-products, fixation of cane price etc. I have no doubt that the free exchange of scientific knowledge and experience will benefit us as other countries. As Minister for Food and Agriculture for India, I shall watch your deliberations with interest and I feel confident that your scientific and expert knowledge will be brought to bear on the solution of many problems facing the sugar industry and contribute to the common good and prosperity of all.

Before I close, I must express my sincere thanks and appreciation for the co-operation given by the State Governments, the industrialists, sugarcane and sugar experts in organising this Congress. If there have been any shortfalls in our arrangements, and there are bound to be many in a poor and under-developed country like ours, I hope that you will be generous enough to overlook them.

I thank you all and wish this Congress big success.

The Hon'ble Minister then declared the Congress open.

PRESIDENTIAL ADDRESS

MR. D. R. NARANG

First of all I have to thank the International Society of Sugarcane Technologists for the honour of electing me the General Chairman for the current term. I also thank the society for agreeing to hold the 9th Congress in India. Since India is at the moment on the threshold of intense technological progress, this international gathering is of great interest to her.

Members of the Congress, let us pay our homage to that spirit of science which makes life worth living. Let us pay our tributes to those eminent scientists and technologists who by their contributions have added to the knowledge of sugar technology and several of whom, I am happy to note,are present here today. Let us also extend our felicitations to all those fellow workers who are carrying the burden of running the sugar industry in all parts of the world. Every sugar producing country has made its own mark in the development of the sugar industry of the world but particular mention may be made of Cuba having recorded the highest sugar production in the world, Hawaii having registered the highest yield of 9.0 tons of sugar per acre, Queensland producing sugarcane having the highest sugar content of 15.2 percent and Formosa recording the highest reduced overall extraction of 90.8 percent.

Ladies and gentlemen, it is said that the sugarcane and the art of making sugar were known to India as early as about two thousand five hundred years ago and travellers and technicians came to India from other parts of the world to see that art ; but in the centuries that followed India remained static while other countries advanced and it was only since 1932 that a white sugar industry worth the name came to be established in India. India still has of course her indigenous cottage industries for the production of crude sugar by the open-pan methods. In so far as the white sugar industry is concerned India endeavoured to develop to some extent but its problems being different it has still to make considerable progress in several directions. This Congress therefore provides a great opportunity to India as well as to other countries of exchanging ideas and discussing various problems. It is indeed a matter of great enthusiasm for all of us that so many eminent technologists from several parts of the world are present here today. I extend to them and to all assembled here a hearty welcome.

Friends, according to recent estimates, the world sugar production in the present season is going to be the highest on record so far. Of the total world output of sugar almost 60 percent is made from sugarcane. The world's export trade in sugar is mainly confined to cane sugar surpluses. The international importance of the cane sugar industry is thus obvious. The objects of holding international conferences such as this, however, is to gather together and review the progress different countries have made since the last Congress met and to discuss the topics that will further advance the cause of sugarcane technology. While you will no doubt fulfil this task during your deliberations in the ensuing week through numerous very good papers that have been received on almost all aspects of sugarcane and its technology I should like to avail of this opportunity of speaking to you something about the Indian sugar industry, its problems and future prospects. Having come to India, you will, I am sure, like to get an overall picture of its sugar industry,a part of which you have also seen by now.

During the first World War sugar became scarce in India and the then Government of India realised that for satisfying the growing taste in India for white sugar and for strategic reasons India's home industry must be developed. Consequently state protection was granted to this industry in 1932. This led to the renaissance of the white sugar industry and within the next few years a large number of sugar factories were established and India became almost independent of foreign imports in the matter of white sugar.

As sugarcane was then readily available in northern India, that is in the states of Uttar Pradesh and Bihar, where it had been cultivated since times immemorial, a large majority of factories came to be established in these regions.

In course of time cane plantations were developed in the southern parts of India and a number of factories came up in these parts also viz., in the Bombay, Madras and Andhra states. Thus a large majority of Indian factories are located in the five states of Uttar Pradesh, Bihar, Bombay, Andhra and Madras. India now has a total of 161 factories of which about 140 factories have been operating during the last few years. Most of these factories lie within the capacity range of 400 to 1400 tons of cane per day. Quite a number of these plants were initially of 400-600 tons capacity and have in later years been extended to 800-1200 tons capacity. The lay outs of these factories have thus become more or less congested and several units of machinery are either ill-balanced or forced to run to their utmost capacity. The average capacity for a unit works out to about 900 tons per day.

Almost all the plants were imported from U. K., France, Germany, Belgium, Holland and Czechoslovakia. It is only since the last few years that some simple units of sugar factory machinery are being fabricated in India.

In contrast with northern India where factories are fed exclusively by a large number of small cane growers, the factories in the south have their own large plantations. Moreover, being nearer to the tropics the factories of the southern regions get a better quality of cane and crush for a longer duration than the factories of the north. The present expansion of the industry is thus mostly confined to the southern regions. The quality of cane is, however, rather poor. In northern India, as you go from west to east, the sugar content varies from about 11.5 to 13.0 percent. In the regions comprising Bengal, Bombay, Hyderabad, Mysore and Travancore-Cochin, the sugar content varies between 13.0 to 14.0 percent but in the Madras and Andhra regions it is again around 11.5 percent ; giving an all-India average of 12.0-12.5 percent. The average yield of sugarcane per acre in the northern regions of India is only about 12 tons per acre but in the south it is about 30 tons per acre. It is, however, possible to raise the yield considerably both in the north as well as south almost to three times the present average figure by adopting suitable varieties, manurial and irrigational practices and other developmental measures. The improved Coimbatore varieties are generally grown for sugar factory use.

As regards the type of equipment in use, almost all factories are of the conventional type. It is in few factories that modern machinery units have so for been installed. Due to the strained financial condition of sugar factories in India, it has not been possible to carry out the modernisation programme to any substantial extent.

The processing technique is largely the double sulphitation method. Only about 16% of the factories follow the double carbonation process. While simultaneous liming and sulphitation is largly practised in the former, the De Haan modification is mostly adopted in the latter. The crystallisation equipment is, in a large majority of cases, still confined to old type of vacuum pans with poor circulation, batch type crystallisers and low gravity centrifugal machines water or belt driven.

Considering the type of equipment India possesses and the quality of cane that is crushed the quality of the plantation white sugar produced is not unsatisfactory, the bulk of production being of the grade D 28 in terms of the Indian Sugar Standards. India's technical efficiency is also fairly high. The all India average for reduced mill-extraction varies between 93.5 and 94.0 and the reduced boiling house extraction ranges between 90.5 and 91.0.

Given a good cane crop India's production capacity at present is 1.5 to 1.6 million tons of white sugar against an estimated consumption of about 1.8 million tons. With the expansion programme that has been set out in its Second Five Year Plan, India aims at producing 2.25 million tons of white sugar.

India's problems largely relate to the poor yield and poor quality of sugarcane, not excluding the spoilage or destruction of crop due to vagaries of nature, unsatisfactory transport conditions and incidences of diseases and pests. The sugar factory plants are old and sufficiently worn out. The cost of replacements and the incidence of capital cost in the programme of future expansion are found to be very heavy.

