CHAPTER – 2

LIMITATIONS FACED BY INDUSTRY WITH PRESENT EXTRACTION METHODS
ABSTRACT:

This chapter deals with the study of problems / limitations faced by the sugar industry with present design of the conventional Three Roller Type Cane Crushing Mills and extraction methods.

We are living in the 21st century and have the luck and pride to witness unbelievable changes - for better of course - on account of fantastic progress brought about in our lives with the help and availability of modern technologies, equipment and gadgets. Every sphere of our life has been influenced by improvements in even our daily chores with introduction of new gadgets and technologies which have seen never before improvements and upgrades almost every month. Take for example the mobile phones and computers, household things like fridges, washing machines, TVs, music systems, illuminations and so on. The land-line phones have now almost disappeared, written letters received through posts are thing of the past and even young children don’t know about these, simply because the way people used to communicate has totally changed, what with phones, e-mails and messages which can be easily and conveniently sent and received on the go with the modern mobiles. New models of automobiles and two wheelers are getting introduced every 4 months or so, household illuminations and fixtures are also getting changed completely and so on and so forth. Manmade satellites are now reaching Mars and pleasure travel to moon now being a near possibility where such bookings have already started, banks getting accommodated in your pocket so that you don’t have to go to your bank branch for anything, sky is now in your reach – virtually! We may next have trains which will take you to Delhi in 4 – 5 hours only; such trains are already serving people abroad in Japan and China. One can plan anything and everything on-line, from breakfast to travel, hotel bookings to dinner and footwear to clothing - thank you progress!

It is no wonder that the manufacturing industry has unavoidably changed a lot with the modern technologies and things like cotton or ginning mills are a history, just for example.
On this encouraging background of achievements and progress in day to day life of a common man, if we take a look at the Cane crushing mills being employed by the Sugar Industry, we will find some stunning and disappointing facts. The conventional three roller mill, which was introduced some 250 years or so before, is still widely used equipment which is being employed in the cane sugar factories all across the world even this day.

We know that about 250 years before, people were riding horses and the wars were fought with swords and spears. In short, that age old Mill technology is still serving the cane sugar industry even today with some marginal changes, where man reaching the Moon is a History; this story is not only of developing or under developed countries but even of the sugar sector in the countries of the so called developed world.

With continuous association of such age old equipment and otherwise lack of changes, improvements and modernization as in case of other equipment or industries the engineers and Managements generally are not in a frame of mind to seek or accept changes. This, perhaps, is one of the reasons why the cane sugar industry is called the “tradition loving industry”.

There is no wonder that the cane crushing equipment, particularly the cane crushing Mill, is fraught with problems and is found heavily wanting.

This chapter attempts a review these.

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<td>The conventional Three Roller Mill, which necessarily has the Trash Plate as an integral part of the Mill, is being used the world over, even today, for last more than two centuries. Let us accept this as a fact, though unbelievable for anybody not familiar with the cane sugar industry and its history.</td>
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The Mill, as we use even today, being a equipment design established nearly 2 centuries ago, is naturally expected to be wanting in many aspects, what with ever rising expectations varieties available for other equipment, which have seen many issues of improvements. The Three Roller Mill can perhaps be said to be the oldest equipment in use. It becomes unavoidable that this Mill design finds many things wanting. These are -

**2.1.1 WASTAGE OF POWER (ENERGY)**

The most important and perhaps damaging factor is that of wastage of power. This factor entails heavier drives and consequently higher expenses of drive equipment as well as running expenses towards cost of this extra power.

Also there are other factors causing problems in working.

**2.1.1.1 Wastage of Power due to Trash Plate**

The most glaring and pertinent problems in working of this conventional mill are provided by this little part – the Trash Plate.

The problems being –

As seen in the discussions earlier, the trash plate merely acts as a bridge for transporting the bagasse mat from the feed roller to the discharge roller of the Mill. This bagasse mat, is however, dragged while it is travelling under pressure - the hydraulic pressure - or load applied on the Top Roller of the cane crushing mill. This pressure, we must accept, is necessary to press the bagasse mat and to empower it to take the juice out of it (the juice extraction). However since the bagasse mat is travelling under pressure of the rotating mill rollers and the Trash Plate is stationery - a non moving part - this bagasse mat while getting dragged over the Trash Plate, under the hydraulic pressure exerted by the top roller of the Mill, has to overcome the frictional resistance, which is quite substantial. For overcoming the frictional resistance created by the Trash Plate, naturally power has to be spent. This element of power, consumed
by the bagasse mat (or thus wasted in the process), amounts to nearly 20% - 30% of power consumed by the cane crushing mill in total and is provided by the Mill Drive. Thus this substantial amount of power is wasted without doing any useful work towards juice extraction process in a cane crushing mill. (E. Hugot states that “20% to 30% of the hydraulic pressure \( P \) is absorbed by the trash plate)”. It can be safely derived that the power absorbed by the trash plate is also 20% to 30% of the applied power.

