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CHINA

Technical Report: Mechanism of Cane Milling*

Prepared for the Government of China

by the United Nations Industrial Development Organization,

acting as executing agency for the United Nations Development Programme

Based on the work of C. J. Laan,
Expert in the Mechanism of Cane Milling

United Nations Industrial Development Organization

Vienna

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SUMMARY

1. With the crushing season almost finished, the request was made to proceed direct to Guangzhou. The author did not have the benefit of any briefing about the state of the sugar cane industry.

2. Upon arrival at Guangzhou airport on April 6th, the author was welcomed by a small delegation of members of the NCSIRC.

3. In Dong Fang hotel a well prepared itinerary was presented for consideration (ANNEX 1). This was accepted with the addition of an immediate visit to Guangzhou sugar factory and the Research Centre prior to the departure for Zhanjiang.

4. In consideration of the special interest by the industry to become more efficient in the use of steam, it was agreed with the approval of Mr Hu Xiaozong, Deputy Director of NCSIRC that part of the lecture time be devoted to this particular subject. During the seminar in the Guangdong Scientific Hall delegates requested that some time be spent in outlining the requirements and procedures involved with the purchase of a sugar factory from manufacturers outside China.

5. In Zhanjiang there was a strong emphasis to increase the crushing capacity of existing mill tandems without installing much additional equipment; an emphasis on Volume-of-Operation with a trend to neglect Quality-of-Operation.
The effect of such a development would be not only to compound present inefficiencies but tend to become even worse when mills are overloaded beyond their normal capacity.
As there is an urgent need to utilize the natural resources of the country to the full extent, Quality-of-Operation should receive as much attention as Volume-of-Operation.

6. Two of the factories visited were still in operation have some very good equipment installed, all of local manufacture . The short visit to these factories does not permit one to express a firm opinion which would necessarily be valid for the rest of the industry as a whole. Nevertheless from observation it is suggested that process design and control could be improved.

7. The seminars in Zhanjiang and Guangzhou were well attended by Directors, Managers, engineers and technologists of the industry. The numbers at each seminar were of the order of fifty people. The morning sessions were devoted to lectures, while the afternoon was made available to answer questions from the audience.

8. A print out of a typical, complete factory design by computer as used by the author, several photographs of factories and brochures of sugar machinery, were shown to the audience.
Some of this documentation was handed over to the NCSIRC.

9. The visits to the factories, the facilities at the seminars were all very well organized.
The hospitality shown to the author during his visit was excellent and without exception, everyone he met was extremely kind.

II. INTRODUCTION

During early March 1985 the author received an invitation from the UNIDO office in Vienna to visit China for a period of one month with the object of giving advice on up to date techniques in the crushing of cane. A job description accompanied this invitation and is included as ANNEX 4.

After obtaining the necessary inocculations and an entry visa into China, the author left the United Kingdom on April 3rd for Guangzhou arriving there on April 6th after a scheduled transit stop of 1.5 days in Bangkok.

Originally the proposal had been to visit Beijing first for a briefing session by the UNIDO SIDFA, but as the cane crushing season was nearly coming to an end, a last minute request was received prior to the departure from the UK to fly direct to Guangzhou. A de-briefing session was to be held in Beijing upon completion of the tour.

The absence of a) an introductory briefing prior to entering China and b) any technical information in the international sugar press about the cane industry in China, meant that the author arrived in Guangzhou only partly prepared. Under these circumstances, it was inevitable that a 'feel' for the state of the industry could only be developed after arrival in Guangzhou and during the course of the tour.
The lack of such background information occasionally led to unforeseeable situations. An example will illustrate the point.

The job description calls for suggestions to reduce horsepower requirements. One obvious solution is the application of roller bearings, which incidentally are still scarcely used by the industry in the rest of the world. The author therefore carried out a literary search regarding the application of these bearings.

During the first lectures it soon became apparent that such an application is already in use in many sugar mills in China. There was obviously no point in pursuing this topic.
The author is not suggesting that the job description was incomplete nor that any briefing beforehand would have avoided such an event. The point in question illustrates the effect of the halo which surrounds the industry and screens it from the rest of the world creating a gap in understanding of what progress is being made in different countries. Undoubtedly, the sugar industry of China has gained more experience in this particular application than most other countries.
However to keep the balance right, there have also been several occasions whereby simple advice by the author has been appreciated by his Chinese collegues.

It is of course precisely this exchange of ideas and information between professionals of similar background that gives value to such visits as covered by this report. The rest of the world would be interested to learn more from the Chinese regarding their wide knowledge of sugar byproduct utilisation.
Upon arrival at Guangzhou airport, the author was welcomed by a small delegation from the National Cane Sugar Industry Research Centre (NCSIRC).

In Dong Fang hotel a well prepared itinerary was presented to the author for consideration (ANNEX 1).
This was accepted with the addition of an immediate visit to Guangzhou sugar factory and a visit to the Research Centre prior to the departure for Zhanjiang. The reason for such a request was to obtain an immediate impression of the standard of a sugar factory and also in the case of the NCSIRC, to see the library and so obtain an idea of the quantity of international sugar literature available to technologists, engineers and researchers.
Both visits made a favourable impression upon the author.

The subsequent visit to the Zhanjiang district was marred by a deteriorating weather situation towards the end of the visit. As a result there were no aircraft departures possible and our party experienced a forced stay of four extra days in Zhanjiang.
Even then the decision had to be made to return to Guangzhou by road in order not to disrupt too severely the lecture programme. This is a journey of about 12 hours. The effect of this delay was a revised itineray appended as ANNEX 2.

The author understands that there had been some difference of opinion amongst the NCSIRC members whether a visit to the Zhanjiang district should be included in the itinerary.
The reason put forward being that one factory was too small and the other too old and both therefore not of great interest to contribute towards future development.

From the author's point of view, it was a very appropriate decision to include Zhanjiang in the itinerary. It is no use only being shown the cream of the industry, it is the impression obtained by visiting a cross section that makes such visits interesting and useful.

When the prepared programme was discussed, the importance of the development of the byproduct industry became clear. Inherent with such a development is the efficient generation and utilisation of steam and electricity in the sugar factory.
Because of this, it appeared appropriate to spend some lecture time on this particular subject. With the agreement of Mr Hu Xiaozong, Deputy Director of NCSIRC, it was decided that the first day of the lecture programme should be spent on steam economy with a discussion of milling techniques during the remainder of the available time. The inclusion of this subject in the lectures meant an expansion of the job description and forms a separate section in the main body of the report.

During the question and answer session in Guangzhou. the author was invited to expand his knowledge and experience in contract negotiations when purchasing plant and machinery from foreign suppliers and also to indicate the procedures involved in obtaining credit loan facilities associated with such purchases.
As this is primarily a non-technical subject, it is not reported in the main body of the report, but discussed extensively in Appendix 4.

The facilities provided for the lectures were very good, in Zhanjiang the venue was the Hai Bin hotel while in Guangzhou the Hall of Science was used.
On average about fifty persons attended the seminars at each location consisting of Deputy Directors and officials of the NCSIRC; Managers, technologists, design and operating engineers of sugar factories and allied industries.
Sound and recording equipment was available, also were an overhead projector, blackboard and last but not least an excellent interpreter.
The latter in particular is very essential in establishing an understanding between the speaker and his audience.
Throughout the entire tour, both sides were fortunate whether by design or default, to have the services of Mrs Qi Li-wu who as a chemical engineer had worked in a sugar factory and was therefore familiar with the jargon of the business.

As stated before, the morning hours during the seminars were spent lecturing on the subjects discussed in detail in Sections 4,5 and 6 of this report, while the afternoon was spent in answering questions from the floor. During these sessions, photographs of sugar factories outside China, equipment brochures by various machinery manufacturers were circulated amongst the audience.

Also shown was a computer print out of a complete sugar factory design as used by the author. On a smaller scale, the author demonstrated the use of a portable computer in the determination of milling efficiency and capacity. In response to requests from some members in the audience, a few computer runs were made relating to their own particular problems of factory operations and print outs were left with them.

Upon leaving China, the author presented to the NCSIRC the brochures of the various machinery suppliers, a copy of an evaporator design calculation, some process design sketches and a copy of the third edition of "System of Cane Sugar Factory Control" published by the QSSCT for the International Society of Sugar Cane Technologists.
A promise was made to post some more information to the NCSIRC upon the return to the UK by the author.

Finally the author wishes to express his gratitude for the extreme kindness and hospital ty he has received during his stay in China.
Officials of the Ministry of Light Industry in Beijing and Guangzhou were most kind and helpful in arranging some off-duty sightseeing as well as finding suitable hotel accomodation during the Guangzhou industrial fair.
Mr Chen Shi-Zhi, Director of the NCSIRC and his many colleques have all, without exception, been very efficient in making the arrangements for the seminars, hotel accomodation and travel arrangements. They also have been very kind and helpful in attending to some of the author's personal wishes while frequently enquiring about his well-being.

The author was very well received at each factory visited with free access to all operating areas and frank replies to every question.

This was a very pleasant tour organized by kind people.

III. VISITS to SUGAR FACTORIES

In the Guangzhou area, the following factories were visited:

Guangzhou sugar factory
Shi Tow - -
Meishan - -
Jiangmen - - , and in the Zhanjiang district:

Yatang - -
Zingzhou - - .

In Jiangmen, the sugar machinery fabrication workshop was also visited briefly.

A. Guangzhou sugar factory

In order that the author had the opportunity to form an impression of the standard and layout of a typical sugar factory prior to the beginning of the seminar in Zhanjiang, a brief unscheduled visit was made to this factory.
The factory was not crushing cane but was in the process of refining imported Australian raws.

The factory has a crushing capacity of 2500 tons of cane per day (2500 tcd) in a milling tandem of 15 rollers,1800mm x 900mm. This is low for a mill of this size in particular with a fibre % cane of only 11. Under these conditions it does not matter very much that the mill has rubber belt intermediate carriers; items of plant not particular noted for their ability to exert a force feed on the mill. Double carbonatation is used for juice clarification. As this is the most efficient traditional method to remove impurities in the juice, it is somewhat surprising that the factory stops for evaporator cleaning about once every two weeks.

B. Shi Tow

This mill also had already completed its crushing season. The capacity is 6000 tcd in a 18 roller tandem, 2000 mm x 1000 mm. All mills are individually driven by DC electric motors, a feature little used elsewhere in the world.

The arrangement is eminently suited to determine accurately the horsepower consumed at different speeds and the effect of changes in mill and trash plate settings. A further innovation was the use of roller bearings on the mill rollers, this is still seldom found in the industry elsewhere in the world. For most countries the cost is considered prohibitive in comparison with the more traditional type of bearing. This may not be the case in China where they manufacture these bearings.

The evaporator operates in quintuple effect supplying vapour to the juice heaters and vacuum pans. The staff had a computer installed to record juice flows, temperatures, pressures and densities. The author was told that the intention is to have the process under full control by the computer by 1986.
The investment cost must be fairly high to reach such a level of sophistication and the author questions the benefits to be obtained in comparison with simple manual control when taking into consideration that wage levels are relatively low.

There are ten vacuum pans of different designs; some of the double diameter type, others with straight sides. All are equipped with electrically operated striking valves while one pan has a stirrer fitted.

All massequites are single cured.

Regrettably, time is always too short during these visits to comprehend fully the operational scheme of boiling and curing massequites. Nevertheless some observations were possible, some of which question the real level of efficiency that is being achieved. A very brief mention of these is made under this heading but is discussed in more detail in Section VI.

Each pan has three steam connections, i.e. vapour, back pressure and boiler live steam; not reduced. This is totally unnecessary, in fact the latter is a dangerous practice. Considering that the efficient utilization of steam is an important factor, there should only be one steam connection to each pan, i.e. vapour.
The evaporator vessels should be designed in such a way that they are capable of meeting 90 % of the steam demand of the pans. For proper operation of the entire system, the pressures of back pressure and vapour should be under automatic control.

In order for the pan station to operate efficiently with low pressure vapour, pan design should receive special attention.
It certainly should not be of the double diameter type.
It was also noted that the vapour lines and valves to and on each pan were far too small, they should at least be twice the present size.

Previously another consultant made the observation that the practice to produce a large crystal, requires the installation of a big pan capacity with corresponding high steam consumption. She also observed the excessive washing of sugar in the centrifugals.

This author suggests and recommends further investigation that massequites be double cured using a small amount of superheated water for washing and that the B-sugar is also put in the bag.

C. Meishan

This is a very modern factory built less than two years ago and entirely of domestic design.
The factory had also already completed its crushing season.

It has at present a capacity of 4500 tcd in a tandem of 12 rollers, 2000 mm x 1000 mm and fitted with Donnelly chutes.
In order to cope with the expected increase in cane supply in 1986, the factory was expanded with an extra mill, TA set, boiler and evaporator vessels. With this expansion, management was expecting to be able to crush 6000 tcd.

The author was told that during the crop just finished, about 4000 tons of coal had been used as supplementary fuel.
If this was happening in an established factory and producing sugar only, one would immediately be concerned about this additional cost. With a new factory like Meishan which has only been in operation for one or two crops, one has to be somewhat more careful in expressing concern.

Nevertheless, the design of steam supply to the pans is very similar to that in Shi Tow and the same comments therefore apply. Different sources are connected to each pan, leaving the option which one to choose to the pan boiler. The simple fact that the valve stem of the live steam valve was very smooth is sufficient evidence that live steam is used to boil pans.

Earlier during one of the Question and Answer sessions, the author was drawn in a debate between different members in the audience about the virtue or otherwise on the principle of having a Zero-Pressure-Evaporator.
This is discussed in some detail in Section VIII.
However, this design feature is apparently incorporated in Meishan factory and unfortunately continues to be part of the expansion programme.

In general terms, the factory is of very pleasing appearance and considering that the entire complex of factory, offices and housing was built in less than two years, all who were involved in achieving this must be congratulated.

D. Jiangmen sugar factory

The factory was no longer crushing cane but was processing imported Australian raws.
The crushing capacity is 6000 tcd in a Stork-Werkspoor mill which was installed about 25 years ago. Insufficient time was available to visit anything else other than the mills and the office.

The author was told that the sugar factory forms the nucleus of a huge complex which is deeply involved in enhancing the commercial value of the sugar factory by-products.
Furfurol, alcohol, baker's and fodder yeast, some medicines, hard board, bricks from filter mud, are all manufactured by this company.