As I have said before, India's requirement of white sugar is estimated to be 2.25 million tons by 1960, whereas the present production capacity is about 1.5 million tons. To meet the gap of about 0.7 million tons, considerable expansion is envisaged during the next five years. The additional production is to be achieved by increasing the acreage under cane, by intensive cultivation, mechanised farming and controlled harvesting, by putting up new sugar factories and by the expansion of some of the existing units. Ways and means are being considered for increasing the yield of sugar per acre, such as payment of cane on the basis of sucrose content in such manner as Indian conditions permit. Licences have already been granted by the Government of India for the installation of 39 new factories and for the expansion of 44 existing units. Considerable expansion and modernization of the Indian Sugar industry is thus inevitable. Means have to be found to cheapen the cost of machinery and modern and highly efficient plants have to be installed.

Modernization must be the need of every country. It is our constant endeavour to expend the least number of man-hours in the production of sugar. In our deliberations therefore emphasis would be laid, I believe, on discussing the merits of the latest improvements in machinery design or processing technique. Before closing I would therefore like to refer briefly to some of the latest advances in the realm of sugar technology in the hope that you would be able to make definite recommendations regarding them for the benefit of the sugar industry of the world.

In the department of milling, turbine drive is being adopted increasingly but it is reported that the steam balance gets disturbed at low grinding rates. The usefulness of applying uniform pressure has been realised and compressed gas-filled accumulators appear to be satisfactory. Effecting saving in power by reducing the width of the trash-plate, by having differential axes of the cane and bagasse rolls and by providing roller bearings for cane mills appear to be very attractive propositions. Further progress in the development of the " Automat " mill, and operation of continuous feeders is also awaited with interest.

In clarification, sustained efforts in Formosa on middle juice carbonation have brought forth very good results. The Saha-Jain process and the Ghosh process of electrical clarification are also promising propositions and their development is watched with keen interest. It is gratifying to note that the Saha-Jain process is at the stage of commercial scale trial in a sugar factory in India and the Ghosh's electrical process and the Ion-exchange processes are on the programme of pilot plant and bench-scale trials respectively at the National Sugar Institute, Kanpur. The latter trial is in collaboration with the National Chemical Laboratory of India.

The search for new clarificants goes on unabated. Bentonite, Clarigel, active Bauxite, active Magnesia, Krilium and Lytron X-886 are being experimented with. I hope the efficacy of these would be fully elucidated in the symposium on " Clarification ". The Ion-exchange process is a revolutionising proposition and its development, particularly in the direction of reducing the cost of regeneration of resins demands urgent attention of technologists.

In evaporation the design of a single shell quadruple effect evaporator has been reported claiming advantages in respect of absence of moving parts inside the bodies, absence of vibration due to movement of liquid, uniform pressure and velocity of vapours and increased circulation. The problem of scaling of evaporators still confronts the manufacturers and the use of various chemicals like sulphamic acid, sodium bi-fluoride and " Versene " has been suggested.

The crystallisation technique has been greatly improved by improving circulation in vacuum pans, preventing variations in temperature, automatic vacuum control and use of control instruments indicating the degree of supersaturation and automatic feeding techniques.

The separation of crystals from molasses has become far more efficient with the use of automatic high speed centrifugals besides giving substantial advantage in labour cost. From the latter point of view the continuous centrifugals score a definite advantage over the high speed centrifugals but the disadvantages due to crystals damage by abrasion and low gravity factor are holding up increased adoption of this unique invention. I hope it will not be long before this shortcoming is satisfactorily overcome.

Efficiency of steam generation has been effectively increased by the use of mechanical stokers particularly those that employ pneumatic distribution of bagasse. The use of steam has been greatly helped by means of the steam flow indicators.

Several other improvements have been suggested but it is not possible for me to recount all of them at this juncture. Suffice it to say that in the race for technological development, the sugar technologists have not lagged behind and I have no hesitation in asserting that theirs has been a proud record.

Since this Congress met last the world situation has improved very much for the better. The threat of a nuclear war is much on the decline. Given the atmosphere of peace, we shall go ahead with our allotted task with speed and concentration and make our own contribution towards the material well-being of mankind.

Ladies and Gentlemen, I thank you all once more for gracing this occasion.

Mr. Norman J. King, General Vice-Chairman, addressing the Hon'ble Minister said " this is a very great occasion for the delegates who have travelled from 25 different sugar growing countries to attend this Ninth Congress in your country. Many of us have travelled in other cane sugar producing countries of the globe and we have learnt to look at what other countries are doing and compared their doings with the experience in our own countries. But in India, I think, we have met with a new set of conditions. Never in any other country of the world have we seen such a set of contrasting conditions as we have done in India-from the high yield of the Bombay Deccan to the relatively low yield in Bihar, from the tropical conditions of South India to the complex climatic environments of Uttar Pradesh. In travelling around these areas, we have seen many differences, some of them quite surprising to most of us, who have come from countries where, due to shortage and high cost of labour, we have had to mechanise very severely. During our tour of some 3,000 miles in your country, we have been very much impressed by what is probably the finest array of sugar institutes and experiment stations as can be found in any country, devoted to the problems of sugar and sugarcane. I feel in this country the utilisation of by-products, particularly at Dalmianagar, has reached its peak. The organising committee has done more than to show us merely the sugar industry in India. They have attended to our interest in the cultural life of India and we have been enable to see some of her ancient civilization, temples and ruines and things of that nature which has given us some idea of the history of this very ancient land. None of these would have been possible without the very great generosity of your Government and the wonderful organisation which has been put into this Congress. It is, therefore, with a real feeling of gratitude and appreciation that I offer you, on behalf of all the delegates present, our thanks for your welcome and for your inaugurating this Congress ".

The Hon'ble Minister then withdrew, and there was a 15 minutes adjournment.

On resumption, the General Chairman declared open the First Plenary Session of the Congress. He asked all present to stand up for a minute in silence for the Members of the Society who had died since the Eighth Congress (Resolution No. 3-Second Plenary Session).

The General Secretary-Treasurer then submitted his report as follows :—

1. I beg to present the report of the General Secretary-Treasurer of the Society for the period ending with this Congress.

2. *Membership.*

The Membership for the Society for the 9th Congress stands at 1,123 as compared with 796 for the 8th Congress held in British West Indies in 1953 and 548 for the 7th Congress held in Australia in 1950. The number of members from various countries is as follows:—

COUNTRIES WITH REGIONAL SECTIONS OF THE SOCIETY

Argentine	—
Australia.	
New South Wales and Fiji	21
Queensland	65
British West Indies (excluding Barbados and Jamaica)	96
Barbados	24
Jamaica	65
Cuba	60
India	422
Indonesia	21
Mauritius	44
Mexico	69
Nicaragua	6
Pakistan	8
Peru	—
Philippines	17
South Africa	45
United Kingdom	17
United States of America:	
Hawaii	31
Mainland	39
Puerto Rico	18

Other Countries (where Regional Sections are not at present constituted)

Afghanistan	1
British East Africa	6
Ceylon	4
Colombia	2
Czechoslovakia	1
Dominican Republic	3
Ecuador	1
Egypt	3
France	2
German Democratic Republic	4
Haiti	1
Holland	4
Indo-China	3
Iran	1
Japan	4
Reunion	2
Taiwan	1
Venezuela	7
West Germany	5
Total:	1,123

The Secretariat of the Society addressed all the members of the 8th Congress and also other interested persons to enrol themselves as members for the 9th Congress. There has, however, been no response from Argentine, Peru, Costa Rica, El Salvador, French West Indies and Panama. It may be mentioned that Argentine and Peru had Regional Sections of the Society and it will be necessary to reorganize the Sections in those countries.