Due to this aspect of occurring of substantial wastage of Power in the Trash Plate and also many problems which are created in other functions of the conventional mill, therefore in many discussions and articles the trash plate aptly is described as “A Devil”.

All these days, before electric power was not attracting greater attention or price, this factor of wastage of power, never received any attention and was not looked to as a “problem”. Not only that, but even bagasse saving, when unintentionally achieved by some cane sugar factories earlier in the past, was considered to be “huge” problem for these sugar factories since disposal of the saved bagasse was always a problem. The saved bagasse had no other use, bagasse based by products being an introduction of the later period, and the managements of such factories did not know how to handle the same. Therefore, the bagasse was disposed off to the farmers, free of cost, for use as household fuel for cooking etc. In later period attempts were made to have bagasse based by-products – particle board, paper etc. - which required bagasse as a raw material. However such plants were far from profit oriented entities and also required heavy capital investments for such manufacturing plants. Therefore such plants, where installed generally faced serious financial problems and many a times had to be abandoned, inflicting loss to the factories. There were also attempts to manufacture “billets” from the bagasse, which could be readily sold as alternative to coal as household fuel. These also appear to have not found expected success.
On account of many practical difficulties there could not be an attractive or workable solution. However, in the present circumstances where the electric power is not only attracting high value or price but in the developing and underdeveloped world particularly, is found to be in shortage since it is produced in lesser quantity than demand. Electric power is being increasingly used not only in the households but in Industry and Agriculture. Also the element of rise in demand of the electric power is much faster than the generation increase, for obvious reasons.

It is now an accepted fact that with careful and proper planning, every cane sugar factory can generate extra electric power over and above its own consumption – known as cogeneration – and sell this extra power to the national grid and earn substantial additional profits for the factory. Since power saved can be sold to the grid to earn additional profits for the factory, attempting power saving in each and every equipment that is installed in a sugar factory has become most important aspect and therefore aim of the Managements.

### 2.1.1.2 Wastage of Power in Closed Pressure Chute

When provided another item which consumes Power, without in any way contributing to the extraction process or efficiency of the Cane Crushing Mills, is the Closed Pressure Chute which is a part of the conventional pressure feeding system widely used all over the world - again.
Fig 2.2: Typical Closed Pressure Chute.

Normally, the Pressure Feeder Systems are installed on the conventional Mills, at a later date after the Mills of the Tandem are in operation. The purpose of the installation of these pressure feeder systems could be generally for increasing the crushing capacity of the installed mills or to seek elemental increase the efficiency of the Mills. Generally it is the prior – increase in the crushing capacity.

Whether it is a two roller pressure feeder system (TRPF) or a three roller pressure feeder system (GRPF + UFR), the closed pressure chute is an integral and unavoidable part of any conventional pressure feeder system. There are many similarities in the function of the trash plate – discussed earlier - and the closed pressure chute.

First of all both the items consume power without contributing to the extraction efficiency of the Mill. Secondly both consume power to overcome the frictional resistance during the travel of the bagasse mat to the mill rollers.

It is an admitted fact that in the design of the closed pressure chute an attempt is made to reduce the frictional loss to some extent by providing flared or diverging opening – the feed opening being less than the discharge opening. This way the possibility of clogging or jamming of the pressure chute is avoided to some extent – to some extent only – because
in spite of this provision the pressure chutes do get chocked up many a times and serious problems like bursting of the pressure chute and even resultant breakages of the mill rollers are not unknown. It is nevertheless a fact that the power loss in the closed pressure chute is much less than that occurring in the Trash Plate, about 5-10%, but it does amount to loss and costs. E. Hugot states that power consumed by TRPF is from “8 % to 20% (1/6th to 1/12th of the total torque of the Mills)”. Hugo also warns of breakages of the pressure chutes in case of excessive ratios of escribed volumes, as has been actually experienced in actual installations in India.