E. Yatang

This factory is only a few years old and was still crushing during the visit.
The present capacity is 1500 tcd but it is intended to increase this to 2000 tcd in 1986 and even more in 1987.

Presently there are two sets of knives as cane preparatory equipment. The mill consists of 12 rollers of 1250 mm x 610 mm, with each mill having small under and over feed rolls.
The mills are driven by DC electric motors and run at 6.78 rpm or 13 m/minute.

The author was put under some pressure to provide a solution to achieve the required capacity without incurring excessive capital cost and without sacrificing extraction. A few computer runs of the existing mill tandem with different speeds and imbibition rates indicated that whatever is altered, the mill is already overloaded. These print outs were left with the manager for him to consider; a copy print out is included as Appendix 6.

The easiest alteration to be made would be to discard the rubber belt intercarriers for a drag type design and install Donnelly chutes with feed rolls. This would certainly improve the feeding of this mill and if the Messchaert grooves were further kept in perfect condition, then some increased capacity might be possible.

Another somewhat odd feature (at least to the author) was observed on the mills. Despite the fact that chokeless pumps are installed, the juice of each pump is still screened through a small, locally made type of DSM screen installed above each intercarrier. To the author it seems a totally unnecessary piece of equipment but an ideal invitation to bacterial infection and inversion of sucrose.
Clarification of the juice is by dcuble sulphitation.
It was noted that there were many floaters being carried over with the clear juice run-off. The juice itself was clear and without turbidity.

The author then observed that no flash tank was installed between the heaters and the clarifier. The juice with a temperature of 104 oC runs straight into the clarifier while flashing inside. The juice inside the clarifier must be much in turmoil rather than in a tranquil state, this may explain the carry over of floaters in the clear juice.

There is a quintuple effect evaporator in use with some supply of vapour to the pans. Again, each pan has all the three sources of steam connected with the vapour piping being far too small.
Despite prior assurances that live steam was hardly ever used, the smooth valve stem suggested a very different story.

Massequites are single cured with plenty of wash water used. The author is not clear how the grain strikes are made, but was told that the C-magma is used as a footing for the B strikes and that B-magma is used as a footing for the A strikes.

This boiling process, the production of a large crystal and the extensive use of wash water in the centrifugals, are rather uneconomic as far steam consumption is concerned.
If therefore there is an economic use for the bagasse, then it would be worthwhile to consider a change in the boiling process.

F. Zingzhou

This factory had been described to the author as 'the old one'. After the visit, the author's assessment is that the buildings may be old and in need of repair, the plant inside is in reasonable condition and certainly deserves better attention.
It would appear that the machinery is suffering more from condemnation by the staff than from old age and fatique.

The mill was still crushing cane at a rate of 1200 tcd in a tandem of 15 rollers of 1200 mm x 630 mm.
Each mill is driven independently by a three phase asynchronous electric motor, thus providing NO means of speed control.
It cannot even be achieved by speed alterations of the TA set, as this unit also supplies to other consumers.

The mills are thus running at a constant speed of 17 m/minute or 8.85 rpm. It was observed that there was no movement at all of the top rollers during crushing, yet the total hydraulic load on the roller was only 115 tons. This figure assumes that the gauges were correct and that the author was given the correct diameter of the rams.

The flow of imbibition juice from some mills was split in that some was returned direct to the mill bed instead of all being pumped back onto the bagasse in the carrier. Obviously there were juice drainage problems.

The powerhouse looked very good and modern.
The boilers also seemed to operate well despite the fact that the boiler feedwater temperature was only 85 oC.

The first vessel of the evaporator appeared to be doing very little work. It was difficult to determine what was wrong as none of the gauges seemed to respond to gentle knocks. Arriving at the last vessel, a notice board indicated a syrup density of 55 Bx. The density testing apparatus was at the ground floor on the pump.
The author leaves it to the professional reader to draw his own conclusions from this.

This factory also uses live steam on the pans; the author also witnessed a liberal application of water in an A-massequite centrifugal.

The author considers that the factory is in a reasonable condition, if anything is lacking it is insufficient care.

G. Jiangmen machinery workshop

This workshop is very conveniently situated along a main river making the import and export of materials and finished goods a very simple matter.
The total annual capacity is in the order of 6000 tons of steel.
In addition to the simple fabrication work, they are capable of manufacturing mills, open and totally enclosed reduction gears, and castings of mill rollers up to the largest size.
All forgings and cast steel castings are bought in.

The author would have liked more time here than just a morning visit. The impression is one of capable staff, well laid out shops and tidy surroundings. However inside the workshops more attention ought to be paid to materials handling. Steel plate material was lying everywhere with no clear indication of lanes of traffic, a vehicle could hardly drive through the shop.

Despite this observation; it would appear a very capable fabrication workshop.

IV. CANE PREPARATION

A. General

In the last 20 years, the industry has shown a greater interest in achieving maximum preparation of cane. The reason for this development is that by better preparation one obtains better results from the first mills. Mills are designed to squeeze the bagasse rather than further rupturing the fibre cells.
The conclusions that the industry has come to is that the rupturing process is better done by equipment that is less costly than a mill unit.

A new range of cane preparation equipment has been developed in different countries during recent years and marketed under such names as shredder, fiberiser, chopper-fiberiser, buster, collectively sometimes called 'ninety plus' machines.
This description stems from the fact that the installation of such equipment results in a preparation of the cane whereby more than 90 percent of the sucrose containing cells have been ruptured. This in contrast to kniving sets which do not achieve a preparation much higher than 70 percent.

The successful development of these machines is partly due to the fact that standard testing procedures have been established which make it possible to determine fairly accurately the percentage of open cells. This knowledge of the exact level of preparation has stimulated the interest in designing better machines than that previously available. Different countries often use different descriptions for what is essentially the same parameter; i.e. preparation index (P.I.), displaceability index, % pol open cells. The author's preference is for P.I. as it adequately describes what it is referring to.

Appendix 1 gives a description of the procedure involved in determining the P.I.

B. Knife arrangements

Almost every sizeable sugar cane growing country has developed its own design of knife sets. Obviously it is impossible to review all of these; the design used in China is a new concept never seen before. The discussion must therefore of necessity be one of a general nature.

The classical arrangement is to have two sets of knives.
The first set usually acts more as a heavy duty leveller rather than cutting the cane. It prepares the cane layer for easy acceptance by the heavy duty set.

The first set should have a clearance between the tip of the blades and the carrier of about 25 - 35 cm.
The pitch between the blades would be 50 mm and the diameter across the blades 150 cm while running at a speed of 750 rpm.
These knives may be driven by an electric motor or turbine, the installed power would be 12 hp per ton fibre/hour.

The second set prepares the cane and should therefore be set at a distance of not more than 20 mm from the carrier. The pitch of the blades would be 25 mm, the diameter across the tips of the blades 150 cm and running also at 750 rpm.
The installed power would be 19 hp per ton fibre /hour.

It should be mentioned that where the bagasse is used for paper making, knifing of cane is less desirable. The fibres are cut in short lengths, whilst the paper industry prefers longer.

C. Ninety plus machines

It is outside the scope of this report to describe the various machines in any detail. Some manufacturer's brochures will be obtained and sent out in due course. The reader is also advised to study the papers published on the subject in the proceedings of the ISSCT.

The principle of operation is that the cane is shredded by the action of swing hammers mounted on a revolving rotor and which pass in close proximity of an anvil plate. The cane is drawn in between the hammers and the plate. The hammers are hard surfaced with a deposit by welding rod of wear resisting material. The power requirements to drive the rotor are in the order of 35 - 50 hp per ton fibre/hour although some installations are even 75 percent higher. The tip speed of the hammers is 75 -100 meters per second with a total diameter of about 150 cm.

It is considered that a P.I. of over 90 increases the capacity of the mill by about 4-5 % on account of a greater density of the cane feeding into the first mill. The extraction increase varies between 2.5 - 0.9 %, the higher figure with a mill tandem of 12 rollers, the lower figure for a tandem of 18 - 21 rollers.

V. MILLING of CANE

A. Three, four and five roller mills

The technique of crushing cane may vary from country to country.

ALLEN* states " A casual reader learning of the variety of roller groovings in use, the numerous trashplate settings, mill ratios, and mill roller speeds, etc., may well think that almost anything will do for the settings and adjustments which are the jealously preserved responsibility of the chief engineer.
The explanation the writer suggests, is that the milling of cane remains something of an art."

Java favours slow speed with high extraction sometimes achieved with maceration bath intermediate carriers.
South Africa today, prefers relatively slow mill speeds but have a tendency towards the development of diffusers.
Australia, Hawaii, etc., have developed in the direction of high mill speeds assisted with pressure feeder arrangements.

It is not easy to define the reasons for approaching mill extraction from different directions. The author believes that it is perhaps a combination of established local practice, existing cane quality, local wage levels, etc. The fact that different approaches can lead to a satisfactory end result, does suggest that each country may have to develop its own style of operation.
The efficient crushing of cane is basically the art of extracting as much sucrose from prepared cane with as high a fibre throughput as possible, all relative to a particular type of milling tandem and a given level of imbibition.
High extraction and high fibre throughput are opposing factors in the milling of cane.

*QSSCT, 25th conference 1958

The sugar industry has for many years used the 3-roller mill and most mills in the world are still of this type. During the 1950's the 4-roller mill appeared but had a short practical life when the so-called 5-roller appeared. The 5-roller description is really a misnomer as the two additional rolls are really heavy duty feeder rolls.
The 4-roller is a truly 4-roller mill as the fourth roller is identical to the other three rollers and contributes to the extraction of juice.
But the mill fitted with the spikey-toothed roll pressure feeder has rapidly overtaken the 4-roller mill as its results have proved to be far superior.

B. Mill feeding arrangements

A number of features or devices can assist in the feeding of a mill, some are good ,some are poor.
The rubber belt intermediate carrier does nothing to exert any pressure in getting bagasse into a mill. The simplest form of device to create some positive force on the bagasse is the slat type intermediate carrier fitted with a nose shaft; not very efficient by present day standards.
An improvement over the slat carrier is the scraper type carrier discharging into a Donnelly chute. This arrangement can be further improved by fitting one or two small feed rolls at the bottom end of the chute.
The latest development is however the use of two heavy duty, spikey toothed pressure feeder rollers, fitted intregal with a 3-roller mill. This mill is sometimes labelled as a 5-roller mill but this is a misnomer.

Often the question is asked 'how does one increase the capacity of an existing 3-roller milling tandem'?
Where it concerns a modest increase of say perhaps 20 percent, the answer would probably be to fit scraper type carriers with Donnelly chutes; where the increase required is larger, the answer would probably be to install another mill or a diffuser.

In the case of scraper carriers, these should elevate the bagasse to a considerable height and then discharge into a Donnelly chute.

DONNELLY* reports that he has seen an installation with a height of 7 meters, but that in Australia the average height seems to be around 4-5 meters. He further reports that the chute should have a angle of about 70^{o} to the horizontal and that the bottom plate of the chute should 'hit' the front roller at about 20^{o} from the vertical centre line of the roller.

The author has been involved with an installation whereby the chutes were installed vertically. In such a case, a bottom feed roll should be fitted with a diameter of about 1/3 the diameter of that of the mill roller. This arrangement provides a sqeeze between the feed roll and the top roller of the mill.
The effect is twofold; a) it removes an initial quantity of juice, b) it assistsin diverting the direction of the vertical flow of the bagasse into a more acceptable direction for entry into the mill.
The opening between feed roll and top roller is usually in the order of 4-5 times the front opening of the mill, but fibre % cane and the rate of imbibition may influence the actual setting. The feed roll should therefore be adjustable; because of this a chain drive from the bottom roll is the simplest way of driving.
In order to avoid any chance of choking, these long chutes are usually diverging from top to bottom. At the top they are about 5 cm wider than at the bottom.

The latest development of spikey toothed feed rolls enables one to achieve an even greater degree of force feeding a mill.
Because the installation is of fairly heavy construction, it seems unlikely that such an arrangement can easily be fitted into an existing 3-roller mill. It is more likely to be an application for a complete new factory or for an existing factory where a new milling tandem needs to be installed.

* ISSCT, 25th conference 1958

The spikey toothed rollers are preferably driven from the mill gearing final motion shaft through a set of spur wheels.
An independent drive by hydraulic or electric motor is possible, but is probably more expensive and complicates the operation should the mill turbine slowdown or stop.
The feed rolls should also be made to follow the behaviour of the mill turbine; technically it is not impossible but in practice it is difficult to maintain in perfect order.
Van Breda* reports a power consumption of 10.8 Kw per ton fibre per hour for the two feed rolls or about 21 percent of the total power delivered by the steam turbine driving the mill.

C. Juice drainage

Ever increasing crushing rates, higher mill speeds and imbibition rates, require that greater attention be paid to adequate drainage of juice in this environment of high performance.
Poor drainage will result in a high liquid to fibre ratio at the entrance of the mill, with the effect that rollers cannot get a grip on the fibre and the mill will slip badly.

Juice drainage takes on two aspects;

a) a degree of pre-extraction before the bagasse reaches the entrance of the mill,
b) drainage in the mill itself.

The design of the rubber belt or slat type carriers is such that the direction of the flow of the bagasse and the direction in which the juice tends to escape are almost directly opposed to each other. When cane preparation was poor, this resulted in relatively large voids remaining in the bagasse and which assisted the drainage of juice.

* Proceedings SASTA, June 1984

Highly prepared cane and therefore less voids, inhibited the easy flow of juice and mill slippage occurred. This was always very apparent at the beginning of a crushing season with new knives fitted; not infrequently the engineer decided to leave some knives out in the beginning in order not to have too good a preparation and mill feeding problems.
After some weeks of operation the remainder of the knives were then fitted.

The nearly vertical Donnelly chute created an almost perfect solution in that the direction of the flow of bagasse and that of the flow of juice sqeezed out by the feed roll and top roller, virtually differed by 90 degrees. This made the acceptance of the bagasse by the mill much easier.
Alternatively, higher imbibition rates could be applied or crushing rates increased.

Drainage in the mill itself, basically consists of the application of Messchaert grooves on the bottom front rollers. Sometimes those grooves are also made on the back rollers but only seldom so. Afterall, 75-80 percent of the juice should be sqeezed out by the front roller and the remainder by the back roller. Perhaps where imbibition rates of over 300 percent on fibre are applied, there might be case for considering to fit on the back rollers.