In response to the Secretariat's request, a number of Technologists from Indonesia, Pakistan and Philippines applied for membership and also requested for setting up of Regional Sections in their countries. Their requests for establishment of Regional Sections were circulated to the members of the Administrative Committee for their approval and I am now glad to announce the establishment of new Sections in these three countries. It is hoped that Regional Sections will also in due course be set up in British East Africa, West Germany and Venezuela as each one of these countries has now five or more members.

3. *Action on recommendation of 8th Congress.*

Necessary action on the various recommendations of the 8th Congress was duly taken. The reports of the Committee set up under Resolutions Nos. 5, 7, 9, 11, 12, 13, 14 and 15 have been received and will be presented at the Second

Plenary Session of this Congress through the sections concerned, where necessary.

4. *Finance.*

The balance in the Society's Saving Account in Hawaii as on December 31,1954, was certified by the Treasurer of the Hawaiian Sugar Planters' Association to be $ 6,823.90 (vide Annexure I). The treasurer has since intimated that the balance in the account of the Society as on January 5,1956 was $ 7,158.09 (vide Annexure II).

The income of the 8th Congress amounted to £ 1653.17.0½ which was completely spent. An amount of £ 1475.11.11½ was contributed towards the printing costs of the Proceedings—the total cost of which was £ 4243.15.5 (vide Annexure III). This action was in accordance with Section 9 of Article IV of the Constitution.

Receipts to-date in connection with the 9th Congress are as follows :—

From the previous General Secretary-Treasurer in accordance with Section 9 of Article IV	Rs. 2,367—3—0
Membership dues	Rs. 52,725—0—0
	Rs. 55,092—3—0

As required under the Constitution 500.00 U. S. Dollars will be transmitted to the next General Secretary-Treasurer and the balance will be contributed towards the printing costs of the Proceedings, which is estimated at about Rs. 75,000 or Rs. 50/- per copy.

5. *Membership dues and sale of Proceedings.*

The membership dues for the period under review were ten dollars and the sale price of the Proceedings of the 9th Congress to non-members will be twenty dollars or its sterling equivalent. This is in accordance with the decision taken vide Resolution No. 8 adopted at the 8th Congress of the Society.

NEW DELHI (India),
January 25, 1956

Sd/- T. Prasad.
General Secretary-Treasurer

ANNEXURE I

YOUNG LAMBERTON AND PEARSON

Certified Public Accountants

1154, Bishop Street
HONOLULU 9, HAWAII, U. S. A.

Cable Address
"AUDITS"
HONOLULU

March 31, 1955

Mr. T. M. Brown, Treasurer
Hawaiian Sugar Planters' Association
Honolulu, T. H.

Dear Sir,

The undernoted statement shows the recorded receipts and disbursements for the year ended December 31, 1954 and the balance of funds in your custody for account of International Society of Sugar Cane Technologists:

Savings account balance December 31, 1953			$ 5,285.00
Bond interest received :			
U. S. Treasury Bonds 2½%			
Nos. 18224D-18225 E-18226F-$ 500.00 each one year.	$ 37.50		
Less : Bank charges on coupons	.20	$ 37.30	
Saving account interest-one year to December 31, 1954.		$ 87.75	
Proceeds from called bond :			
Commonwealth of Australia	$ 500.00		
Less : Bank Charges, postage insurance	.69	499.31	
Syndicat des & Febricante de sucre		350.00	
Ministerio de Agriculture, Venezuela		140.94	
Sales of books for year ended December 31, 1954		520.01	1,635.31
Less :			$ 6,920.31
Customs service and duty on books received	$ 62.25		
Freight on above	$ 27.58		
Postage on books sold	$ 6.58	96.41	
Savings account balance December 31, 1954			$ 6,823.90

The balance in Savings Account as on December 31, 1954 was confirmed to us by bank of Hawaii.

The U. S, Treasury Bonds in your custody were examined by us.

Yours very truly,

(Sd.) Young, Lamberton and Pearson

ANNEXURE II

HONOLULU, HAWAII, U. S. A.

January 5, 1956.

Mr. T. Prasad
General Secretary-Treasurer
9th Congress, International Society of
Sugar Cane Technologists
C/O Ministry of Food & Agriculture
" Jamnagar House ", New Delhi, India.

Dear Sir,

For your information we advise you that the status of your funds with the Hawaiian Sugar Planters' Association is as follows :

Balances as on December 31, 1954		$ 6,823.90
Sale of publications of Congresses of the I.S.S.C.T. January 5, 1955 to January 5, 1956		755.00
June 16, 1955 Coupons, Bond 18224D	6.25	
Bond 18225E	6.25	
Bond 18226F	6.25	
	18.75	
Less charge	.10	18 65
June 30, 1955 Interest		51.66
December 15, 1955 Coupons		
Bond 18224D	6.25	
Bond 18225E	6.25	
Bond 18226F	6.25	
	18.75	
Less charge	.10	18 65
December 31, 1955 interest		51.97
		$ 7,719.83
Less		
Payment to Hawaiian Sugar Planters' Association for postage advanced for mailing of books sold :		
for 1954	$ 30.00	
for 1955	37.80	
Draft to Mons. Le President Syndicat des Febricants de Sucre. Ile de la Reunion	350.00	

(*Contd.*) ANNEXURE II

Ing. Agr. George Casas Briceno		
Venezuela	140.94	
Bank charge	3.00	
Total, deductions	$ 516.74	
Balances as on January 5, 1956		561.74
		$ 7,158.09

Yours truly,

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

(Sd.) T. M. Brown, Treasurer

(Custodian, I.S.S.C.T.)

ANNEXURE III

INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS

STATEMENT OF INCOME AND EXPENDITURE FOR THE EIGHTH CONGRESS

British West Indies 1953

	L. S. D. *Sterling*		L. S. D. *Sterling*
To Mr. T. Prasad for 9th Congress ($500.00 U.S.)	$178.5.1	By Recd. from Mr. Norman J. King, 7th Congress ($ 500.00 U. S.)	177.18.5
To Congress Organizing Committee towards printing cost £ 4243.15.5), in accordance with Section 9 of Article IV of the I.S.S.C.T. Constitution.	£ 1475.11.11½	By Membership dues 796 Members 1950-53	1402.0.11
		By sale of 14 copies of 1953 Proceedings to non-members	73.17.8½
	£ 1653.17.0½		£ 1653.17.0½

It was moved by Mr. D. R. Narang, and seconded by Mr. Norman J. King and carried unanimously that the General Secretary-Treasurer's report as submitted be received and adopted.