### 2.1.2 MILL SETTING

Mill settings are most essential factor to attain the desired goal of performance – whether that of efficiency or capacity - of the cane crushing Mills. However, as stated elsewhere, the aim should be to achieve the optimum performance. Nevertheless it must be noted that the mill setting is not merely limited to deciding the arranging of the various openings of the feed, top and discharge rollers, but has many other matters to be considered cautiously. The optimum compaction ratios for opening at each stage of the passage of the cane mat has to be considered while providing for installations like –

i. Donnelley Chute to Pressure feeder or
ii. Donnelley Chute to Under Feed Roller
iii. Pressure Feeder to Mill Feed nip or
iv. Under Feeder to Mill Feed nip
v. Mill feed to trash plate
vi. Trash plate to discharge.

Thus the various openings are decided, on the basis of experience and/or, acceptable formulae. Many different formulae are available, most of them empirical ones, to calculate openings, to deliver desired described volume, the rate of fibre at the desired compaction and using densities and ratios etc. based on experience.

There are many formulae used by different people.
The formula generally used and widely accepted is -

Delivery work opening in mm = Fibre rate × 1000

\[ L \times S \times \vartheta \]

Where

- \( L \) = length in meters
- \( S \) = Roller surface speed in meters per minute.
- \( \vartheta \) = Density of fibre kgs/M3

Also –

Fiber rate kg/Min. = Crush Rate TCH × Fibre % Cane × 1000

\[ \frac{1000}{60} \]

(For example if fiber % cane is 14.5 it is to be taken as 0.145).

This formula is based on cane preparation index PI = 85, as per standard practice followed in Indian Sugar industry.

While it is a fact that the mill settings are very carefully calculated on the basis of tried formulae and experience, it must be noted that in actual practice the mill settings are never satisfactory for the simple reason that these cannot remain steady. This is on account of the fact that ‘top roller lift’ is allowed and is to be necessarily provided for. Therefore the feed and discharge openings and ratios change depending upon the lift of the top roller of the Mill, during working.

With the best of the mill settings, the compression ratio of the mill may not be ideal, as it depends upon so many factors like cane quality and variety, nature of cane fibre, cane PI, feeding characteristics of the feeders and Donnelley Chute etc. These deviations would naturally affect the Mill efficiency and also re-absorption.

### 2.1.3 BEHAVIOR OF BAGASSE OVER THE TRASH PLATE

Trash plate has substantial impact on almost all parameters of milling. The behavior of bagasse while dragging over it (over the trash plate) and feeding to the discharge roller is completely unknown and is always a mystery. This factor has influence on the mill performance almost on every account.
2.1.4 RE-ABSORPTION

We have seen that the Trash Plate is called a Devil by many. However the trash plate may be called a Devil which can be seen, but the Re-absorption is another Devil which cannot be seen but which can cause much damage like loss of power and loss of efficiency, and to be precise, both.

As per the theory, the bagasse mat while travelling from feed to discharge opening gets progressively compressed and in the process, in the first stage the entire contents of the air in the bagasse mat are removed. What remains balance is the bagasse mat with liquid / juice - both of these are effectively incompressible. During further progress of the bagasse mat, the pressure in the bagasse mat goes on increasing and juice trapped finds outlets, backwards, through the bagasse mat following it, the pressure during further travel of the bagasse towards exit reaches a peak shortly before the work opening between the two rollers of the Mill. AT this peak pressure, the free juice cannot any longer escape backwards through the travelling, densely compacted bagasse mat and at the same time, is not able to bear the pressure any longer. Not finding route for escaping backwards, the juice, under unbearable pressure, and helped by groove surfaces duly lubricated by the cane juice, escapes forward through the bagasse mat fibre through the work or discharge opening, travelling at a velocity higher than that of the surface speed of the mill roller - this phenomenon is popularly called “squirting” of the juice. The juice, in the process escapes collection, while getting mixed with bagasse.
Thus the juice gets mixed up in the bagasse exiting the discharge opening and instead being collected in the juice tray, gets down to the next mill along with the travel of the bagasse mat. Thus not only the extraction efficiency is negatively affected but the power or energy applied for extraction process is also wasted partly, thereby causing double loss.