During recent years a new development has been introduced in attempting to drain juice from the top roller. Small holes are drilled radially in the top roller shell which are connected to a larger, longitudinal hole inside the shell from which juice is to emerge at either end of the top roller.
The author is not aware that this invention is finding wide application.

Messchaert grooves are cut in the front roller shell about every other pitch of the normal V-grooving.
They are not more than 5 mm wide and about 35-40 mm deep.

Spring steel scrapers of 4 mm thickness are fitted in a solid square bar and whose purpose is to keep the grooves clean from bagasse during operation.
It is therefore very important that these grooves are not or do not become wider than 5-6 mm, otherwise bagasse will pack solidly in these grooves. No scraper gear will be able to free them from this bagasse when this happens.

D. Capacity of a tandem

Within reasonable limits, there is no definite capacity that one can assign to a milling tandem without reference to the extraction being achieved or desired to be achieved.
As the extraction is also determined by the rate of imbibition, any discussion about the capacity of a milling tandem must be associated to levels of extraction and imbibition.

However, every sugarman has subconsciously acceptable levels of extraction and imbibition in his mind and on this basis may be talking about 'a capacity of X tcd with a mill of Y rollers of Z size'. Such levels may on average be around 94 percent actual extraction at perhaps a rate of imbibition of 200 percent on fibre.
It is on this basis that the author proposes to further the discussion on the capacity of a tandem.

When one travels and meets the sugar industry staff in different countries, one discovers that many have developed and follow their own pattern of calculations and expressions as regards capacities and settings of their mills. Not only does sometimes the principle of their approach differ, but they also may indicate different equations in their calculations depending upon whether they work in metric, imperial or local system.

The author considers it outside the scope of this report to recall all these differences, an almost impossible task in its own right, but rather wishes to single out one or two established practices and discuss the principle of these.
The reader should always be aware,however,that milling of cane is not an exact science and all theories postulated originate from empirical data.

The extensive work that was carried out in pre-war Indonesia under the auspices of the research station in Pasuruan, has resulted in a basis of mill caculations that is still being followed in some form or another in other countries.
Based upon a combination of empirical data and actual research, Pasuruan used to issue or revise each year a set of tables for use by operating engineers which gave guidelines regarding the maximum amount of 'grammes of fibre per 100 cm^2 of roller surface of a 30" x 60" mill' it would be capable of crushing.
These tables are still in use in Java today, the author is not aware whether they are at present regularly revised.

The tables indicate this amount of fibre for every tandem configuration and for every mill in the tandem. As the figures are based upon a 'standard' 30" x 60" mill, conversion tables accompany the first set of tables which enables the engineer to arrive at the correct amount for a mill of different dimensions.

Given this information and applying the speed of the mills, the engineer would then be in a position to arrive at the total tons of fibre per hour and by applying the expected fibre % cane figure, the total amount of cane per day.
The grammes of fibre per 100 cm^2 surface area, is termed the fibre loading of the mill, typical figures might be:

Crusher	1st mill	2nd	3rd	4th	5th	6th
115	130	150	165	175	185	195

By publishing such tables, Pasuruan made the suggestion to the industry that if their figures were used, the mill might expect a reasonable extraction at reasonable imbibition.
Whether the mill manager chose to use these figures is a totally different matter, a large amount of cane available may dictate him to increase the throughput in excess of the suggested level with the inherent probability that his extraction would be somewhat below an average level.

Some countries hold the view that the thickness of the bagasse blanket should be related and be in direct proportion to the diameter of the mill roller.
They call this the specific fibre loading and it is expressed in 'grammes of fibre per 100 cm^2 of roller surface per 10 cm of roller diameter'.
As a 30" diameter roller is equivalent to 76.20 cm, the specific fibre loading for the first mill using the above typical figures, would be 130 x 10 : 76.20 = 17.0 grammes.
For the tandem as a whole this would be nearly 21 grammes.

In South Africa, an empirical figure is used to determine quickly the maximum capacity of a mill tandem. They use the concept of Total Roller Volume (TRV) expressed in cubic meters.
For example, a five 3-roller tandem of 2000 mm x 1000 mm, would have a TRV of $5 \times 3 \times 2 \times 1^2 \times 0.785 \times 3.14 = 23.55\ m^3$.

To obtain acceptable results, they seek to have not less than 1.00 m^3 TRV per ton fibre/hour with a maximum installed in some mills of about 1.4 m^3.
On this basis, the above mill would be capable of crushing a maximum of 23.55 tons fibre/hour, any lower throughput would mean a 'comfortable' rate of crushing cane.

E. Power requirements

Most of the power required to drive a mill is absorbed by the friction in the bearings of the mill rollers and by the bagasse being drawn over the trashplate.
In relation to these two, the power loss in the reduction gearing and to drive the intermediate carrier is negligible.

Trashplates set too high, cause the friction of the bagasse on the plate to be excessively high and therefore a much higher power input is required.
Extra care should be taken to avoid this.

Mills which have been designed for vertical adjustment of the bottom rollers have a certain advantage over the horizontal designs. Vertical adjustment allows the narrowest centre distance of the bottom rollers and therefore also the smallest trashplate width which means less friction and power.

The absence of King bolts in the mill headstock allows for a thinner central web of the headstock which again enables the bottom rollers to be located at closer centres further reducing the width of the trashplate.

With regard to the power loss in the mill bearings, the author understands that many mills in China are already equipped with roller bearings. This is of course a step in the right direction towards further reducing the power requirements.
The rest of the world sugar industry has until now not rushed into using roller bearings for this application, China could offer the industry some practical guidance in this respect.
Many mills in China are driven by DC electric motors, it must be an easy matter to determine the actual power consumed with slightly different trashplate settings, the reduction achieved with roller bearings, different cane varieties,etc.

When involved in the design of a sugar factory, the author would install about 18 hp/ton fibre/hour/mill. This is obviously higher than the average consumption, but the safety margin allows for the turbine being capable of getting the mill started under load.

F. Mill setting calculations

The end result of the calculation will give the engineer a good enough guide to set his mills fairly close to the optimum setting, the final adjustments should be made during crushing operations based upon the performance analysis described in Subsection J.

Pasuruan in pre-war Indonesia issued tables indicating the amount of fibre in kg that could be passed through 100 cm^3 of back opening volume. In a similar way as the fibre loading, the figures were drawn up for every mill in every conceivable mill tandem configuration. Typical figures for a 30" x 60" mill would be:

1st mill	2nd	3rd	4th	5th	6th
0.35	0.56	0.73	0.83	0.89	0.93

In Java the procedure to calculate the settings for each mill involves the following steps:

1. The total amount of fibre is calculated from total cane multiplied with fibre % cane,
2. Calculate the roller area; circumference x length,
3. Choose appropriate fibre loading (subsection D) and if existing mill is not a 30" x 60", adjust fibre loading to suit mill size under calculation,
4. Determine the RPM by dividing '3' into '1',

5. Determine total volume required by dividing appropriate figure from above table into '1',
6. Determine total area by multiplying '2' and '4',
7. Determine back opening in operation by dividing '6'into '5'.

The roller area is based upon the average diameter of the roller. This diameter is found by measuring the combined volume of Vee, Messchaert, Chevron grooves and which is expressed as an equivalent opening across the length of the roller and which is then deducted from the diameter across the tips.
In Indonesia they go to extraordinary length to determine this volume accurately.
One sixth of the roller surface is filled with mud, allowed to dry and subsequently measured by displacement in water or oil. Multiplied by six will give them the total correction volume of the roller.
The author considers this being over zealous in accuracy and certainly does not agree that Messchaert grooves be included.

Having determined the discharge setting in operating conditions, the next step is to calculate the front setting.
It is of course a question of applying a ratio to multiply the discharge opening with. It is these ratio's that are perhaps one of the most contoversial subjects in milling techniques in different parts of the world.

In Java they will use:

1st mill	2, 3 & 4th	5 & 6th
2.2 - 2.6	1.6 - 2.0	1.5 - 1.8

In the America's they will probably use:

1.75	$\frac{3}{4}$--------÷	2.25 - 2.75

It can be seen that there are two approaches; one decreases its ratio from 1st to last mill, another one increases from 1st to last.

The author is not aware that there has been an attempt by anyone to explain which approach is the correct one. His own preference is for a ratio which increases from the 1st to the last mill, but the degree of increase is probably also dependent upon the amount of imbibition water applied and the length of the tandem.
The reasoning is as follows:-

The quantity of material (juice + fibre) that passes through each mill is larger in the beginning of the tandem than towards the end. On the basis of a given amount of imbibition water being applied, then the combined quantity of that imbibition and some juice is proportionally smaller at the beginning of the tandem to the total amount of material that passes through than at the end.
This being so, it suggests to the author that the ratio of front to back opening should be increasing from 1st to last mill.

However, having adopted a ratio for a mill in the tandem, the discharge opening should be multiplied with this ratio in order to obtain the front opening. To obtain a setting at rest, an amount representing the top roller lift should be deducted from the operating openings. In doing so, care should be taken to multiply the actual vertical lift with the Cosines of the top angle and deduct the amount obtained from the operating openings.

The reader will have observed that the validity of these settings is very much effected by the validity of the figures given in the tables indicating the weight of fibre that can be passed through a volume of back opening.
As these figures are derived from empirical data, it is essential that the engineer checks the performance of the mill once in operation and makes adjustments if not satisfactory.

The South African Milling Research Institute in 1958 started a programme with the object to re-confirm or otherwise whether HELMER of Pasuruan in pre-war Indonesia was correct in his quantities of fibre through each mill discharge opening as expressed in the tables mentioned before.
This research programme has undoubtedly been the most comprehensive study carried out on milling techniques since the war. The reader is advised to read the paper published in the 12th ISSCT proceedings*.
It is outside the scope of this report to enter into details of this study, but the following synopsis may be useful to stimulate interest.

By collecting and collating numerous milling results of Java factories over a number of years, Helmer had concluded that the best extraction results were obtained when the FIBRE INDEX

$$M = \frac{\text{kg fibre per minute}}{\text{escribed volume per minute}} = 0.58 \text{ for the 1st mill, and}$$

0.94 for the last mill(see Typical figure earlier this section).

If one then further sets targets of F = fibre % bagasse for each mill as follows:

	15 rollers	18 rollers
1st mill	0.32	0.30
2nd	0.40	0.39
3rd	0.45	0.43
4th	0.48	0.46
5th	0.50	0.48
6th	-	0.50

it became apparent that
M : F = virtually constant for each mill @ 1.77
This is the apparent density of the bagasse under compression.

*Milling research in SA 1961-1964

The paper concludes that after collecting numerous milling data over a number of years about all the South African mills, it was found that HELMER's empirical figures were still acceptable today for their conditions.

Therefore by accepting that M = 1.77 F and by applying the Fibre Index for each mill, the required discharge volume is easily determined.

Rather then using the tables by Pasuruan and using the confirmation by the South African Milling Research Institute that the apparent density of the bagasse is constant at 1.77, a simpler formula may be developed to calculate the back opening.

Let

C = metric tonnes of cane per hour
f = fractional fibre content of cane
D = average diameter of roller in cm
L = length of roller in cm
F = target fibre % bagasse each mill (see table)
rpm = revolutions per minute of roller
K = back opening in operation in cm

then $M = \text{kg fibre} / 100\ \text{cm}^3$

$$= \frac{C \times f \times 1000}{60 \times rpm \times 3.14 \times D \times L \times K} \quad \text{or}$$

$$K = \frac{5.30 \times C \times f}{rpm \times D \times L \times K} \quad \text{or} \quad K = \frac{5.30 \times C \times f}{rpm \times D \times L \times M}$$

' M ' may be substituted for 1.77F, thus

$$K = \frac{5.30 \times C \times f}{rpm \times D \times L \times 1.77F} = \frac{3.00 \times C \times f}{rpm \times D \times L \times 1.77F}$$

G. Trash plate setting

A construction widely adopted throughout the sugar world was developed by Muller-von Czerniky and Gogle in pre-war Indonesia.
The construction is simple and should be made full scale on the drawing board. This enables one to make a template from the drawing for use in the machine shop making the plate.
For reference, see illustration as Appendix 2.

1. After calculation of the front and back openings in operation, draw the triangle FTB and the outer roller circles,
2. Draw SF at angle 1/6 of angle FTB,
3. Draw arc of circle with centre T and TS as radius cutting the back roller at D,
4. Extend TD with 4 % of SD to obtain point H,
5. To obtain point C, circle radius TD from the centres S and H,
6. From point C, draw the arc SH which gives the position and profile of the trash plate.

The nose of the plate at S should be flattened slightly in order not to have too thin a section at this point.

H. Hydraulic loadings

There are a number of different ways in use in expressing the load on the top roller, different countries use different criteria.
Examples are:- total tons on the top roller, tons per unit length of roller, tons per projected unit area of the roller and this may then be expressed in the metric or imperial system.

Obviously the end result is the same; what is the total load applied ?

The author mostly uses metric tonnes per one meter length of roller. One finds that small mills may have a maximum load of 160 tonnes per 1 m length, while the largest mill may go up to 300 tonnes per 1 m length.

Generally the trend in milling seems to be for low load and high speed of the first mills going gradually towards high hydraulic load and low speed at the last mill.

It cannot be too strongly emphasized that it is no use applying a high load if it makes the top roller sitting solid in its bearing. The load is then not applied to the bagasse but rather transmitted through the bearing to the mill headstock(see IIIF). During operation, the top roller must be 'floating' all the time.

J. Performance analysis

Introduction

This section describes some of the techniques available to the mill engineer to check the performance of each mill in the tandem during the crushing season. Such information enables him to adjust the settings of each mill for optimum performance.

The co-operation of the factory laboratory is essential in the collection of the samples and the analysis of them.

The Brix curve method

This method was originated in 1929 by Luce and by Smith. It arose from the fact that, prior to its proposal, individual mill analysis had been conducted as Dry Milling Tests which, it was realised did not conform to actual operating conditions.

Samples of juice expressed by the back roller of each mill are collected when all conditions are normal and analysed for ^{o}Brix. A hand refractometer expedites this process very considerably. The Brixes are then plotted on the vertical scale of a graph against the mill number on the horizontal axis. The result should be a concave curve. If this procedure is repeated at regular intervals, a typical pattern will build up and when an abnormality occurs, such pattern will be disturbed. Examples of typical curves are included as Appendix 3.