GREETINGS

The General Secretary-Treasurer read messages for the success of the Congress received from Dr. P. Honig of West Indies Sugar Corporation, New York (U.S.A.); Mr. W. W. G. Moir, Regional Vice-Chairman, Hawaiian Section, Honolulu (Hawaii); Dr. Dean G. Conklin, President, Hawaiian Sugar Technologists, Honolulu (Hawaii); Mr. S. L. Platt, Secretary, Hawaiian Sugar Planters' Association, Honolulu (Hawaii); Mr. Gilberto Villagra, Regional Vice-Chairman, Argentine Section, Tucuman, (Argentine); Mr. Ruben A. Bonilla, Regional Vice-Chairman, Puerto Rico Section, Riopiedras (Puerto Rico); Dr. E.W. Brandes, Canal Point, Florida (U.S.A.); Dr. George Arceneaux, Canal Point, Florida (U.S.A.) and Mr. R. C. Gibson on behalf of Bingera Management, Bundaberg (Queensland).

ADMINISTRATIVE COMMITTEE

An administrative Committee consisting of the following persons was then formed to consider the Agenda and other matters to be placed before the Final Plenary Session :

D. R. Narang — General Chairman
Norman J. King — General Vice-Chairman
T. Prasad — General Secretary-Treasurer

*Regional Vice-Chairmen or their nominees (i.e., Leaders of Delegation)

M. C. Alcantara — Nicaragua
K. S. Arnold — United Kingdom
E. G. Baber — New South Wales & Fiji
S. J. P. Chilton — U. S. A. (Mainland)
Charat Ram — India
G. F. Clarke Jamaica
F. N. Coombes — Mauritius
W. E. Dickinson — Cuba
K. Douwes Dekker — South Africa
A. G. Gallardo — Mexico
O. M. Henzell — British West Indies
A. J. Mangelsdorf — Hawaii (U. S. A.)
J. J. Mirasol — Philippines
Qaiyum Ahmed — Pakistan
G. A. W. Wagenaar — Indonesia

*New sections were constituted for Indonesia, Pakistan and Philippines, during the Congress.

RESOLUTIONS COMMITTEE

The following were appointed on the Resolutions Committee to consider and frame resolutions proposed by the various sections of the Society, or arising out of the Congress discussions:

Norman J. King	(Queensland)—	Chairman
K. S. Arnold	(United Kingdom)	
F. N. Coombes	(Mauritius)	
K. Douwes Dekker	(South Africa)	
A. J. Manglesdorf	(Hawaii)	
T. Prasad	(India)—	Secretary

The General Chairman then announced the names of the Chairmen for the Sectional Meetings of the Congress. Thereafter, the Session terminated.

SECOND PLENARY SESSION

Thursday, 2nd February, 1956, 10-30 A.M.

The General Chairman declared open the meeting and announced that the first business was the consideration of the Resolutions drafted by the Resolutions Committee. The following Resolutions were then presented:—

RESOLUTION NO. 1. *Thanks and appreciation*

WHEREAS the International Society of Sugarcane Technologists with delegates attending from most of the sugarcane growing countries of the world, has been, priveleged to hold its Ninth Congress in India, and

WHEREAS the delegates have been honoured by governmental recognition and official courtesies, have been afforded many excellent opportunities to observe the progress of the sugar industry in India, and have been warmed by the wholehearted cordiality and generous hospitality extended to them from all quarters,

BE IT THEREFORE RESOLVED that we accord a rising vote of thanks and appreciation to :

The President and Government of India
The Minister for Food & Agriculture, Government of India
The Governor and Government of Bombay
The Rajpramukh and Government of Mysore
The Government of Hyderabad
The Governor and Government of Uttar Pradesh
The Indian Central Sugarcane Committee, New Delhi
The Sugar Technologists Association of India, Kanpur
The Deccan Sugar Technologists Association, Bombay
The Deccan Sugar Factories Association, Bombay
The South Indian Sugar Mills Association, Madras
The Indian Sugar Mills Association, Calcutta
The U. P. Branch of the Indian Sugar Mills Association, Lucknow

The Directors and Staff of the following Institutions:

The Sugarcane Research Station, Padegaon
The Sugarcane Breeding Institute, Coimbatore
The Central Sugarcane Research Station, Pusa
The Indian Institute of Sugarcane Research, Lucknow
The Sugarcane Research Station, Shahjahanpur
The Indian Agricultural Research Institute, New Delhi
The U. P. Government Agricultural College, Kanpur
The National Sugar Institute, Kanpur
The H. B. Technological Institute, Kanpur
The Indian Institute of Science, Bangalore
The National Physical Laboratory, New Delhi

The Indian Standards Institution, Delhi
Shri Ram Institute of Industrial Research, Delhi
The Central Drug Research Institute, Lucknow
The Botanical Gardens, Lucknow
The President and Members of the Coimbatore Rotary Club
The President and Members of the Nilgiri Rotary Club, Ootacamund

The Proprietors, Directors and Staff of the following Companies :

Godavari Sugar Mills Ltd., Kanhegaon
Maharashtra Sugar Mills Ltd., Tilaknagar
The Belapur Co. Ltd., Harigaon
Walchandnagar Industries Ltd., Walchandnagar
Indian Sugars & Refineries Ltd., Hospet
Gangapur Sugar Mills Ltd., Gangapur
K. C. P. Ltd., Vuyyuru
Texmaco Ltd., Calcutta
Albion Jute Mills, Howrah
Lothian Jute Mills, Howrah
Ramnuggar Cane & Sugar Co. Ltd., Calcutta
Rohtas Industries Ltd., Dalmianagar
Begg Sutherland & Co. Ltd., Kanpur
Hindustan Sugar Mills Ltd., Golagokarannath
Carew & Co. Ltd., Rosa
Mysore Sugar Co. Ltd., Mandya
Mohanvi Corporation, Lucknow

The following Persons :

Shri D. R. Narang, Lucknow
Lala Charat Ram, Delhi
Sir C. V. Raman, Bangalore
Shri G. K. Devarajulu, Coimbatore
Shri V. Ramakrishna, Madras
Lala Karam Chand Thapar, Calcutta
Shri S. S. Kanoria, Calcutta
Shri R. L. Nopany, Calcutta
Shri S. P. Jain, Calcutta
Shri M. R. Jaipuria, Kanpur
Sir Padampat Singhania, Kanpur

BE IT FURTHER RESOLVED that copies of this Resolution be sent to the persons and organizations referred to above.

Moved by Mr. K. S. Arnold, seconded by Mr. W. E. Dickinson and carried unanimously.

RESOLUTION NO 2. *Gratitude to Officers etc.*

WHEREAS the successful organization and conduct of this our Ninth Congress is due in large measure to the conscientious work of our general officers and the members of the regional committees who have not spared themselves in their efforts for the smooth conduct of our meetings and visits to the sugar districts of India,

BE IT THEREFORE RESOLVED that we express by rising vote our thanks and gratitude to:

Mr. D. R. Narang, General Chairman
Mr. Norman J. King, General Vice-Chairman
Mr. T. Prasad, General Secretary-Treasurer
The Members of the Organising Committee under the Chairmanship of Mr. T. C. Puri, I.C.S.
The Members of the Bombay Regional Committee under the Chairmanship of Seth Gulabchand Hirachand
The Members of the Bengal - Bihar Regional Committee under the Chairmanship of Mr. S. P. Jain
The Members of the South Regional Committee under the Chairmanship of Mr. P. Hadfield
The Members of the Delhi-U.P. Regional Committee under the Chairmanship of Lala Charat Ram
The Members of the Technical & Publication Sub-Committee under the Chairmanship of Sir T. S. Venkatraman
The Staff of the Directorate of Sugar & Vanaspati, Ministry of Food & Agriculture, Government of India, and in particular Mr. K. P. Jain Director (Sugar), Mr. Gyan Chandra, Secretary, Development Council for Sugar Industry, Mr. N.S. Jain, Technical Officer (Sugar) and Mr. J.P. Vaish, Assistant Secretary (I.S.S.C.T.).