2.1.5 PROBLEMS FOR EXPANSION
Expansion of any cane sugar factory is almost a continuous as well as essentially unavoidable process. The expansion activities may be called for due to many reasons like increasing availability of cane, market demand and attractive product price feature. Planning for lucrative by-products also could be another reason for seeking expansion. Therefore a convenient, cost competitive and faster expansion is desired by the Managements. Such expansions could have many alternatives as far as the Mill Station is concerned like, use of all existing mills or use of some existing mills with some new mills: use of existing drives or use of supplementary drives. In early times even parallel tandems were also installed, in addition to the existing tandem to avoid possible loss of a crushing season. These various alternatives call for careful analysis and thorough planning with the help of experienced personnel.
2.1.5.1 Common Drive Mills

In the early period of cane sugar factories in India, the factories generally had a Mill Tandem with Mills having common drive system. That is, in this system a set of two Mills was driven by a common steam turbine, or earlier even a set of four Mills was driven by a common or single steam Engine, thus was driven by a common drive. Therefore, for a Mill Tandem consisting of 4 Cane Crushing Mills, only two sets (of Turbines) or one set of (Steam Engine) drives were provided. This arrangement necessitated placing of such set of mills closely so that the gearing train driving the mills could be planned and spaced economically.

When crushing capacity expansion was planned, it became a problem for such Mill Tandems, since any type of pressure feeding system could not be installed for want of required space between two consecutive Mills. A solution was therefore found, where the mills were re-arranged by providing sufficient space between the two adjacent mills to accommodate the pressure feeder system. This became a major operation since the mills were required to be shifted for which additional foundations were to be made and two sets of new drives were to be provided for the two shifted cane crushing Mills. Since large civil works were required to be planned, this became a time consuming affair, requiring big chunk of time and many times the factories lost a complete season while completing such expansion projects.

2.1.5.2 Drive Power for Mills

Another problem was the availability of required additional power. Since with such projects, the 50% available extra power of the previous mill drives was not fully utilized, the mill drives were working “under capacity” or below capacity. The efficiency of the drives is substantially reduced when the power of the drives is not properly used.

To get over such problems, sometimes parallel tandems were installed so that no time was lost during expansions and headache of planning of mill shifting was totally avoided.
As a matter of common sense, the cost of working of two Mill Tandems is always more than cost of working of a single tandem with larger capacity or equivalent to the capacity of two tandems put together, since additional manpower and maintenance cost required for operation of two tandems is to be necessarily provided.

Also in case of increase in crushing capacity of the Mills, larger drive power was required demanding replacement of the existing drives completely.

### 2.2 Configuration of Mills in a Tandem

Configuration of a Mill Tandem depends upon various factors like the process of Juice Extraction followed, Efficiency Parameters desired, Plant capacity, planning for future expansions, cane variety etc.

#### 2.2.1 Diffusion Process

As we have discussed earlier, there are two types of raw materials for manufacturing sugar, one is the beet and the other is the cane. For the beet sugar production Diffuser Process is unavoidable. However, This Diffuser process is also used for cane juice extraction in some countries of the world. It has to be noted, however, that in India, where largest number of cane sugar factories are working – about 700 numbers – there may be less than 10 factories in all, employing the Diffusion Process.

In both the different processes, using cane as raw material, cane crushing mill has to be commonly incorporated along with the Diffuser and forms a major unavoidable factor in the juice extraction by the Diffusion process also.

In the Diffusion Process, there are, again two types - one is the Cane Diffuser and the other is the Bagasse Diffuser. The Cane Diffusion being comparatively the latest.

#### 2.2.1.1 Bagasse Diffusion Process

In the bagasse Diffusion Process the Bagasse Diffuser is the principal equipment and this necessarily requires a Cane Crushing Mill before the
Diffuser, called the Primary Mill and two Cane Crushing Mills after the Diffuser, called the de-watering Mills. Thus the Diffuser has to be complemented with minimum two Mills, generally three Mills.

Fig 2.4: The Bagasse Diffuser Layout.

In both the Diffusion systems the preparation section is similar to the normal cane crushing mill tandem, the major difference being that the Diffusion Process demands a high degree of cane preparation index. For normal cane crushing mill tandem a PI of about 85 is acceptable however the Diffusion Process, in common, requires + 90 PI.

Though it is not relevant here, it has to be noted that the Cane Preparation requires large amount of power for driving the cane preparation equipment and to get rise of PI from 85 to 90, the additional input of Power or energy for the cane preparation section may be + 20%. Thus for about 5% increase in preparation index the power addition has to be + 20% about.