The Brix extraction method

In any one mill, Brix extraction is related to Pol extraction. By sampling the juice from the front roller of a mill, from the back roller of a mill and the mixed juice as it comes off the mill and analysing these three samples for ^{o}Brix, it is possible to calculate the percentage of the unit's extraction accomplished by the front roller and the percentage accomplished by the back roller.

For example, assume that:

Brix front roll juice	= 13.0
Brix back roll juice	= 15.9
Brix mixed juice from mill	= 13.6

Then :

$$\text{Front roll extraction} = \frac{(15.9-13.6)}{(15.9-13.0)} \times 100 = 79.3\ \%$$

Back roll extraction = 100 - 79.3 = 20.7 %

For the unit to play its full part in obtaining a desired overall extraction of the tandem as a whole, it is considered necessary that the front roll extraction should not be less than 75 %. A really good working mill may achieve 80 %.

The pol extraction method

This method which gives the cumulative Pol extraction from the first to the last mill, entails a certain amount of preparation and a good deal more work in the laboratory. The laboratory must have the capacity for several simultaneous Moisture % Bagasse and Pol % Bagasse determinations.

Cane of known variety and in sufficient quantity is positioned on the carrier to carry out the sampling judiciously for each mill in the tandem.
Starting with the first mill, samples are taken of the back roll juice and the bagasse as discharged from the mill across the full width. Care should be taken to avoid any imbibition juice run back in the sample.
The samples must be stored in covered containers to avoid loss of moisture. This process is repeated for each mill ensuring that sampling is carried out on the same cane as it passes through the mill.

To illustrate the calculations, assume the following analytical results :

	Pur.	% Pol	% Brix	% Moist.	% Fibre
1st Mill.					
Back roll juice	85.8				
Bagasse		8.11	9.45	57.40	33.15
2nd Mill.					
Back roll juice	83.2				
Bagasse		5.41	6.50	51.88	41.62
3rd Mill.					
Back roll juice	80.10				
Bagasse		3.44	4.29	49.00	46.71
4th Mill.					
Back roll juice	77.50				
Bagasse		2.69	3.47	45.91	50.62

Suppose Fibre % Cane for the previous day or that of the sample being analysed, was 13.93.
Calculate Pol % Cane from 1st expressed juice analysis and Java ratio; assume a result for this purpose of 13.76.

From this it follows :

$$\text{Bagasse ex 1st mill \% cane} = \frac{13.93 \times 100}{33.15} = 42.02$$

similarly:

Bagasse ex 2nd mill % cane =33.47
Bagasse ex 3rd mill % cane =29.82
Bagasse ex 4th mill % cane =27.52

Then:

Pol in bag. ex 1st mill%cane = 8.11x42.02:100 = 3.41

similarly:

Pol in bag. ex 2nd mill%cane = 1.81

Pol in bag. ex 3rd mill%cane = 1.03

Pol in bag. ex 4th mill%cane = 0.74

Thus:

Pol in bag.ex 1st mill% Pol in cane = 3.41x100:13.76 = 24.76

Cumulative extraction of the mill = 100 - 24.76 = 75.22

similarly:

Pol in bag.ex 2nd mill% Pol in cane =13.12

Cumulative extraction of the mill = 100 - 13.12 =86.88

Pol in bag.ex 3rd mill% Pol in cane = 7.49

Cumulative extraction of the mill = 100 - 7.49 =92.51

Pol in bag.ex 4th mill% Pol in cane = 5.38

Cumulative extraction of the mill = 100 - 5.38 =94.62

The individual mill extractions are therefore:

1st Mill		= 75.22 % Pol in cane
2nd Mill	86.88 - 75.22	= 11.66 % Pol in cane
3rd Mill	92.51 - 86.88	= 5.63 % Pol in cane
4th Mill	94.62 - 92.51	= 2.11 % Pol in cane

	Total	94.62 % Pol in cane

Examples of density curves

The analysis of mill tandem operating conditions for the purpose of locating the unit responsible for a poor performance is perhaps the most difficult problem that confronts the mill engineer.

Pol extraction tests with imbibition are not easy to carry out, they require a considerable time before results become available and are subject to errors in sampling of bagasse in particular.
A dry crushing test is simpler to perform than the Pol extraction with imbibition on, but the dissimilarity with normal operating conditions, must make the results suspect.

Experimental work carried out by factory staff in various countries have confirmed the value of the results of these tests and the use as a tool of the curves that emanate from these analyses. If these tests are carried out on a regular basis, the curves will take on a different shape when changes occur in the milling process and it is the interpretation of these changes that can greatly assist the engineer in pinpointing where the problem of poor performance is occurring. The accuracy of the results is determined by the accuracy of the sampling.

Care should therefore be taken to ensure that the sampling of the various juices is done correctly at the exact time and that the samples are collected in marked containers to avoid confusion in the laboratory when 12 or 18 samples are brought in at the same time.

A number of curves from various mills under various conditions are attached as Appendix 3. These are usefull in understanding the interpretation of the sampling process.

In Fig. 1, mill 'A' shows the average of a group of juice density tests made at a 12-roller mill where the extraction was 98.7. The 'B' curve shows similar data at a mill where the extraction was 95.8. The crusher juice density is approximately the same for the two mills, but in 'B' the juice expressed at the first mill is considerably higher, leaving more juice in the bagasse to be extracted at the latter units.

From this we can conclude that the work at the 'B' mill crusher is distinctly inferior. This poor work not only imposes an extra load on the next units in the tandem, but because of inefficient crushing which causes course cane to pass through the mill, the imbibition is less effective.

Fig.2 shows average Brix curves of juice coming from 2-roller crushers and 9-roller mills. Mill 'B' has no knives and the cane is flumed, while mill 'A' has knives, but the cane is brought to the carrier by railroad. The performance of mill 'B' is excellent except that too much flume water is carried in the cane, while that of mill 'A' is poor.

Fig. 3 shows the averages of juice density curves for different mills having 2-roller crushers followed by 12-roller tandems. These curves can be used as standards except for flume water noted above as the extraction at these mill ranges from 97.8 to 98.6.

Fig. 4 shows the curves at two different mills, the extraction at mill 'A' being 98.2 with imbibition % cane of 33, and at mill 'B' the extraction is 94.7 with an imbibition % cane of 22. Although the juice density at the crusher of mill 'B' is considerably lower, the extraction at the crusher is low. This is reflected more or less throughout the curve. The curve for mill 'A' is typical for this factory.

Fig. 5 shows the averages of a number of juice densities at one factory. This factory has a 2-roller crusher, shredder and is followed by a 9-roller mill. The tonnage crushed is about the same for all factories. It is interesting to note that the general slope is much the same. Curve 3 shows that the second and third mills were not extracting their quota of juice, consequently the extraction of 94.6 was exceptionally low. Conditions were much improved in curve 2, the last two units doing better work and the extraction being 96.2.
In curve 1, the last two units have been improved to the extent that the extraction has been increased to 97.4 percent.

Fig. 6 - Mill 'A' is a 2-roller crusher followed by a 15-roller mill. Mill 'B' is also a 2-roller crusher, but is followed by a shredder and a 15-roller mill.
The curve of mill 'A' shows that the crusher is doing poor work and so is the last mill in the tandem.
The curves of mill 'B' are normal for this type of mill tandem.

The objective sought is to secure a low juice density from the back rollers of the last mill. However, a result too low may be an indication of poor work at the unit rather than good work. This may sound confusing, but may be explained as follows.-

When imbibition water is applied, much of it surrounds the particles of bagasse without mixing with the heavier residual juice of the bagasse proper. When it is squeezed out it is found that the first juice expressed by the front rollers is very much lower than that taken out by the back rollers.
As an extraction by the back rollers increases, an increasing amount of this heavier residual juice is expressed, thus bringing up the density of the back roll juice.

If now, due to a thin feed or too wide openings in the front rollers, they will not take out as much juice as they should and thus a greater quantity of this thin juice remains for the back rollers to extract. If at the same time the back rollers are taking out their full share of the heavy residual juice, the density of the juice expressed by the last rollers will not be much higher than that from the front rollers.
Thus when juices of low density are obtained without being accompanied by a low moisture of the bagasse, it certainly would indicate that the mill is not doing its full share of work.

In order to determine whether a low density juice is a true indication or not, a calculation is carried out of the ratio of the density of this juice to the density of the theoretical residual juice remaining in the bagasse as follows:

Brix last expressed juice = as determined by analysis

Pol % Bagasse / Pur.last exp. juice = Brix % Bagasse

Brix % Bagasse + Moist.%Bagasse = Residual juice % Bagasse

$$\frac{\text{Brix \% Bagasse}}{\text{Residual juice \% Bagasse}} = \text{Brix residual juice}$$

$$\text{Factor} = \frac{\text{Brix last exp. juice}}{\text{Brix residual juice}} = 55 \text{ to } 80$$

If this factor is calculated from data shown on the weekly reports for some of the factories obtaining excellent milling performance, it will be found to be in the range of 55 to 80. The factor may be as low as 25 for mills showing poor extraction performance. In working out such a factor, care must be taken that the figure reported is for juice from the last two rollers of the mill unit.

Further information may be obtained which will serve as a valuable guide in interpreting juice curves by securing the densities of the front, back and total juice from a mill and inserting the densities in a Cobenz diagram (see 3. Brix extraction method). Good work is indicated when the figures for the extraction for the two front rollers is high.

K. Material compositions

Roller metal analysis should be approximately as follows:

NAME	ANALYSIS	BRINELL	CUPOLA CHARGE
	3.2 %Cr		25% medium phos.pig iron
"CRT"	0.15 % S	185	20% iron briqettes
	1.6 % Si		10% steel
	0.5 %P, 0.6Mn		30% cast iron scrap

The rate of cooling the shell after casting has a pronounced effect on the structure of the grain of the metal. The correct procedure and therefore structure can only be found by experience.

Trashplate material should have a hardness which is ten Brinell higher than that of the roller shell material.
It should be of fine grain with about 0.4 % carbon.

Mill pinion material should be cast steel, machine moulded, 42/50 tons/square inch, elongation 12 % minimum, hardness 190/225 Brinell.

Pinions should not be machined from blanks but cast, with no other machining than the bore and keyway.

L. Roller shell arcing

In order to increase and maintain the high fibre loadings in their mills, countries such as Australia and South Africa have developed a technique to keep the surface of their rollers in a rough condition. During crushing operations the procedure is to draw an electric arc between a hand held electrode and the roller. One or more persons at each mill are employed to carry out this task. During this action only a small amount of metal is deposited, its prime purpose is to roughen the shell material by the action of the arc. The 'welding' rod consists of a special material and is traded in some countries under the name of Afrox 80 or CR70.

When carrying out this operation, special care must be taken that an adequate facility is fitted at the end of the roller which guarantees a complete loop for the electric curent. Failing to provide such a faclity will mean that the current is seeking its way back via the roller bearings which will result in damaging these. This is of even greater importance when roller bearings are fitted to the rollers.

VI. EFFICIENT USE of STEAM

A. Principle of reducing consumption

One begins with the assumption that China requires to utilize its natural resources in the best possible way, the question is asked 'what role can the sugar industry play in this'?

Within the limitations of the job description, this report deals only with the efficient use of steam, the object being to save bagasse for alternative uses or to reduce coal consumption.

The report also aims to approach the subject through the eyes of the Manager rather than tackling it from an engineer's point of view by producing yet another thermo-balance.
Many articles can be found in the international sugar literature describing in detail how such balances can be drawn up, the author does not feel the need to repeat these data in the report.

The reason for following this line of argument is because in the final analysis it is commercial judgement that must decide what degree of steam economy is desirable in a particular situation.
Thermo-balances are excellent in that they present a concise picture of what the situation on steam economy **might** be in a given situation.
The author holds the view that these balances are as valuable to the Manager as a calculator is to an engineer.
The question is 'what does the Manager do with it when he finds such a balance on his desk'?

The answer is that if he starts with a new factory he can exert an influence at the design stage; however in an existing factory his ability to achieve improvements is subject to constraints imposed by existing plant layout, unit equipment design, process technology, etc.

In a sugar factory steam is consumed for two different purposes, i.e. by the prime movers for the purpose of generating power, and by the 'pots and pans' to evaporate the water present in the juice. In this process, the prime movers use high pressure steam and discharge low pressure steam; the 'pots and pans' use this low pressure steam and discharge condensate water.
In an ideal situation the consumption of the two consumers would be in balance, in practice this is never achieved.

An imbalance situation can either mean that the prime movers consume more than the boiling process which will result in a situation whereby the back pressure steam is blown off to atmosphere; the reverse is that the boiling process consumes more than the prime movers in which case boiler steam must be supplied to the former.
Either way, a permanent ,large imbalance must be avoided as it constitutes uneconomical operation.

Experience has taught factory designers that the start is to begin with determining the steam consumption required to evaporate the water in the process and relate this quantity of steam to the power required to operate the factory.

A simple calculation regarding the quantity of water to be evaporated in the process house will assist in focussing the attention where improvements could be made.
For ease of understanding, a capacity of 100 tc/hour is assumed, which with an imbibition rate of 175-200 % on fibre will give one a quantity of mixed juice of about 100 tons/hour at say 13 Brix (ignoring such additions as milk of lime, filter water).

If one further assumes a syrup density of 60 Brix, then the evaporator will evaporate about 77 tons of water per hour. The theoretical amount of water to be removed in the pans is then 100 - 13 - 77 = 10 tons/hour.

The actual amount of water to be evaporated in the pans can vary greatly and is determined by the amount of water that is used by the operators for washing pans, dilution of molasses, wash water on the centrifugals, melting false grain, remelting of surplus lower grade sugar as well as the type of boiling scheme adopted.

Experience has shown that the excess water may vary from 25-125 percent. In the above example, the quantity may therefore be as low as 12.5 tons or as high as 22.5 tons water/hour.

From a bagasse usage point of view, it makes little or no difference whether the steam required to evaporate this water, is back pressure or live boiler steam. Using vapour from the evaporator to boil the pans does however make a great deal of difference in bagasse requirements.