Moved by Mr. F. N. Coombes, seconded by Mr. Alfonso G. Gallardo, and carried unanimously.

RESOLUTION NO. 3. *Obituaries*

WHEREAS during the three years period since our Eighth Congress the following members of our Society have been removed by death from our ranks:

R. E. Baker (Trinidad)
J. D. Brown (Hawaii)
S. Duncan (British Guiana)
G. C. Dymond (South Africa)
Charles A. Farmell (Louisiana)
Charles Godchaux (Louisiana)
J. C. McMichael (Antigua)
W. E. Walwyn (St. Kitts)
Noel Deerr (U. K.)
Prinsen Geerligs (Holland)

BE IT THEREFORE RESOLVED that this Society express its feeling of deep sorrow at the passing of our esteemed colleagues and its heartfelt sympathy with their families.

Carried unanimously, the Congress rising in silence as a mark of respect.

RESOLUTION NO. 4. *I.S.S.C.T. Constitution and Regulations*

WHEREAS at the Eighth Congress of the I.S.S.C.T. held in the British West Indies it was resolved that a Constitution & Regulations Committee be appointed to revise the Constitution of the Society, where deemed necessary, and

WHEREAS the Constitution & Regulations Committee so appointed submitted to the Ninth Congress a revised Constitution, and

WHEREAS further alterations were suggested during the period of the Ninth Congress,

BE IT THEREFORE RESOLVED that the proposed amended Constitution, and the suggestions made at the Ninth Congress, be referred to a new Constitution & Regulations Committee to be appointed by the incoming General Chairman for further consideration, and that the new Committee be requested to submit to the Executive Committee and the Regional Vice-Chairmen at the earliest possible date, a revised draft of the Constitution, and, following their majority concurrence, to present the final draft to the Tenth Congress for adoption.

BE IT FURTHER RESOLVED that if any member has suggestions to offer relative to the Constitution, he should send them to the incoming General Chairman by December 31, 1956.

Moved by Mr. Norman J. King, seconded by Dr. A. J. Mangelsdorf and carried unanimoulsy.

RESOLUTION NO. 5. *Augmenting Congress Trust Fund*

WHEREAS the Ninth Congress of the International Society of Sugarcane Technologists considers it most desirable that the Trust Fund of the Society should be augmented for the purpose of carrying out many worthy projects which would enhance the efficiency of the world cane sugar indusry,

BE IT THEREFORE RESOLVED that the Executive Committee of the Tenth Congress be requested to appoint at the earliest possible date a Committee to investigate means of raising funds

BE IT FURTHER RESOLVED that if such investigations result favourably, the Executive Committee be empowered to take appropriate action.

Moved by Mr. T. Prasad, seconded by Mr. F. N. Coombes, and carried unanimously.

RESOLUTION NO. 6. *International Journal*

WHEREAS the Society, at its Eighth Congress held in British West Indies, considered the proposal to establish an International Journal on Sugar Chemistry and Technology and appointed a Committee to explore the possibilities of the proposal and make recommendations to the Administrative Committee in that regard, and

WHEREAS that Committee submitted to the Administrative Committee its report to the effect that it would not be possible to publish an International Journal on Sugar Technology under the auspices of the I.S.S.C.T. at the present time, and

WHEREAS the Administrative Committee was of the view that in the circumstances explained by the Committee no further action was possible

BE IT THEREFORE RESOLVED that the report of the Committee be tabled

BE IT FURTHER RESOLVED that the Committee be thanked for its careful study of the proposal.

Moved by Dr. K. Douwes Dekker, seconded by Dr. K. S. G. Doss and carried unanimously.

RESOLUTION No. 7. *Message to Mr. Srivastava*

WHEREAS Mr. R. C. Srivastava, C. I. E., O. B. E., has had a long association with the I.S.S.C.T. and has made many valuable contributions to the Indian Sugar Industry, and

WHEREAS the delegates attending the Ninth Congress had looked forward to the pleasure of meeting him during the course of their visits and meetings, and in particular at Kanpur during the visit to the National Sugar Institute, and

WHEREAS they were distressed to learn that Mr. R. C. Srivastava was ill and unable therefore to participate in any activities of the Congress,

BE IT THEREFORE RESOLVED that this Society expresses its sense of distress at Mr. Srivastava's illness and its disappointment at not being able to meet him, and that its earnest wish for his early recovery to health be communicated to him.

Moved by Dr. H. W. Kerr, seconded by Sir T. S. Venkatraman and carried unanimously.

RESOLUTION NO. 8. *World Collection of Sugarcane Varieties*

WHEREAS this Society, at its Eighth Congress, through Resolution No. 12 passed unanimously at that Congress, reaffirmed its interest in a World Cane Collection to insure the safety of valuable breeding material, and

WHEREAS the proposal of a pro-rata assessment of sugar cane producing areas in support of a Cane Collection Project did not prove feasible, and

WHEREAS the Government of India has satisfied the major objective of the Cane Collection Project by authorising the expansion of the Cane Collection maintained by the Sugarcane Breeding Institute, Coimbatore, India, to the status of a World Cane Collection, essentially duplicating that maintained by the United States Department of Agriculture at Canal Point, Florida.

BE IT THEREFORE RESOLVED that the Society, on behalf of sugar cane technologists all over the world, express its appreciation to the Government of India and to the Sugarcane Breeding Institute of Coimbatore, India, for their generous and farsighted action in undertaking (a) to establish a World Collection of sugar cane varieties of breeding importance, and (b) to safeguard the collection against disease.

BE IT FURTHER RESOLVED that the Society recognise the U.S.D.A. Cane Collection at Canal Point, Florida, and the Cane Collection at the Sugarcane Breeding Institute of Coimbatore, India, as World Cane Collections.

Moved by Dr. H. M. Tysdal, seconded by Mr. A. Gonzalez Gallardo and carried unanimously.

RESOLUTION No. 9. *Germ Plasm and Breeding*

WHEREAS the cane breeding group of the Ninth Congress has expressed a desire for a Committee to promote the progress of sugarcane breeding, to focus the attention of sugarcane breeders throughout the world upon important problems, to disseminate information on breeding behaviour of canes and on new breeding procedures, and to encourage co-operative effort wherever possible, and

WHEREAS there is need for a Committee to support and assist in augmenting the World Sugarcane Germ Plasm Banks, and

WHEREAS the present Standing Committee on Varieties could well enlarge its scope of activity

BE IT THEREFORE RESOLVED that the present Standing Committee on Varieties be continued, with the appointment by the Chairman of that Committee of such additional members as may seem desirable and that this Committee be renamed the " Standing Committee on Germ Plasm and Breeding " with objectives such as outlined above.