2.2.1.2 Cane Diffusion Process

In case of the Cane Diffuser, the Primary Cane Crushing Mill may not be required but only the two De-watering Mills are necessary.
Fig 2.5: Cane Diffuser Layout.

It must be noted that in any type of Diffuser, the Imbibition % is quite high and can be even up to 400%. The De-watering of bagasse therefore becomes a critical issue on account of the fact that this bagasse is the fuel for the boilers and the boiler efficiency obviously depends upon the factor of moisture in the bagasse. It is commonly observed that in spite of having two dewatering mills of conventional type with heavy duty pressure feeder systems and therefore high amount of mill drive power, the moisture % bagasse is well above 52% which is much above the acceptable figure of 50% moisture. The moisture in bagasse is now a most important and critical factor in any cane sugar factory operation and it may be noted that the moisture of as low as 48% only is now generally targeted by modern cane crushing Mill Tandem units.

Further, in case of Diffusion Process, it may thus be noted that in any case, any Diffusion system necessarily includes minimum two numbers of cane crushing mills, and considering the fact that a normal cane crushing mill tandem consists of minimum four numbers of mills, the Diffusion Process includes minimum half the normal cane crushing mill tandem. Also, the Diffusion process necessarily requires high PI – about 5% higher than normal mill tandem requirement – but consumes about 20% additional drive power for the Preparation. There are no other variations as far as involvements of cane crushing mills are concerned, in the Diffusion Process. In some cases, since the two dewatering mills do not deliver satisfactory moisture control, even three dewatering mills have to be employed.
There is also almost no scope for enhancement of capacity in the existing Diffusers, as is available in the case of Mill extraction. Therefore, the only way for expansion in capacity has to be met with installation of additional diffuser only, inviting high costs.

### 2.2.2 CANE MILLING PROCESS

As stated earlier, the layout of any Cane Crushing Mill Tandem depends upon various parameters targeted, like efficiency, capacity and provision for proposed expansion.

It is also to be noted that extraction efficiency of any mill depends upon the drive power applied, the pressure feeder system installed, hydraulic pressure applied and the surface speed of the Mill Rollers selected. Besides, there are other factors like the Preparation Index, imbibitions, number of compressions and above all extraction outlets available and so on.

All these will be discussed in details in later chapters.

Let us take review of Cane Milling -

#### 2.2.2.1 Standard Mill Tandem with a Crusher

Earlier, when the cane preparation was dependent upon two sets of knives only and preparation equipment like Fibrizer or shredder were not available, a two roller Mill was placed as a first Mill and was called as a “crusher” acting as a “Preparation” equipment.

Thus the function of the ‘crusher’ was to “prepare” the cane for further milling by not only removing part of the juice but also breaking open the fibre sales as much as possible and in the process helping further mills to do their work with added efficiency. This was required since the knives set could not deliver expected or desired Preparation Index - PI.
Those days the PI achievable was only about 70-75, as against +85 of today. The crusher was therefore supposed to work as an additional preparatory device to help ease the task of juice extraction of further mills.

When the preparation by only one crusher installed ahead of a mill tandem consisting of 4 no.s of conventional mills was not satisfactory, even the initial preparation unit consisting of two consecutive crushers was also sometimes employed (Fig 2.7).

2.2.2.2 Normal Mill Tandem of 4 Conventional Mills
Later on with availability of better and efficient fibrizer or a shredder and improved preparation, the need to install the 1st Mill as a crusher was eliminated altogether. The Mill Tandem now consisted of all conventional Mills. A Tandem of six no.s of Mills was considered desirable. However generally, as a first step a Tandem of 4 Mills was installed and space was left for addition of Mills at a later date. Sometimes even foundations for
the future mills were also cast in the first stage only, when 4 mills were installed.

A standard Mill Tandem now comprised of minimum 4 numbers of conventional three roller Mills in a row. Donnelley Chute being considered as standard equipment installed along with the mill (Fig 2.8).

However for further improvement in overall performance of the mill tandem, the mills were strengthened with an Under Feed Roller or the 4th roller, installed initially on the 1st Mill for improved Primary Extraction (Fig 2.9). This also helped in improvement of the overall extraction efficiency of the Mill Tandem to some extent.

Later on, such under feed rollers were installed on rest of the mills also thus having under-feeders on all the mills of the tandem (Fig 2.10).
These Mills were also called four roller mills when the Under Feed Roller was installed in the headstock only as an integral part or supplied with the mill itself.