If the pans and the rest of the system are so designed that they can operate successfully on 2nd vapour, then the steam consumption from a bagasse point of view would be at best about 12.5 : 3 = 4.2 tons/hour. This consumption, compared with the worst situation of 22.5 tons makes for a difference of about 18 tons of steam/vapour per hour/100 tons cane. This difference in steam consumption represents 8 tons bagasse per hour or about 2-2.5 tons of coal (depending upon quality).

What value one should attach to this difference in fuel consumption, is of course very much dictated for each factory by the fact whether it has an alternative usage for its bagasse or whether it can reduce its coal costs.

B. Boiling and Curing of massequites

The lowest steam consumption would be with the scheme whereby massequite is boiled and cured in a single stage and all sugars produced put in the bag.
Unfortunately there are such forces at play which desire a high recovery of sucrose and a high polarization of the sugar produced and which oppose the adoption of the simple process.
A compromise needs to be considered, the extent of which is dependent upon prevailing circumstances.

The author has heard that legislation requires that a minimum pol and crystal size be produced if penalties are to be avoided.
It is not within the terms of the job description to make comments or recommendations as to whether such standards are aimed at a level which may be considered appropriate in relation to the general economy of the country.
Except to make the observation that a high pol and large grain size require more intensive processing techniques and therefore increase the cost of production.

Also outside the terms of reference and, not having had the time to observe nor to study laboratory reports, the author cannot make any specific recommendation regarding the correct processing techniques.

In general terms however, one should aim at a process which achieves a certain standard with the least amount of re-circulation of material. The rule is that once the syrup has entered the boiling house, the sugar should be in the bag as quickly as possible. The least amount of circulation can be achieved by obtaining a high exhaustion (high purity drop between a massequite and its spun-off molasses) and putting B-sugar in the bag. The latter suggestion may abhor some purist collegues amongst the sugar fraternity.

It is in the end simply a question of what is the best economic sense relative to the prevailing level of the economy of the country.

A high exhaustion is closely associated with producing a regular grain size and total absence of false grain. Cooling and reheating of massequites also play their supporting role in achieving a satisfactory degree of exhaustion. Regularity of grain size is very much influenced by good vacuum pan design, this is discussed in Subsection C.

The author strongly believes that it would be possible to produce an acceptable quality of sugar by adopting an A-B-C boiling scheme (if juice purities are in excess of 80) and whereby the B-sugar is also put in the bag.

C-strikes made on grain footing and made into a magma should serve as a footing for both A and B strikes. The immediate advantage is that it eliminates or at least reduces the amount of surplus C-sugar which is normally melted and probably mixed with the incoming syrup.

The A and B massequites are separately cured, these sugars are mixed together and made into a magma in a screw conveyor mounted below their centrifugals, and cured again in a second set of centrifugals. The effect of double curing greatly reduces the need for heavy washing in the centrifugals, only a small amount of superheated water is needed, this amount should be timer controlled.

Any argument that may be raised about the cost of extra centrifugal capacity is nullified by the fact that because of reduced circulation of material, less pan and crystallizer capacity is required for a given capacity.

Important also is that molasses must never be diluted to less than 65 Brix, anything below this figure would mean unnecessary extra water having to be evaporated.

Finally, whilst the evaporator is at the centre of the design criteria which enables one to reduce the steam consumption, there must be the initiative by managements to make alterations to the process of boiling and curing of massequites in order to achieve this reduction.

C. Vacuum pan design

The basic requirements of a vacuum pan are well known:

- low footing volume to the total volume,
- high heating surface to volume ratio,
- low massequite height above top tube plate,
- good circulation.

In addition there are many other details which make up for a 'good' pan, e.g. steam distribution in the calandria, incondensable gas removal, size of striking valva, type of catch-all,etc.

A 'good' pan would have all the above qualities in some form or another, but some of these qualities are contradictory to each other; the end product is therefore likely to be a compromise. Frequently the machinery manufacturers go astray when put under pressure to produce a design with one or two exceptional qualities and in doing so, sacrifice some others.

A typical example is the double diameter pan, it achieves a low footing to total volume ratio and a low height above the tubeplate but largely at the expense of a good heating surface to volume ratio and good circulation.
The pockets of stagnant circulation just above the tubeplate are ideal for further crystal formation and thus contributing to the presence of irregular grain in the massequite.
This greatly effects the proper working of the centrifugals and reduces their capacity as the molasse does not readily spin off naturally.

Excessive wash water is then required to rectify partly a bad job caused by poor pan design, partly because the process of washing also melts some of the sugar in the centrifugal which lowers the exhaustion and in the case of the C-massequite increases the purity of the final molasses.

There is no doubt that a pan should be of a design with straight sides, shallow calandria and large steam inlets with good internal distribution in order to operate satisfactory on vapour.

A sketch showing a good design with pricipal dimensions is included as Appendix 4.

D. Evaporator design

The configuration of the evaporator station and the manner in which it is operated, greatly effect the overall steam consumption of the sugar factory. It is almost universal practice in the sugar industry to express the consumption as a percentage of cane crushed. The figure can vary greatly between factories; steam % cane may be as high as 75, it may be as low as 40 -45.

The beet sugar industry achievs even better results, sometimes less than 40 percent on beet sliced. Their achievement is not necessarily because they have better designers, but largely a question that beet juices will accept to be subject to higher temperatures and the industry therefore is able to use pressure evaporators.

In order to avoid colour formation in cane juice in the first vessel, one must be cautious not to exceed a steam temperature in the calandria higher than 125 - 130° C. This imposes a limit on the pressure of the backpressure system of about 1.5 kg/cm2.

Maintaining the pressure at this level and with a vacuum of 635 cm Hg on the last vessel, there is an adequate pressure drop available across each vessel to allow the evaporator to operate in quintuple effect.

In the design of an evaporator, there are two separate issues involved; firstly, there is the design of the individual vessel, secondly there is the design of the various vessels in one unit.
The design features of the individual vessel are perhaps slightly less critical than those of a vacuum pan, nevertheless there are 'good' and 'bad' vessel designs.

A good vessel would have such features as:

- a voluminous vapour space above the tubeplate,
- an adequate sized catch-all,
- sealed downtake,
- stainless steel tubes,
- 33 mm tubes in the first 2-3 vessels, 45 mm in the others.

A large vapour space is an essential feature in reducing the risk of juice droplets being carried over. A large volume combined with a well designed catch-all virtually eliminates this risk. Again some equipment manufacturers when subject to severe price cutting will reduce their design parameters and come up with vessels that are short in height and thus inadequate for maximum performance.
These mistakes are made very frequently causing major problems during operation. Sometimes elaborate apparatus or systems are then devised to prevent entrainment of condensate, which are totally unnecessary if sufficient attention was paid to the design of the vessel in the first instance.

Juice levels in the vessels need to be controlled. This can be achieved by manual valve control in the juice line between two vessels, or by automatic controller, or by having a sealed downtake arrangement.

The author dislikes the first method, primarily for reason that the operator has an easy means of manipulating the levels. When the syrup tank is full, it is very tempting to let the vessels fill up and be used as storage tanks. This practice increases the danger of juice carry over.
Automatic controllers are a better arrangement but it is an expensive proposition.

The sealed downtake is a self regulatory device and will work properly provided steam and vapour pressures are kept constant and there is a regular juice flow.

Stainless steel tubes are preferred in favour of brass simply because they are mechanically stronger. Where heavy scaling takes places and therefore frequent cleaning, there is no doubt that stainless steel is far superior. In many countries the cost of stainless steel tubes is no longer much higher than those made of brass.

However, one should not only consider the initial purchase cost, a frequent replacement of brass tubes or the nuisance factor that leaking brass tubes will cause are also factors to be taken into account.
If, however, stainless steel proved to be too costly, the author would still suggest that at least the first and second vessel be fitted with such tubes. It reduces considerably the risk of leaky tubes and therefore contamination of boiler feedwater.

The increase in density of the juice towards the last vessels means that circulation becomes increasingly sluggish.
There appears to be a distinct advantage in fitting a slightly larger diameter tube in these vessels which will compensate for an otherwise reduction in circulation.

The design of an evaporator as a complete station requires considerably more attention if it is to carry out its design duty satisfactorily. Many examples of such design calculations can be found in the international sugar literature, the author therefore considers it unnecessary to repeat these.
Also, each calculation refers to a particular application and wich is different for almost every factory.

Operating in quintuple effect, the following operational criteria may be considered typical:

	gauge kg/cm2	absolute	temp. oC	heat Kcal	bp rise oC
Backpressure	1.4	2.4	126	521.6	-
1st vapour	0.88	1.88	118	527.1	-
2nd --	0.44	1.44	109.5	533.0	0.2
3rd --	0.00	1.00	100	539.0	2
4th --	33 cmHg	0.58	84.5	548.1	4
5th --	63 cmHg	0.18	57	565	6

Extensive use of various vapours for heating juices and boiling of massequites will greatly assist in reducing the total steam consumption of the factory. The beet industry even recovers heat from the vapour of the last vessel, but this is not a practical proposition in the cane industry where one operates in an ambient temperature of 30 oC or more.

For the proper operation of the first vessel it is important that the clear juice is heated to the temperature prevailing in the vessel. The last heater should therefore be heated with backpressure steam.

All massequites should be boiled on 2nd vapour only.
Subsection C and the Appendix 4 briefly indicate what the features should be of a 'good' pan to boil efficiently on second vapour, however the evaporator must be capable of keeping the pans supplied at a constant pressure.
The question of keeping the pressure constant is discussed in Subsection E, the following will discuss 'how to get the vapour to the pans'.

In subsection A it was indicated that for a crushing capacity of 100 tc/hour, the theoretical amount of water to be evaporated was about 10 tons/hour. Dilution and wash water may increase to perhaps 17 tons/hour.
It should beremembered that this is an average demand.

When an A-pan starts with footing of magma, the evaporation rate and steam demand are substantially higher. Experience has shown that for the first 20-30 minutes the average demand is exceeded by as much as 35 percent (the greater the number of pans, the more the individual load fluctuations even out and the lower this figure of excess over average becomes).
During occurrences of peak demand,the pans may be drawing vapour at the rate of 17 x 135 % = 23 tons/hour.

In order to avoid pressure fluctuations at the pan's manifolds, the pipeline supplying the vapour, should be sized sufficiently large to cope with this peak demand.
The velocity of the vapour at this pressure should not exceed 27 meters per second, the required diameter of the pipeline at a crushing rate of 100 tc/hour should not be less than 600 mm.

This would be the correct size if the pipeline carried few bends, valves of the correct type and was of a reasonable length.
If globe type of valves are used instead of gate valves, then a correction factor must be introduced. With regard to the length of the line, the A-pans which draw most of the vapour should be located as close as possible to the 2nd vessel of the evaporator.

Therefore, and **this is important**, evaporator and pan station should be erected **parallel** to each other and never in one long line **after** each other. A parallel arrangement makes short vapour lines possible. The heaters should be located on the other side of the evaporator. If it is unavoidable to have evaporator and pans in one line, then the first vessel of the evaporator and the A-pans should be located in the middle, the 5th vessel and the C-pans should be at the extreme ends.

A rule in plant layout is that ' if the material cannot be pumped, then the vessels which contain this material should be located as closely as possible to each other; if it can be pumped, then distance becomes less important'.

This presentation has until now assumed the use of the convential type of Robert's evaporator. There are, however ,two other features ocassionally in use in the cane industry; firstly, there is the Kestner type of evaporator vessel,secondly, the use of vapour compression.

The author has had personal experience with both of these applications, neither of which were very successful. This does not suggest that there is no advantage to be obtained from using either of them, the difficulty is primarily one of making and keeping them working properly.

It is his experience that for either of these applications to work properly, the actual operating conditions must fairly closely resemble the situation for which they were designed.
Too much of a deviation in the flow of juice, different steam pressures, soon effect the proper function of these features.
In other words, they greatly reduce the flexibility of operation that a convential Robert's evaporator has.
Vapour compression can be carried out in two ways, one can have thermo-compression or mechanical compression.
The first method uses live steam to circulate and compress the vapour, the mechanical device is simply a rotary compressor.

Thermo compression has the advantages that it has no moving parts, but is sensitive to fluctuations in the live steam pressure.

E. Control of steam and vapour pressures

It cannot be too strongly emphasized that continuity and regularity in the process are the most important features to achieve efficient operation of a sugar factory. Therefore, amongst others, pressures must be kept constant.

A sugar boiler can hardly avoid the formation of false grain if the vapour pressure and thus the temperature fluctuates.

The massequite boiling will slow down at one time or boil vigorously at another. Similarly, an evaporator attendant cannot avoid producing a low density syrup if the backpressure steam drops. He will attempt to avoid this by temporarily filling up the vessels but there is the obvious danger of entrainment with subsequent vigorous boiling when the pressure is restored.

Manual control of pressures is inadequate, automatic control by instruments is essential. Such control must not only operate relief to atmosphere when the pressure is too high, but also make up from high to low pressure when the latter is too low.

With the pans operating on 2nd vapour only and taking into account the surges that occur when an A-pan starts with a footing, this 2nd vapour must have a pressure contoller that makes up from the 1st vapour when the demand is high and relieves to atmosphere when demand is low and 2nd vapour has the tendency to rise above a set value.

If on account of this action the 1st vapour was to drop in pressure, this must be made good with an automatic controller that makes up from the backpressure system and relieves to atmosphere when the 1st vapour exceeds a certain value.

Similarly, when the backpressure falls,it must be made up from boiler live steam and blown off to atmosphere when too high.

Appropriate type of controllers are made by most instrument manufacturers. They are all the similar for the above application, with th exception that make-up and relief valves would be of different sizes. In the case of make up from boiler live steam to backpressure, this requires the installation of a de-superheater. The reason is that starting off with a highly superheated steam from the boilers and reducing this further in pressure, would result in an undesirable, very highly superheated backpressure make-up.

This facility is not necessary for the saturated vapours from the evaporator. The location of these controllers should be in the vicinity of the first evaporator vessels.

Evaporator vessel sizes should be calculated in such a way that the quantity of vapours generated should amount to about 95 percent of the average demand by the pans. This ensures that there is not the extremely wasteful blowing off of backpressure to atmosphere.

If by reason of irregular pan work, heavy surges of vapour demand do occur and there would be an equally increased demand on live steam to make up the backpressure, then it would be more appropriate to inject some hot process water in the clear juice and let the extra evaporator vessel vapour take care of the surge rather than the live steam.

The reason for this is explained in Subsection F.