Moved by Dr. H. M. Tysdal, seconded by Dr. J. J. Mirasol and carried unanimously.

RESOLUTION NO. 10. *Listing of Sugarcane Diseases of the World*

WHEREAS the Pathology Section of the Society has undertaken and completed the preparation of a list of all the known sugarcane diseases of the world and their world distribution, which is being presented to this Congress, and

WHEREAS the publication of this list would be of great value to research workers, students of sugarcane agriculture, producers of sugarcane, and others throughout the world

THEREFORE BE IT RESOLVED that the Society publish this list as a part of the Proceedings of the Ninth Congress, and authorize the printing of an additional one thousand reprints that can be offered for sale by the Society.

Moved by Dr. B. L. Chona, seconded by Dr. E. V. Abbott and carried unanimously.

RESOLUTION NO. 11. *Technical Monograph on Sugarcane Diseases of the World*

WHEREAS there is need for an authoritative monographic treatise on the principal sugarcane diseases of the world, and

WHEREAS because of the diversity of the diseases in different countries the task of summarising and evaluating the vast amount of information on all of them would be so great as to be burdensome for any one individual to undertake, and

WHEREAS the cost of publication of such a treatise would be beyond the resources of most sugarcane research institutions, and

WHEREAS the benefits of such a treatise would be inestimable to research workers, students of sugarcane agriculture, producers of sugarcane, and others throughout the world,

THEREFORE BE IT RESOLVED that this Society authorize the Pathology Section to proceed with the preparation of a monograph on each of the most important sugarcane diseases of the world through the co-operative effort of pathologists having specialized experience with the different diseases, each monograph of a major disease or group of diseases to be published separately in a form that can be periodically brought up to date, and

BE IT FURTHER RESOLVED that the Society recommend, foster and co-ordinate the publication of the monographs as completed on recommendation of the Pathology Section.

Moved by Dr. E. V. Abbott, seconded by Mr. G. F. Clarke and carried unanimously.

RESOLUTION NO. 12. *Technical Monograph on Sugarcane Pests of the World*

WHEREAS the Administrative Committee has been presented with a proposal to sponsor the publication of an authoritative monographic treatise on the principal sugarcane pests of the world, and

WHEREAS the Committee commends the proposal inasmuch as the benefits of such a treatise would be inestimable to research workers, students of sugarcane agriculture, producers of sugarcane and others throughout the world, and

WHEREAS the Committee recommends the appointment of Standing Committee of Entomologists for the purpose

BE IT THEREFORE RESOLVED that the recommendation of the Administrative Committee be approved to wit that a Standing Committee be appointed by the incoming General Chairman and that the Committee be requested to investigate the feasibility of the preparation of a Monograph as outlined above and to present its recommendation to the Tenth Congress for consideration.

Moved by Dr. H. Evans, seconded by Mr. M. C. Alcantara and carried unanimously.

RESOLUTION NO. 13. *Symposia*

WHEREAS the Engineering Section of the International Society of Sugarcane Technologists has requested that consideration be given to the inclusion in the

Tenth Congress of a Symposium on research matters relating to the field of sugar engineering

BE IT THEREFORE RESOLVED that the incoming General Chairman be requested to appoint an Engineer with the appropriate qualifications to invite research workers engaged on subjects relating to sugar engineering to contribute papers on different aspects of the subject suitable for presentation collectively as a Symposium at the next Congress,

BE IT FURTHER RESOLVED that a recommendation be made to the incoming General Chairman that a Symposium be arranged in similar manner for the Manufacturing Section.

Moved by Prof. M. Shaw, seconded by Dr. K. Douwes Dekker and carried unanimously.

RESOLUTION NO. 14. *Publication of Booklet on System of Cane Sugar Factory Control of I.S S.C.T.*

WHEREAS the Society, at its Eighth Congress held in British West Indies by its Resolution No. 14 desired that the booklet " System of Cane Sugar Factory Control of the I.S.S.C.T.", which was out of print, be brought up-to-date and reprinted at the earliest opportunity, and

WHEREAS in pursuance of the said decision the booklet was brought up-to-date by Mr. J. L. Clayton and its Second Edition published by the Queensland Society of Sugarcane Technologists

BE IT THEREFORE RESOLVED that the Congress expresses its appreciation and thanks to Mr. J. L. Clayton and the Queensland Society of Sugarcane Technologists for their contribution towards this worthy cause,

BE IT FURTHER RESOLVED that copies of this Resolution be transmitted to them with the best wishes of this Congress.

Moved by Mr. R. Gonzalez Rivera, seconded by Dr. H.W. Kerr and carried unanimously.

RESOLUTION NO. 15. *Officers : Uniformity in Reporting Factory Data*

WHEREAS Mr. Norman J. King has resigned as Chairman of the Special Committee on Uniformity in Reporting Factory Data,

BE IT THEREFORE RESOLVED that Mr. J. L. Clayton, Central Sugarcane Prices Board, Brisbane, Queensland, be appointed as Chairman.

Moved by Dr. K. Douwes Dekker, seconded by Mr. R. Gonzalez Rivera and carried unanimously.

RESOLUTION NO. 16. *Uniformity in Reporting Factory Data*

WHEREAS the Manufacturing Section of the Ninth Congress of the I.S.S.C.T. considered the Report of the Special Committee on " Uniformity in Reporting Factory Data " on the various Resolutions referred to it for study at the Eighth Congress, and

WHEREAS the Manufacturing Section of the Society feels that there is need for continuation of efforts for bringing about this uniformity in the methods of factory control and reporting data and has therefore recommended that the said Committee be preserved and that its activities be maintained to the end of making the factory control system up-to-date and international,

BE IT THEREFORE RESOLVED that the Report of the Chairman of that Committee be adopted.

Moved by Mr. S. N. Gundu Rao, seconded by Mr. R. Gonzalez Rivera and carried unanimously.

The General Chairman announced that if the delegates had any other resolution or suggestion to make, they were welcome to do so.

Mr. Alfonso G. Gallardo said that although the official language of the Society was English, many sugar producing countries of the world, specially the Latin American countries, spoke Spanish. In Mexico, not more than 5 percent of the people engaged in the sugar industry could read English. The Technologists from these areas were members of the Society, but were not able to derive any benefit from the valuable publications on sugar and sugarcane published by it from time to time. He, therefore, suggested that a Standing Committee be appointed to go into the matter and if possible, arrange to translate into Spanish and French the Proceedings and other publications issued by the Society in English. Mr. M. C. Alcantara seconded the proposal.

Mr. B. K. S. Jain said that the study of agricultural implements for growing sugarcane was as important as any other aspect of the industry. There was therefore great scope for organising in future Congresses a separate Section devoted entirely to this aspect, which could be named "Agricultural Engineering".