### 2.2.2.3 Mill Tandem of 4 Conventional Mills with TRPF

Depending upon the desired increase of crushing capacity of the Mill Tandem, the TRPF System, either heavy duty or light duty was installed after the mill tandem is in operation.

### 2.2.2.4 Mill Tandem of 4 Mills with GRPF for 1st Mill

In case better Primary extraction is desired the 1st Mill is added with GRPF with UFR system, either heavy duty or light duty type.
Such an installation on the 1st Mill also delivers slight increase in the crush rate of the original tandem. However, necessary extra power for the GRPF has to be installed, in case the mill itself does not have drive having enough power to drive GRPF also, or depending upon design criteria.

2.2.2.5 Mill Tandem of 4 Mills with GRPF for First and Last Mill

As a further step, such a pressure feeder system is installed on the last mill also in the second instance for further improvement in the performance like marginal increase in the milling extraction efficiency and also further slight increase in crushing capacity (Fig. 2.13).

The availability of power for the GRPF system is an important factor and must be verified prior to installation of such system to ensure desired results.
As an alternative and depending upon performance target TRPF is also selected instead of the GRPF for installation on either first Mill or on both – the first and the last Mill.

### 2.2.2.6 Mill Tandem of 4 Conventional Mills with GRPF

Depending upon the desired crushing capacity of the Mill Tandem and the milling or extraction efficiency desired, the GRPF System with UFR, either heavy duty or light duty is installed after the mill tandem is in operation (Fig. 2.14).

![Fig. 2.14: G. A. of Tandem of 4 conventional Mills with GRPF+UFR.](image)

However, since the GRPF System is a “Passive Feeder System”, for better results additional drives for the GRPF System are necessary. In case the mother Mills have sufficient excess power available, the same can be used for sharing with the GRPF.

### 2.2.2.7 Mill Tandem of 4 Mills with large size First Mill

When more increase in crushing capacity is desired, say by more than 40% or so, a new of large size Mill is required to be installed as a ‘Zero’ Mill with required drive for the planned higher crush rate (Fig. 2.15). The size of the new Zero Mill has to be carefully selected depending upon, the availability of additional cane and time required, so that the new Mill can deliver the crush rate over due period of time and no further addition would be required to reach the desired crush rate.
In such cases the capacity of the existing balance mills is required to be verified for suitability to desired crush rate and necessary modifications like installation of pressure feeder systems on the balance mills is to be undertaken.

2.2.2.8 Mill Tandem of 4 Mills with replaced large size Last and First Mill

With slight variation of the above steps, many a times, depending upon careful assessment of target and existing situation, the existing 1st Mill is replaced by a large size 1st Mill in the initial stage. Then in the next stage the existing last mill is also replaced by a large size mill similar to the new 1st Mill (Fig. 2.16).

However care is required to be taken for assessment of capacity of the existing intermediate Mills, as before, and necessary additions like TRPF / GRPF is planned.
Such addition of 1st and last mills, in stages is convenient; however many times such replacements are also carried out simultaneously. It is also to be noted that in case of conventional Mills, replacement of large size Mill requires making of new foundations to suit the new Mill. Necessary study and planning of the work has to be carefully ensured so that the entire work can be satisfactorily completed in the given period of time.

Along with the addition of the new Zero Mill, even the existing cane carrier has to be widened or its depth increased, depending upon the design requirement and desired crush rate increase.

2.2.2.9 Mill Tandem with addition of large size Last and Zero Mill

As further step after the above (vii), when in an old tandem where four mills are installed, to increase crush rate as well as efficiency of the existing Mill tandem a new zero mill of large size is installed. As a next stage, in this mill tandem, which now has 5 Mills, a new last Mill of large size similar to the new zero Mill is installed.

Thus the modified tandem now becomes a tandem of 6 numbers of Mills, with large size new Zero and Last Mill and four numbers of earlier smaller mills.

As in the previous case, care has to be taken to verify the capacity and adequacy of the drive of the old tandem of 4 intermediate Mills.