It may be appropriate at this stage to compare the system of steam and vapour dsitribution described above with that observed in one or two of the factories visited. The system just described, provides the pan boiler with only one source of vapour to boil his massequites. He has no choice in the matter but is guaranteed a medium at fixed, constant pressure.

The present situation in the factories is that he has three options; 1st vapour, backpressure or live steam. Because the vapour lines are too small, it is likely that many pans are boiled on backpressure and if the pan boiler is in trouble, he will use live steam. There are two inherent disadvantages in giving the pan boiler these options.

Unwittingly, any pan boiler has the ability to depress the proper operation of the first and second vessel of the evaporator. Human nature is such that when he is boiling on vapour and this pressure drops, he will crack open the backpressure or live steam valve on his manifold to compensate for this loss of pressure of the vapour.
He should be changing over completely to backpressure, but as these pressure changes occur frequently by pans striking and starting, he would be working constantly during his 8 hour shift changing between one source or the other. He will not do this, instead he will find a compromise by combining two sources together which will give him the right pressure in his calandria.
This method of operation will result in the vapour pressure and thus evaporator performance being affected by whatever actions pan boilers take to boil their massequites.

F. Boiler feedwater - Condensate return

Roughly 70 percent of the cane brought into the factory consists of water, about 60 percent of which is removed in the process as condensates while the remainder leaves the factory as condensor waste water. On this basis the sugar factory should have surplus water, importation of raw water should not be necessary.

Of prime concern is naturally boiler feedwater, and this concern increases the higher the steam pressure of the boilers. The author holds the view that; firstly, if the design layout of condensate return is correct, if secondly, strict supervision of process operation is maintained, then the process is quite capable to satisfy the needs of the boilers without the need to import water.

In discussing these two points, the author wishes to start with the second one first.
Following the method of operation recommended in Subsection E, the make-up from boiler steam into process amounts to five percent. Whether this is a loss from the boilers point of view, depends of course whether the condensate from the pans is returned as a source of boiler feedwater.
Considering the freedom the pan boilers have in selecting any source of steam supply to boil their pans, the author expects that they have a similar freedom with regard to the removal of their condensates. Also, if they use more live steam than the designed five percent, the loss as boiler feedwater is even greater and therefore the problem becomes proportionally greater. Incidentally, because of their low temperature, pan condensates are not very suitable as boiler feedwater. In order to avoid this problem of boiler feedwater shortage from the process, there should thus be be a strict supervision on the use of live steam other than for supplying a prime mover.

If one accepts the fact that five percent is needed to make up into the backpressure, further considering a three percent loss due to regular boiler blow down, the make-up should not exceed more than eight percent.

There is no reason why this cannot be made up from the 2nd vessel condensate, totally eliminating the need to import water.

To use this condensate without a continuous fear of contamination being present, simply requires a tall 1st vessel and keeping juice levels low as discussed in previous sections.

With regard to point two, the author wishes to refer to a sketch included as Appendix 5.

The cycle of live steam-backpressure-condensates-feedwater, should be a closed loop with strict control over any attempt to use any for other purposes without it coming back as condensate. The condensate from the first vessel comes from backpressure steam and is totally free from any contamination and leaves the vessel with a temperature of 115-118 oC.

This condensate should be send to a receiving tank near the boilers and which is elevated to height not less than perhaps five meters. This tank acting as the suction tank for the boiler feedwater pump, also doubles up as the de-aeration tank. The tank is to be connected to the 1st vapour system by a fairly large pipeline.

The tank being elevated and under 1st vapour pressure, ensures that a positive pressure is exerted at the suction of the boiler feedwater pump avoiding problems in handling hot water.

A level controller in this tank will allow the required amount of 2nd vessel condensate to be pumped to the tank to compensate for the loss of blow down and make-up into process.

In addition to the above arrangement, there should be a storage facility containing a quantity of clean water for the boilers having a capacity of about two hours' full steaming.

The condensates from the 3rd, 4th and 5th vessel, heaters and the pans should be pumped to the hot water storage tank for process utilization.

If such an arrangement was installed, it would be the design of the plant which determines which steam should be used and which ensures adequate boiler feedwater, rather than leaving this to the action of some operators.

VII. RECOMMENDATIONS

1. The author has not seen enough of the factories to allow him to make firm recommendations. It is therefore at this stage more a question of suggestions based upon some short factory visits. A second opportunity when more time would be spent in visiting operating factories, should put one in a better position to make recommendations.

2. Representative organisations or individual members of the Chinese cane industry should consider becoming members of the International Society of Sugar Cane Technologists (ISSCT) and attend their Congresses held once every three years in different countries. Indonesia will be the host in 1986.

The benefit of being a member, but above all in attending the Congress, is that exchange of ideas and experience takes place between the delegates which leads to a better understanding and efficiency of the industry. Isolation leads to a stereotype existence remaining unaware of progress made by others.

The knowledge of outside progress should be channeled through the NCSIRC, modified by them to suit the Chinese sugar industry and offered by them to the industry in an acceptable form.
The author feels that the NCSIRC should play a more leading and dominant role in the development of the cane industry; sugar as well as by-products. This seems important in order to avoid otherwise a wasteful proliferation of ideas, attempts and effort by individual factories.

4. While therefore the NCSRIC is the collector and disseminator of ideas by other countries, it must also develop its own creative ideas. It can do this in two ways; in a theoretical, statistical sense and by practical example.

The statistical duty should consist of the collection of operating data, analyzing these for consistency and abnormality and re-issue the re-formed data in a suitable form with comments to all the factories. The extremes in this distribution of operational performance data, should draw the attention of the NCSIRC and its offic. s should investigate.

6. With regard to the practical examples, the author is of the opinion that the NCSIRC should have posession of a medium size factory in fairly close proximity to the centre's office. This would enable them to carry out full scale experiments under their own close supervision. Upon successfull completion of such experiments, these developments can then be released for commercial application in other factories.

The author understands that at the moment the officers of the NCSIRC are supervising experiments in individual factories. While this is encouraging, he is of the opinion that the constraints imposed upon the officer working in an environment where he has no managerial authority, severely limits his ability of being sucessful. Any experiment will cause a ripple effect in the rest of the sugar process, which the commercially minded may dislike.

7. If the NCSIRC were in posession of such a factory, it could implement the suggestion of boiling only on 2nd vapours, double curing of masequites and B-sugar in the bag. Once such experiments were proven, this could then become the standard design of factory process.

It would ensure that there will be equal emphasis in a factory for Quality-of-Operation along side Volume-of-Operation. In recalling these two aspects from the Summary, it is perhaps opportune to make the observation that in general factories are more inclined to understand volumes rather than qualities. Their rural environment is primarily responsible for this. It is to an institute like the NCSIRC to inject the quality element into the rural factories, however the NCSIRC must have or be given the tools to carry out that job.

The author feels strongly that if there is a conscious policy of expansion and improvement of the sugar industry, then solid foundations should be built first upon which the rest of the industry can rely.

The impression gained from visits to some old but also new factories, is that mechanical design comes out strongest, but that process design and control could be improved.

VIII. SOME QUESTIONS and ANSWERS

Question:
What you consider to be the maximum speed of the mill rollers.

Answer :
Different countries have different opinions on this, it also depends upon the condition under which the mill is operating.
The old Java school preferred slow speeds and it is still being adhered to there in the majority of cases, South Africa also prefers to keep the speeds down. Australia and others when new plant was installed, have adopted higher speeds.
In Java it is very common to see speeds of 10 m/min, South Africa up to about 12-13 m/min, while Australia will go up to 20 m/min.
The author's preference is for 5 rpm as a maximum.

Question:
Do you have any opinion about the strength of the mill standards or housings.

Answer :
I have no stress calculations with me to show, in any case I am not a mechanical design engineer.
Obviously the material for optimum strength should be cast steel, although there are one or two fabricated, mild steel designs available.
The absence of any King and Queen bolts makes it possible to have slim design of the web of the standard. This allows for closer centres of the bottom rollers and therefore a narrower trash plate, thus less horsepower.
In my office I may have some stress calculations but not with me.

Question:
What should be the type of material used for trash plates.

Answer :
The hardness should be about 10 Brinell higher than that of the roller shell material. Different countries use different materials or solutions; cast steel, cast iron, Meehanite cast iron, or some factories shape their plates from discarded roller shafts. Not very satisfactory in the author's mind.

Question:
In one of your lectures you made the point about taking some precautions when using a triple reduction gearbox as the final drive of the mill.
Can you explain this further.

Answer ·
There are two points to be considered.
Firstly, the bearing of the final motion shaft in such a box is most likely to be a roller bearing. Care should be taken to impose upon this type any stresses other than for which it is designed. However a lifting toproller with a single coupling bar will impose just such stresses. With such an arrangement, one must ensure that the maximum lift of the toproller cannot exceed say 30 mm and also that the coupling bar is made as long as possible. This arrangement imposes the minimum possible stress on the bearing of the box. Gearbox manufacturers are not always aware of this extra stress situation.

Secondly, lubrication within the box should be carefully considered. The low speed end with high torque requires in fact a different lubricant than the high speed end of the box.
It may be difficult to obtain a lubricant which fully satisfies the requirements of both ends.

It is for this reason that frequently a single stage reduction is preferred as the final stage. This type of reduction is fitted with bronze bearings which stand up to extra stresses much better than roller bearings.

Question:

What is in your opinion the right amount of imbibition water, its temperature and place of application.

Answer :

An acceptable level seems to be 200 - 250 percent on fibre, although a few countries go as high as 350 percent. Obviously the more water you pour on the lower your pol losses, at least that is the general theory.

It is really a commercial decision; if the extra revenue you get from lower losses is greater than the cost of fuel required to evaporate the water, then put on more if the mill accepts it.

With regard to temperature, it seems the higher the better, but some experts claim that the juice of cane high in wax will then cause trouble in the clarification. Perhaps 65 oC would be a correct level.

With regard to the place of application; that is a tricky question to answer.

The simple answer to obtain the best results is to spray it on the bagasse before the bagasse gets the opportunity to expand again when it emerges from the back opening.

Khainovski in pre-war Indonesia discovered that such expanded bagasse was full of air bubbles and that the imbibition water was unable to replace these bubbles if applied subsequently.

In other words, the mixing only began when the bagasse entered the next mill, but that is really too late.

Some trials are under way whereby the back opening of the mill is totally enclosed with side plates and seals fitted to the rollers and which is filled with the imbibition juice in order to let the emerging bagasse enter into a bath of liquid.

Question:

During your visit to Yatang sugar factory, you commented that the mill was overloaded. Can you explain.

Answer :

From the figures given to me and looking at the mill in operation, my practical experience tells me that so much cane is passing through at such a speed that the extraction must suffer.

However I will have a trial run on the computer and give you a print out later (a reference copy also attached as Appendix 6).

Another guideline; the TRV for this factory is 0.623 m3, as explained elsewhere, it should not go below 1 m3.

Question:

What is your opinion of a zero-pressure evaporator.

Reply :

I donot understand the principle of a zero-pressure evaporator.

Follows an explanation by the questioner

We have a few factories where we installed an extra vessel in front of the first vessel. This extra vessel receives back pressure steam of about 4-5 kg/cm2 and boils raw water only.

The vapour produced is used to boil the juice in the first vessel evaporator.

Follows comment by the author

The way it is described to me, I can only remark that you have an expensive pressure reducing valve which admittedly produces clean condensate from raw water. The turbine's back pressure is 5 kg/cm2 which means that their steam consumption per Kw is high and all you get for it is an extra amount of clean condensate. An expensive way of producing extra clean water. Presumably the main purpose is to ensure a source of clean water for the boilers. However,if you enlarge your 1st vessel in order that you donot get juice entrainment in your 2nd vessel condensate, then it is perfectly acceptable to use the 2nd vessel condensate as make up for your boiler feed water.

You must, however,excercise strict control over the use of back pressure steam to the evaporator only in order that you loose any of it as clean condensate.

In such a case the make-up from 2nd condensate will be relatively small. I regret, but I donot see the merit of the zero-pressure principle.

Question:
We suffer badly from heavy scale in the evaporator. Do you know of any solution.

Answer :
The author is not aware of any inhibitors in the market which work efficiently. Chemical additives have been tried, so have instruments that create an electro static field, even plastic balls in continueous suspension in the juice, none are really successful.
The only advice I can give is to improve upon the clarification process itself, if you take the impurities out before they get into the evaporator they cannot deposit on the tubes. I am aware that that is easier said than done.
Double carbonatation is of course the best clarification process to use, but expensive to run.
Are you sure your liming levels are correct?
A Blanco Directo process developed by Tate & Lyle uses certain polymers and phosphate flotation for the mainstream juice and filtrates and removes many impurities.
It might prove a solution for your worst cases.

Question:
What type of juice straining do you recommend.

Answer
Without any doubt, the DSM screen is the simplest and is effective. It has no moving parts and is therefore virtually maintenance free.
For mixed juice the taper slots should be 1.0 mm wide, for clear juice not more than 0.3 mm. The bars are stainless steel, while the housing is usually of mild steel.

Question:

We are somwhat surprised and feel concerned about your suggestion of possibly changing the boiling scheme and to put the B-sugar in the bag as well as the extra cost of centrifugals by double curing. Would we not reduce the quality of the sugar.

Answer :

My suggestion is simply based upon the consideration of what is more economical.

A possible slight drop in the pol of sugar by putting B's in the bag (I donot necessarily accept that that would be true at the present level of pol of the sugar), may be less unpalatable than having to burn 4-6000 tons of coal in a season or to be able to save more bagasse for paper making.

By putting B's in the bag, one uses a lot less steam.

With regard to the extra cost of centrifugals, this is largely offset by obtaining increased capacity of the pans; or putting it another way, you need less pan capacity for a given throughput.