Dr. K. S. G. Doss referred to the programme of discussions of scientific papers and the symposia arranged during the Congress and said that some of the delegates felt greatly handicapped because owing to clash in programme, they could not participate in all the items. This was particularly so in regard to the Symposium on Sugar Engineering. He, therefore, suggested that the new Administrative Executive be requested that in the next Congress care might be taken to see that overlapping of programme was avoided as far as possible. Mr. K. S. Arnold, explaining on behalf of the Programmes Committee, said that the point raised by Dr. Doss was fully kept in view while arranging the programme. The position in respect of the Sugar Engineering Section was that there were only 16 papers to be read in that Section, whereas in the Sugar Manufacturing Section there were more than thrice that number. As all the papers on Sugar Manufacture could not be finished within the allotted time, a special meeting of that Section was arranged at the same time when the Sugar Engineering Symposium was held. Looking to the large number of papers read and the other activities, it should not be surprising that some unavoidable overlapping did occur at the Session.

However, a suggestion could be made to the new Committee that the programme at the next Congress be arranged so as to avoid, as far as possible, overlapping of programme relating to symposia on the Manufacturing and Engineering Sections.

The General Chairman thanked the members for the suggestions made by them. Referring to the resolution moved by Mr. Gallardo, he said that it would certainly be useful to publish the proceedings of the Society in other languages also for the benefit of those who did not understand English. But the translation and printing would entail lot of cost and he was not very sure if the Society had funds enough for this purpose. In his opinion, it would not be very appropriate to pass a resolution as the new Executive might find it difficult to undertake the work for financial and other reasons. He therefore suggested that the Society might pass a Resolution for consideration of the new Executive for such action as might be deemed feasible. The suggestions made by Mr. Jain and Dr. Doss were also very useful and could be passed on to the new Executive for appropriate action. This was carried unanimously.

PLACE OF NEXT CONGRESS

The General Chairman informed the Congress that an invitation had been received from Hawaii. He requested Dr. A. J. Manglesdorf to convey it to the meeting. Dr. Manglesdorf then read out the following letters inviting the Society to hold its 10th Congress in Hawaii in 1959 :—

Letter from Mr. W. W. G. Moir :

" With a great deal of pleasure, the Hawaii Section of the Society wishes to extend to you an invitation to hold the 10th Congress in Hawaii in 1959. With the support, aid, and good wishes of the Hawaiian Sugar Planters' Association and the Hawaiian Sugar Technologists, we are certain that the members of the Society will find much of interest in Hawaii. No definite date has been established but a survey will be made as to the most suitable time of the year to hold it if we are granted our request.

We sincerely hope that this distinguished gathering at the Ninth Congress in India will favour us with a vote of acceptance. With our sincere wishes for the wonderful success of the Society at the 9th Congress and a continuance of the excellent examples of the Organising Committee of our several Congresses, we extend to you our thanks and aloha for the consideration of our bid for the future. Aloha."

Letter from Mr. Alan S. Davis :

" It will be recalled that the First Congress of the International Society of Sugar Cane Technologists met in 1924 at the Experiment Section of the Hawaiian Sugar Planters' Association. It would seem fitting that the Tenth Congress should commemorate the founding of the Society by meeting on the site of its birth. The Hawaiian Sugar Planters' Association therefore joins with the Hawaii

Section, I.S.S.C.T., in extending to the International Society of Sugar Cane Technologists a cordial invitation to reconvene in Hawaii in 1959 ".

Mr. Norman J. King moved the acceptance of the Hawaiian invitation and on being seconded by Mr. S. N. Gundu Rao, the motion was carried unanimously with Society's thanks to the people of Hawaii, U.S.A.

The General Chairman added that the sugar industry of Hawaii was highly mechanised and delegates would find many things of great interest there. Hawaii was also the country where the Society was first organised and it was but desirable that its Tenth Congress be held in that country. He expressed the hope that many members now present would gather again in Hawaii in 1959.

Dr. Manglesdorf expressed his great pleasure and thanks for the honour the Society had done to the Hawaiian people in accepting their kind invitation.

ELECTION OF OFFICERS

Mr. F. N. Coombes nominated as GENERAL CHAIRMAN for the 10th Congress :

Dr. L. D. Baver,
Director,
Hawaiian Sugar Planters' Association,
Honolulu,
Hawaii (U.S.A.)

Dr. H. Evans seconded the nomination and the Society unanimously elected Dr. Baver as General Chairman.

Mr. G. F. Clarke nominated as GENERAL VICE-CHAIRMAN :

Dr. St. John P. Chilton,
Head of the Botany Department,
Louisiana State University,
Baton Rouge, La. (U S.A.)

Dr. J. J. Mirasol seconded the nomination and the Society unanimously elected Dr. Chilton to be General Vice-Chairman.

Mr. Norman J. King nominated as GENERAL SECRETARY-TREASURER :

Mr. W. W. G. Moir,
American Factors Ltd.,
Honolulu,
Hawaii (U.S.A.)

Sir. T. S. Venkatraman seconded the nomination and the Society unanimously elected Mr. Moir as General Secretary-Treasurer.

Mr. Norman J. King nominated as GENERAL CUSTODIAN OF RECORDS:

Hawaiian Sugar Planters' Association,
Post Box 2450, Honolulu-4,
Hawaii (U.S.A.)

Sir. T. S. Venkatraman seconded the nomination and the Society unanimously elected Hawaiian Sugar Planters' Association to be the General Custodian of Records.

Mr. Norman J. King nominated as TRUSTEE :

The Treasurer,
Hawaiian Sugar Planters' Association.

Mr. K. S. Arnold seconded the nomination and the Society unanimously agreed to the nomination of the Hawaiian Sugar Planters to be its Trustee.

With this the business of the Session concluded, and the retiring General Chairman in a short farewell address thanked Mr. Norman J. King and other officers of the Society who had worked so assiduously for the success of the Congress. He said that his task had become easy and pleasant, because of the extraordinarily good work done by the members of the Organising Committee.

CONSTITUTION OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS

(As amended and adopted at the Seventh Congress, Brisbane, 15th September, 1950)

ARTICLE I

Name and object

Section 1. The name of this Society shall be the International Society of Sugar Cane Technologists.

Section 2. The objects of this Society shall be to promote the discussion of the technical problems of the sugar-cane industry in both field and factory, by means of conventions held as far as practicable every three years, and to foster at all times the free and frank interchange of technical information by medium of publications or other means.

ARTICLE II

Membership

Section 1. Any person who is contributing or has contributed to the progress of the sugar-cane industry in any country is eligible for membership in this Society.

Section 2. Except as provided in Article III, Section 2, nomination to membership shall be made in writing by at least two members in good standing to any Vice-Chairman of this Society. The approval of the Vice-Chairman in writing to the General Chairman will constitute election to the Society.

Section 3. Upon receipt of the dues from the person elected in accordance with the provisions of Section 2, the General Secretary-Treasurer shall forward to him a certificate of membership, and he shall thereupon become a member.

Section 4. Any member may be deprived of membership for non-payment of dues or for other reasons by a vote of the Executive Committee of this Society.

ARTICLE III

Representation in Sugar Countries

Section 1. The Society shall consist of a number of sections, a section being formed for each sugar-producing country or centre which is represented in the Society by at least five members. In countries or centres where there is not the requisite number for the formation of a section membership may be obtained by application to the Vice-Chairman of any established section. Approval of the Executive Committee shall be necessary for the formation of a new section.

Section 2. Upon application to and with the approval of the Executive Committee of the International Society of Sugar Cane Technologists, local associations of sugar-cane technologists may constitute the regional section of the Society, and members of the local association will *ipso facto* become members of the International Society of Sugar Cane Technologists upon payment of the requisite dues as set forth hereunder.