IX. ANNEX 1

ORIGINAL itinerary of Mr. C.J. Laan's visit in Guangdong

April 6th - 27th 1985

April 6th Sat.	Arrive Guangzhou
7th Sun.	Sightseeing within Guangzhou
8th Mon.	To Zhanjiang by the 3321 flight
9th Tues.	Visit Yatang sugar factory
10th/12th	Lecture and symposium in Zhanjiang
13th Sat.	To be arranged
14th Sun.	Back to Guangzhou by plane
15th/20th	Lecture and symposium in the Guangdong Scientific Hall
21st/22nd	Visit Meishan sugar factory and stay the night there
23rd Tues.	Visit a sugar factory
24th Wedn.	Visit the Sugar Cane Research Institute
25th/26th	A.M. Symposium, P.M. free
27th Sat.	Leave Guangzhou

IX. ANNEX 2

ACTUAL itinerary of Mr C.J. Laan's visit in Guangdong

April 6th - 27th and to Beijing from 27th - 30th April 1985

April 6th	Sat.	Arrive Guangzhou
7th	Sun.	A.M. Sightseeing Guangzhou P.M. Visit Guangzhou sugar factory
8th	Mon.	A.M. Visit Sugar Cane Research Institute P.M. To Zhanjiang by flight 3321
9th	Tues.	Visit Yatang sugar factory
10th/11th		Lecture and Symposium in Hai Bin hotel
12th	Fri.	Visit Zingzhou sugar factory
13th/15th		Owing bad weather, forced stay in Hai Bin
16th	Tues.	Return to Guangzhou by road - no flights
17th/20th		Lectures and Symposium in Guangdong Scientific Hall
21st	Sun.	Free
22nd	Mon.	A.M. Visit Shi Tow sugar factory P.M. To Meishan sugar factory and stay the night
23rd	Tues.	A.M. Visit Meishan factory P.M. Return to Guangzhou
24th	Wedn.	To Jiangmen to visit sugar factory and machine workshop
25th	Thur.	A.M. Visit Jiangmen workshop P.M. Visit Jiangmen sugar factory and return to Guangzhou
26th	Fri.	Lectures at Sugar Cane Research Institute
27th	Sat.	To Beijing
28th	Sun.	Sightseeing
29th	Mon.	Visit UNIDO office - Mr A W Sissingh
30th	Tues.	Leaving Beijing and China

IX. ANNEX 3

Principal persons met during the visit

Mr	YU LIANNAN	Dep.Director	Ministry Light Industry-Beijing
Mr	YAN ZENGLU	Dept. Chief	- - - -
Mme.	XIAO ZONGQUAN	Engineer	- - - -
Mr	CHEN ZHE WEN	Dep. Director	- - - Guangzhou
Mr	CHEN SHI-ZHI	Director	Sugar Cane Research Institute
Mr	HU XIAOZONG	Dep. Director	- - - -
Mme	BAO GUO-YU	Dep. Director	- - - -
Ms	QI LI-WU	Engineer	- - - -
Mr	ZHANG XUEXUAN	Secretary	- - - -
Mr	LI JINDING	Project Off.	- - - -
Mme	LI	Librarian	- - - -
Mr	LIN LOK XIN	Engineer	Design Inst. M.L.I. Guangzhou
Mr	LU HANLYNN	-	Sugar % Paper Industry G'dong
Mr	DING WEI SHAN	Vice Director	G'zhou Hua Qiao Sugar Factory
Mr	FANG XUE GAO	Director	Meishan Cane Chemical Industry
Mr	CHIANG SUNG-CIEN	Tech.Dir.	Shi Tow Industrial Company
Mme	CHEN WUAN-SIAN	Engineer	Shi Tow Sugarcane Chemical Works
Mr	ZHONG JIN-DA	Dep. Director	Jiangmen Machinery Workshop
Mr	HUANG ZHAN	Engineer	- - -
Mr	LIU WEI-HAI	Dsgn Engineer	- - -
Mr	XIE ZHAO XIONG	Manager	Sugar & Paper Industry-Zhanjiang
Mr	A W SISSINGH	SIDFA	UNIDO - Beijing

IX. ANNEX 4

JOB DESCRIPTION

Post title	Expert in the Mechanism of Cane Milling
Purpose of project	To furnish detailed information, practical knowledge and research activities on the up-to-date development of cane juice extraction technology and equipment;suggestions on ways and means of improving the specific capacity and sucrose extraction of the milling tandem in the country, with lower power consumption, in order to reach the world's standard.
Duties	The expert will specifically be expected to:

1. Provide information on the latest development of cane juice extraction technology and equipment in the world; relate and compare the current, most popular equipment for the preparation of cane, providing detailed information on that with a better effect;

2. Provide information on the experience gained from and measures to reduce the power consumption of milling tandem and the technical basis for choosing longer or shorter train;

3. Introduce those measures which from experience have proved successful in improving the cane feeding of mills;

4. Provide information on more advanced mill testing devices;

5. Provide information on the successful experience gained from improving the method of draining juice from the mill;

6. Provide information on the development and prospects of cane diffusion;

7. Make suggestions on the ways and means of improving the specific capacity of milling tandem in the country.

The expert will also be expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.

Background The specific capacity of the milling tandem in the country is, on average, 40-50 % lower than that of the more advanced countries. For example, the capacity of the 1000 mm x 2000 mm mill is only 5 - 6000 tcd whereas the capacity of the 42" x 84" mill abroad is 10 - 12000 tcd.

The National Cane Sugar Industry Research Centre is undertaking research work on juice extraction in the sugar factory. During 1984/1985 it will collaborate with two design units and one sugar factory with regard to production experiments. The plan is to increase the factory's grinding capacity of 1200 tcd to 1800 tcd. This would provide a model for the other sugar factories in planning their mill tandem extension and potential tapping.

X. APPENDIX 1

Method to determine the Preparation Index

Analytical procedure

Two procedures can be used depending on equipment available for leaching. The preferred procedure is based on the use of plastic bottles which are rotated on a special frame.
An alternative procedure using tumbling drums is also given for those mills which have this equipment.
The two methods have been found to give closely comparable results but the first method is preferred because of the larger sample and shorter tumbling time.

1)Rotating bottle method

1)Leaching

500 g of prepared cane from before the 1st mill and 3000 g of water are weighed into a plastic bottle. The bottle is rotated on a specially designed frame for 30 minutes. The Brix reading of the filtered extract (B1) is measured by means of a precision refractometer.

2)Disintegration

333 g of prepared cane and 2000 g of water are weighed into a cold disintegrator and disintegrated for 20 minutes. The Brix reading of the filtered extract is measured (B2).

2)Tumbling Drum Method

1)Leaching

200 g of prepared cane from before it feeds into the 1st mill and 2000 g of water are weighed into a 4.5 litre drum fitted with internal baffles. The drum is rotated for 60 minutes at 45 rpm. The Brix reading of the filtered extract (B1) is measured by a precision refractometer.

2)Disintegration

200 g of prepared cane and 2000 g of water are placed in a cold disintegrator which is run for 20 minutes. The Brix of the filtered extract is measured (B2).

Calculation.

$$\text{Preparation Index} = \frac{B1}{B2} \times 100$$

Note: The use of pol instead of brix will effect the results because of differential extraction of pol and brix during leaching.

X. APPENDIX 2

Purchase of equipment from overseas -- Points of interest

Question:
In the light of your experience in contract negotiations for sugar factories, could you elaborate briefly on the main points involved.

Answer:
Understandingly, there are three distinctly different aspects to be considered in purchasing from overseas; technical, contractual and possibly credit finance.
There are also two different methods of approach in setting this about:

1) issue Invitations To Tender (ITT) to a number of suppliers
2) enter into a discussion with one preferred supplier.

Concerning the approach, depending on which route is chosen, this determines the type and amount of preparatory work the Buyer has to have carried out before the stage of contacting the overseas party(ies).

Following route 1, the supplier needs to be informed officially about full technical details of the machinery or plant to be supplied. However, this information should not be so detailed and thus restrictive to the supplier that his standard designs could not comply with the requirements of the invitation. The ITT should also contain the desired performance guarantees and penalties to be applied in the event of possible failure to achieve these and also for late delivery.
The ITT should further give an indication about the manner in which the supplier will receive payment; whether it is by letter of credit against shipping documents or whether the Buyer desires a loan facility enabling him to pay for the goods over a number of years.

This ITT needs to be prepared, issued to a number of overseas suppliers, their proposals once received to be evaluated, to start contract negotiations with the two most favoured and subsequently conclude a contract with the most suitable.

Route 2 is somewhat easier to carry out in the sense that it does not require an extensive ITT to be prepared, nor does it require the evaluation of a number of proposals.
It does mean, however, that the Buyer must carry out a prelimenary selection excercise of which supplier is most suited to meet the Buyer's needs.
Once a selection is made, the Buyer issues an invitation to have prelimenary discussions.
This route is usually quicker and less cumbersome.

As far as the technical, contractual and financial aspect are concerned, if the basic requirements and procedures are understood by both parties, then this will greatly simplify the understanding between Buyer and Supplier.

Technical

Obviously the Buyer will have a clear understanding of the capacity of the factory or equipment to be purchased, process to be adopted, quality of sugar to be produced, etc.
There are, however, a number of points of detail which frequently escape the notice of the buyer and which if not clarified before, might at a later stage cause some frustration.
It is not possible to list all these points at this stage, but quoting one of them will illustrate the point made.

The reduction gearing of the mill can be designed in different ways; a light and therefore cheaper version or robust and therefore somewhat more expensive.
The difference manifests itself in the face width of pinions and wheels.

A light design is narrow, a robust design is wider and has less wear and lasts longer.
The basis of the design is the number of 'life hours' used; 27000 is low, 54000 is good.

Contractual

Depending on the extent of the purchase, a simple agreement or comprehensive contract needs to be drawn up which establishes the relationship between the Buyer and Supplier during the period that the contract is in force.
Performance guarantees need to be agreed, penalties to be spelled out, payment terms to be agreed, etc.

Credit finance

A substantial purchase like a factory or milling tandem, is rarely paid for in cash against shipping documents.
It is more the practice for the Buyer to obtain a loan facility from the Supplier's bankers, which enables the Buyer to pay for the goods over a number of years. The Buyer will be charged an interest on this loan.

In order for the Buyer to obtain such a facility, it is necessary that the Buyer provides a form of guarantee to the satisfaction of the Supplier's banker which assures the re-payment of the loan and interest.

In these cases of extended credit facilities, it is almost inevitable that there will be a government involvement also.
It is for this reason important that the Buyer during his preparatory work explores the fact that the governments of the Buyer and Supplier are on a 'friendly' footing.
If not, much time and effort will be wasted if in the end no credit facility proves satisfactory.

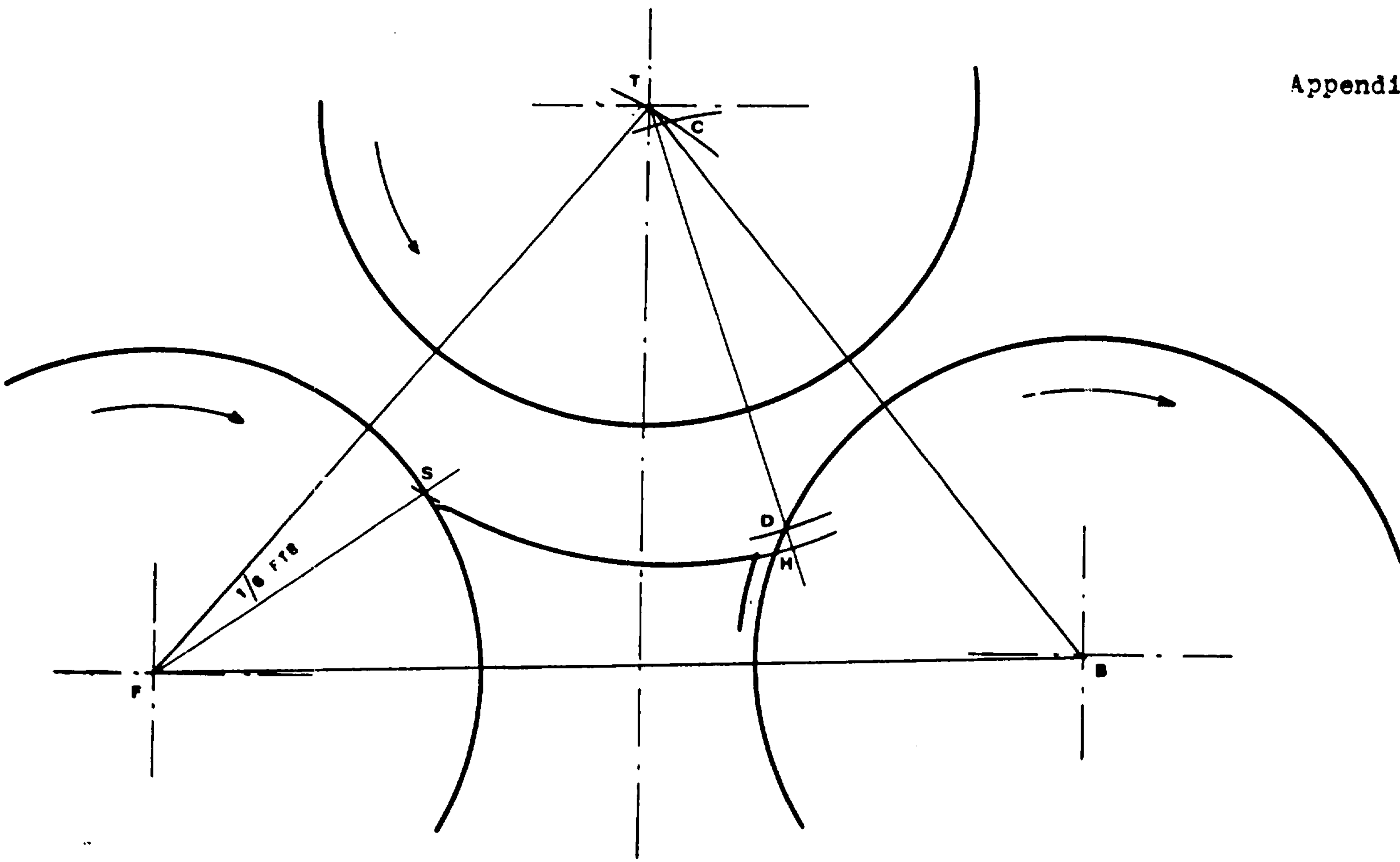
A final word on this question of being able to obtain the best possible terms.

If a substantial purchase is considered, then it is highly desirable that all of it is placed with one supplier in one country. The reason for this is that a large purchase attracts better terms as to duration of the loan and the level of down payment.

There should be no concern by the Buyer about the question of him wishing to have specialized items of machinery which are not of the Supplier's own manufacture.

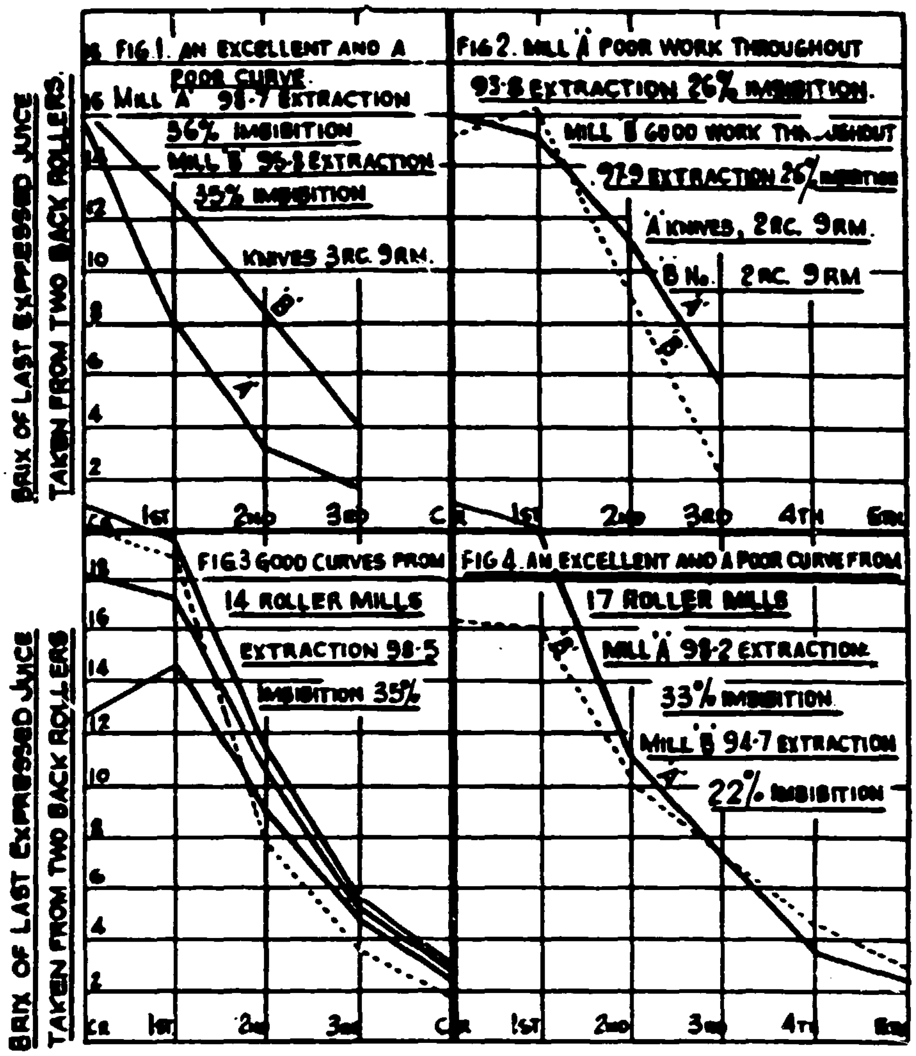
Within reason, any Supplier will be able to incorporate such goods in his supply despite that these items may not be manufactured by him.

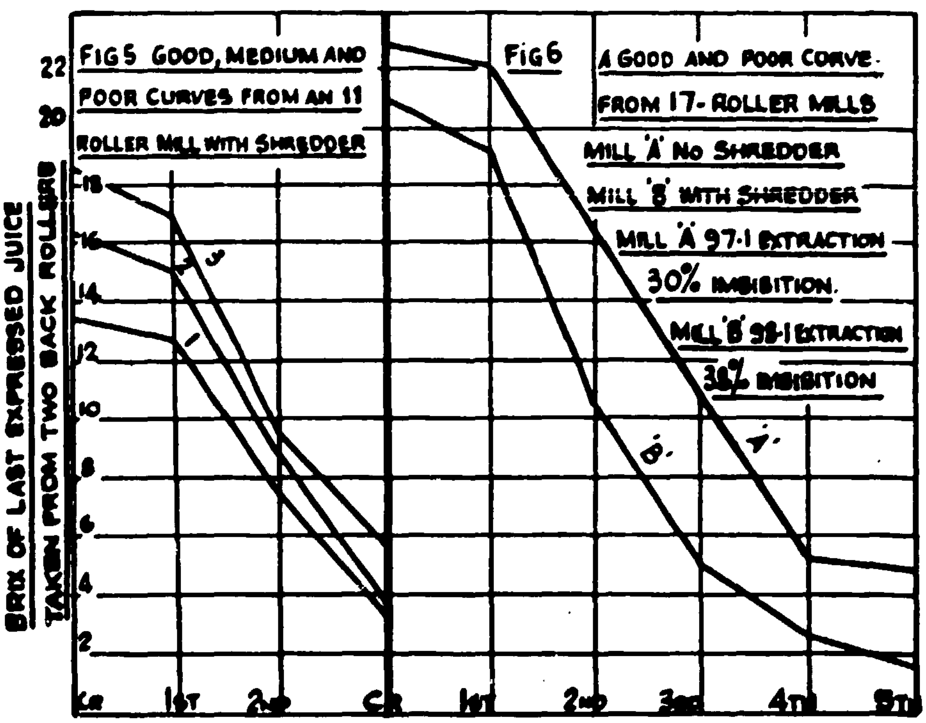
Appendix 3



TRASH PLATE SETTING

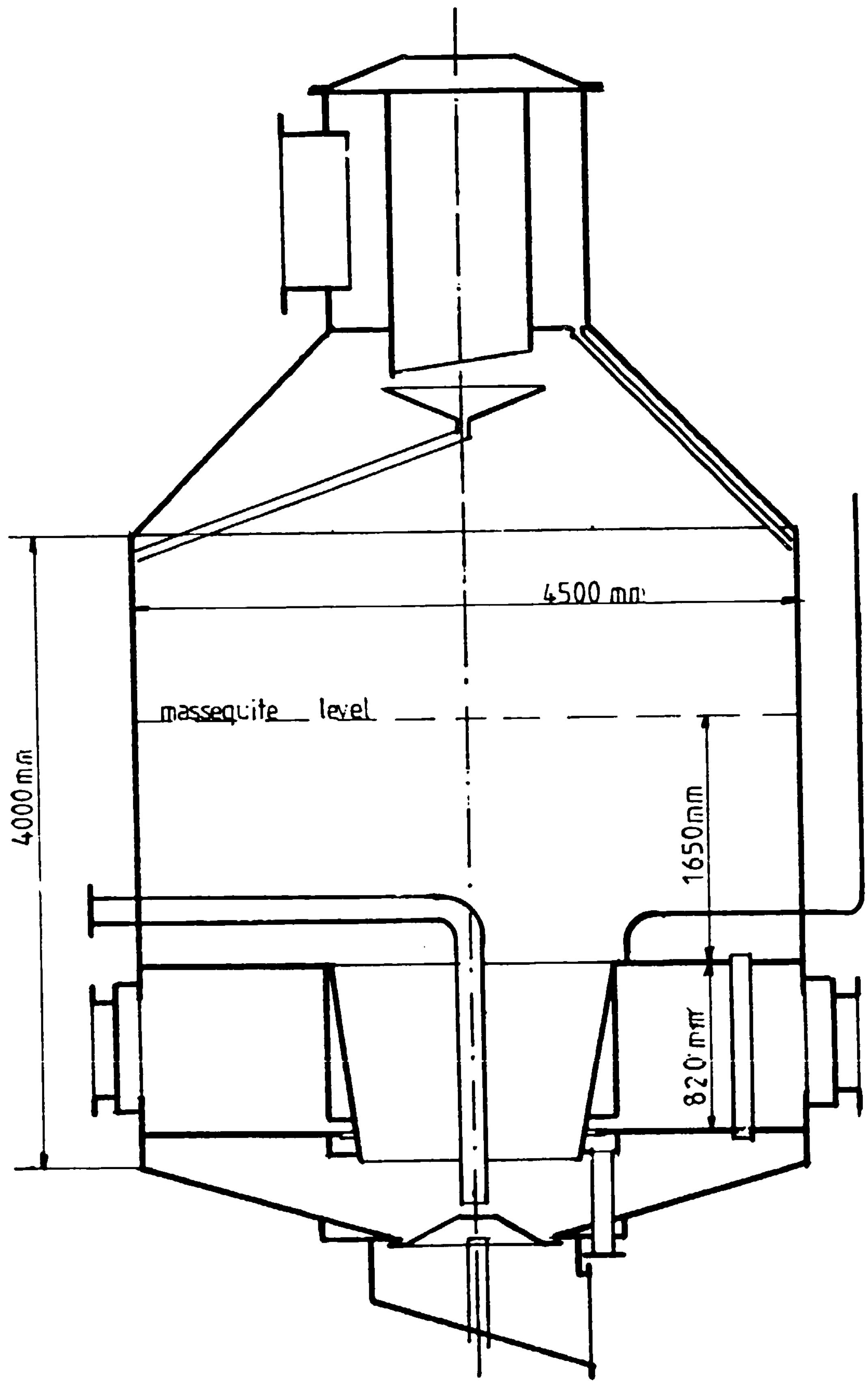
Appendix 4



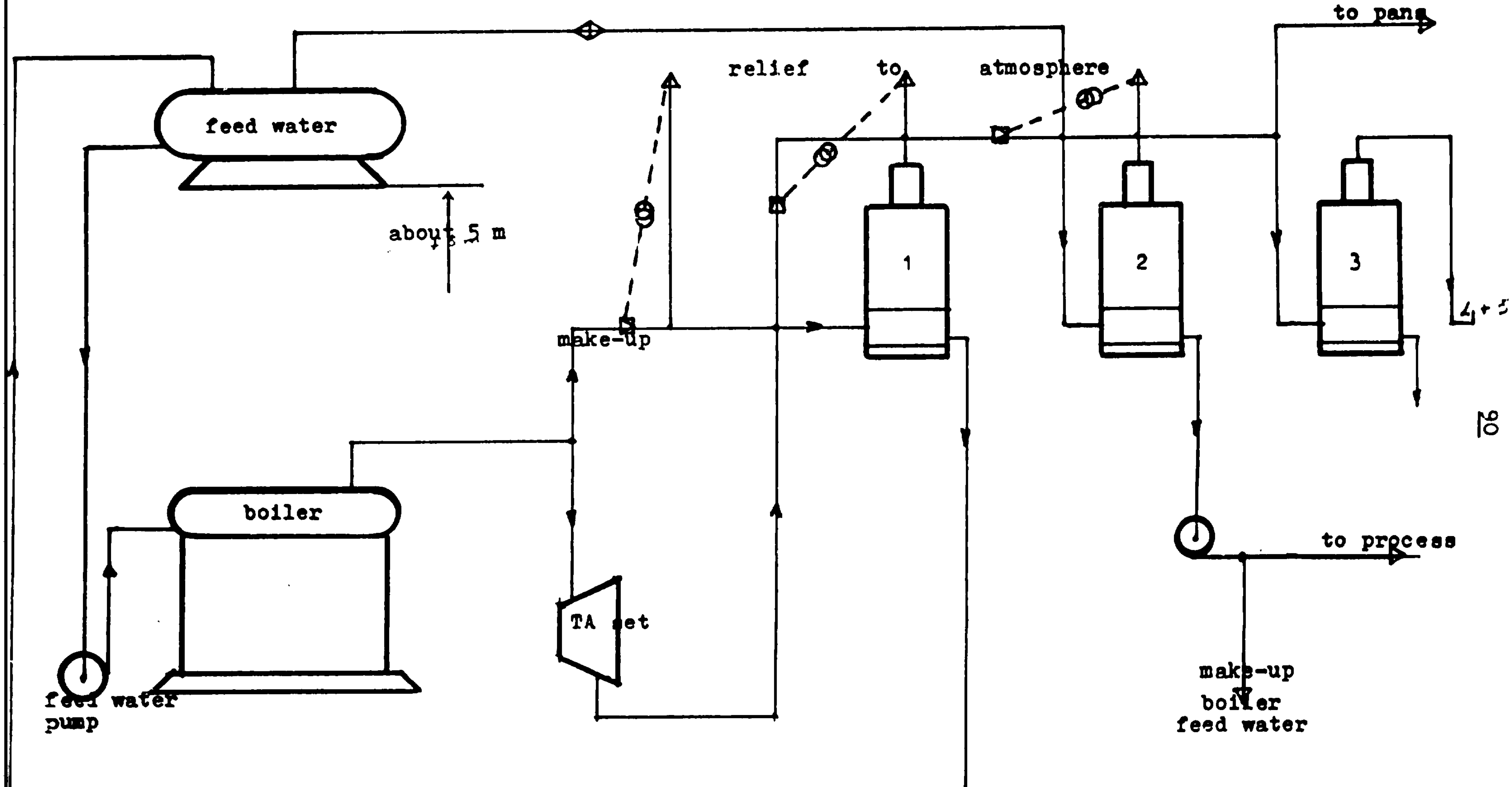


BRIX CURVES

Appendix 5



Vacuum pan 400hl



Steam distribution & Condensate return for boilerfeed water

Appendix 6

NAME of FACTORY = YATANG

Run no: B 1

B: EXTRACTION - basing upon the following data:

Preparatory equipment is two sets of knives	
Each mill has two light feed rolls	
Diameter of rollers	= 24
Length of rollers	= 47.25
Number of rollers in tandem	= 12
RPM of rollers	= 6.75
Fibre % Cane	= 12.8
Pol % Cane	= 13
Imbibition % Fibre	= 140
Crushing rate in metric tonnes per hour	= 70
Fibre in metric tonnes per hour	= 12.8

THEN, operational data which would normally be expected are:

DESIGN horsepower of leveller knives	= 98.56
DESIGN horsepower of heavy duty knives	= 170.24
DESIGN horsepower of EACH prime mover in tandem	= 188.16
Milling loss	= 7.5691
Pol extraction	= 92.5473
Reduced extraction, Noel-Deer	= 92.747
Reduced extraction, Mittal	= 92.722
Whole Reduced Extraction	= 92.4309

ACTUAL specific fibre loading in grams/dm2/dm diameter roller = 16.0463

COMMENT:

A figure for the specific fibre loading which might be considered NORMAL for this type of mill tandem configuration would be in the order of: 14.869

The mill is highly loaded: Pol extraction is lower and Moisture % Bagasse higher than might normally be expected for this mill.