ARTICLE IV

Officers

Section 1. The officers of this Society shall be a General Chairman, a General Vice-Chairman, a Vice-Chairman for each section, a General Custodian of Records, a Trustee or Trustees, and a General Secretary-Treasurer, the last named to be resident in the country of the subsequent Convention.

Section 2. At the last business session of each regular meeting, elections shall be held for the general officers, including Trustee or Trustees, to serve from the adjournment of that meeting until the adjournment of the subsequent regular meeting of the Society.

Section 3. The General Chairman, General Vice-Chairman, and General Secretary-Treasurer shall be elected by the Society by nomination and on oral vote. In the event of two or more nominations for each office, election shall be by a plurality of votes of qualified voters present and voting.

Section. 4. In the event of an office falling vacant through death, resignation or other causes, the Administrative Executive shall be empowered to fill such vacancy, and the surviving members of the Executive Committee or Administrative Executive may continue to function notwithstanding any vacancy in any office. Any office may by a majority vote of the Executive Committee be declared vacant.

Section 5. A Vice-Chairman shall be elected by each of the various sections within 12 months after each Convention and the retiring Vice-Chairman (who shall be eligible for re-election) shall forthwith notify the General Chairman of the result of such election. In the event of no appointment being made in the terms of this clause, the Administrative Executive shall be empowered to fill the vacancy. The procedure of election shall be decided by the individual sections.

Section 6. The General Chairman shall preside at the meetings of the Society, perform other duties provided for in these rules, and carry out such other functions as usually pertain to the chief officer of such a Soicety.

Section 7. The Vice-Chairman shall approve nominees for membership in accordance with the provisions of Article II, Section 2, and shall in general represent the Society in the country in which he resides. He shall be responsible for the collection of dues of the members in his section and their remission to the General Secretary-Tresaurer.

Section 8. The General Secretary-Treasurer shall notify members of meetings to be held, and execute such duties as usually pertain to the office of Secretary. He shall act as custodian of all current documents, and at the conclusion of his term of office shall forward to the Custodian of Records all such documents and letters as are required for the permanent records of the Society. He shall receive the funds of the Society, keep a detailed account of receipts and expenditures and render a written report at each regular meeting.

Section 9. The past General Secretary-Treasurer shall within two months after the publication of the Proceedings of the Convention for which he was General Secretary-Treasurer, and in any case not later than 12 months from the conclusion of such Convention, remit to his successor a statement of receipts and expenditure certified as directed by the General Chairman, and the said statement shall be published in the record of Proceedings of the following Convention. The past General Secretary-Treasurer shall transmit to his successor in office a sum of $ 500.00 U. S. currency, or its equivalent in the currency of the country in which the next Convention shall be held. The balance of funds held by the past General Secretary-Treasurer in excess of this sum, shall be made available to the body which has been responsible for the production of the Proceedings of the immediate past Convention as a contribution towards printing costs. Any funds not required for use as a contribution towards printing costs shall be remitted by the past General Secretary-Treasurer to the Trustee or Trustees as the Executive Committee shall direct.

Section 10. The duties of the Trustee or Trustees shall be to hold the funds of the Society in trust and/or invest the same as directed by the Executive Committee in approved trust securities. He or they shall make available to the General Secretary-Treasurer such sums as from time to time the Society at a regular meeting shall direct. At the 30th of June in each year he or they shall submit to the General Chairman a statement (certified as the General Chairman shall direct) of all accounts under his or their control.

Section 11. The duties of the General Custodian shall be to provide for the safe custody of all documents remitted to him.

Section 12. An Administrative Committee shall be formed consisting of the General Chairman, General Vice-Chairman, Vice-Chairmen, and the General Secretary-Treasurer. The General Chairman shall be presiding officer of the Committee. The Executive Committee shall direct the policies of the Society as charged by members in general meetings.

Section 13. An Administrative Executive shall be formed consisting of the General Chairman, General Vice-Chairman and General Secretary-Treasurer.

Section 14. The General Vice-Chairman shall in general assist and co-operate with the General Chairman and General Secretary-Treasurer in their duties.

ARTICLE V

Dues, Lists of Members, etc.

Section 1. The dues shall be $10.00* U. S. currency or as determined from time to time by the Administrative Executive, per member, for the period from the termination of one regular meeting to the termination of the subsequent regular meeting, or in the case of new or re-instated members, for the uncompleted portion of such period. Dues shall be payable to the Vice-Chairman of the section, who shall forthwith remit them to the General Secretary-Treasurer.

Section 2. The General Secretary-Treasurer shall prepare a list showing the names and addresses of all persons who were financial members at the time of such regular meeting, together with the names and addresses of the secretaries of local associations or regional sections, and publish them in the Proceedings of the Congress.

ARTICLE VI

Section 1. A convention shall be held as far as practicable every three years. The place of meeting shall be decided by vote of the Society at the previous regular meeting. In case of differences among members concerning the meeting place, the matter shall be put to the vote of the members by the General Chairman or presiding officer; the selection of the subsequent meeting place shall be determined by a plurality of votes of qualified voters present and voting.

Section 2. Special meetings may be called at any time by any one of the officers if authorized by the Executive Committee. Society business, however, shall be transacted only at regular meetings.

Section 3. The General Secretary-Treasurer shall notify members of the proceedings of the regular meetings and such other activities as may occur.

ARTICLE VII

Voting

Section 1. Any person being a financial member at the time of the preceding regular meeting shall be eligible to vote for the election of Vice-Chairman.

Section 2. Voting at a regular meeting shall be restricted to financial members provided that not more than five members of each section shall be qualified to vote. In the event of the number of any section present exceeding five the Vice-Chairman of such section shall appoint the members of his section who also shall be qualified to vote, and shall submit their names in writing to the General Secretary-Treasurer prior to the regular meeting of the Congress.

ARTICLE VIII

Section 1. This constitution may be amended at any regular meeting by a majority vote of the qualified voters present and voting.

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*Membership fee raised from $ 5.00 to $ 10.00 vide Resolution No. 8 passed at the Eighth Congress of the Society.

ARTICLE IX

Amendment

Section 1. If through unforeseen or unavoidable circumstances it is not practicable to carry out the provisions of Article VI Section 1, at the time of the regular meeting of the Society, an Interim Committee of six members shall be appointed (elected) by the Administrative Committee with full power to act in selecting the next place of meeting, the decision to be made as soon as practicable after the last regular meeting of the Society.

Section 2. In the event of failure to carry out the provisions of Article VI, Section 1, at the time of a regular meeting, procedures of the Society usually predicated upon a definite choice of the next meeting place, including election of the general officers and remission of the statement of the General Secretary-Treasurer, a General Chairman, who shall be Chairman of the Interim Committee, and Trustee or Trustees shall be elected by the Society in the usual way indicated in Article IV, Section 2, but the General Vice-Chairman and General Secretary-Treasurer shall be elected by the Interim Committee immediately after selection of the next meeting place, and the General Secretary-Treasurer shall remit to his successor the statement of receipts and expenditures mentioned in Article IV, Section 9, within twelve months of election of his successor and prior to the next general meeting.