It is to be noted that there is no set formula or practice for carrying out such modifications as above. It is only the long association and experience with the industry would assist proper and satisfactory selection to deliver desired results and targets.
CONSUMPTION OF POWER IN DIFFERENT
SECTIONS OF THE MILL EQUIPMENT AND
FEEDING SYSTEMS

The Cane Crushing Mill Station is the most important station in a cane sugar factory for the simple reason that this station controls or delivers the overall production efficiency of the factory and indirectly affects the profitability of the factory. As far as the power consumption is concerned, the Mill Station consumes maximum power – about 40% Power or energy of the total factory. The item or factor of Power consumption is extremely important in every aspect of running the industry.

This factor of power consumption of the Mill station becomes too important in the changed context and circumstances related to national policies and energy generation. As it is already an established fact, the cane sugar factories can play a very important and supportive or complimentary role as far as energy or electricity generation of any nation is concerned. A study of the Power Consumption of the Mills is therefore most important.

Study of the working of the cane crushing mills is also vitally important on account of the fact that the Mills also control the quality of fuel – the bagasse – which is burnt in the boilers. These boilers in turn generate the steam which is used in the Turbines driving the power generators. The quality of fuel or bagasse, delivered by the Mill section decides the efficiency and quality of the steam and influences the power generation.

We have discussed earlier the aspect of Optimization with regard to power consumption of the cane crushing Mill. The same principle has to be carefully applied here also. While the performance of any equipment will remain proportional to power or energy applied, this increase or improvement of performance will cease to be so after certain stage is reached, when the rate of improvement will slow down and same will not be in proportion to power applied. In other words, the improvement in performance of any equipment will happen within only certain limit. We
must find a balance in the applied power and the performance delivered. This is optimization.

Like the Mills consume substantial power, the preparatory equipments – particularly the Cane Fibrizers or the Shredders also consume substantial power. The extraction efficiency of the Mill Station depends upon the Preparation of the cane, measured in terms PI – the Preparation Index. The Power consumption of the Fibrizers depends upon the targeted PI and is directly proportional to the same. However a higher PI or preparatory index causes what is known as “slippages” in conventional Mills and would actually reduce the Milling efficiency.

The other power consuming equipment in the Preparation section are – cutter, Leveller, chopper etc.

Other than the Cane Crushing Mills, the following are other important equipment in the Mill Station –

2.3.1 CANE HANDLING
The Cane Handling system generally consists of following. However the exact scope of installation depends upon factors like, type of transport of cane, like Bullock Carts, trucks, Tipplers, Trailers, Railway Wagons or or combination of these, as the case may be -

   i. Truck tipplers for cane
   ii. Feeder Tables to suit truck tipplers
   iii. Head end cutters for Feeder Tables in (ii) above.
   iv. Auxiliary Cane Carrier when i, ii & iii are provided
   v. Cane un-loaders either sling type or grab type.
   vi. Feeder tables when sling type un-loaders (iv above) are provided.
   vii. Main Cane Carrier

Again depending upon previous experience and choice the type and equipment is selected.
2.3.2 CANE PREPARATION

Before the Cane Fibrizers were introduced there used to be following configuration –

i. Kicker
ii. Cutter
iii. Leveller

Depending upon the degree of preparation desired sometimes even two sets of cutter knives were also installed.

Fig. 2.17: General arrangement of cane unloader with feeder tables.

Fig. 2.18: G. A. of cane handling with preparation section.

However after the shredder / fibrizers were introduced the preparation improved tremendously and the configuration adopted is

i. Chopper
ii. Leveller
iii. Fibrizer or Shredder

Some of the modern Fibrizers, particularly the Swing Hammer Fibrizers, require only a Leveller, making or simplifying the layout of the section
more convenient and efficient. Typical equipment designs and layouts of various preparation equipment are depicted in the drawings below. These are chosen on the basis of requirement of performance and capacity.

Fig. 2.19 : Typical Cane Leveller.

Fig. 2.20 : Shredder with Feed Drum.

Fig. 2.21 : Typical layout of Shredder with Chopper.
Fig. 2.22: Mill Feeding Arrangement with Shredder.

Fig. 2.23: Typical arrangement of a Shredder with head end cutter.

Fig. 2.24: Typical arrangement of a swing hammer fiberizer with kicker and leveller.
2.3.3 RAKE ELEVATOR
As in case of Cane handling, the items of Rake Elevator as well as the Donnelley Chute for the Mills consume power depending upon crush rate and size of the Mill etc. and hence are not considered here.

2.3.4 DONNELLEY CHUTE FOR EACH MILL
As above. (As in case of Cane handling, the items of Rake Elevator as well as the Donnelley Chute for the Mills consume power depending upon crush rate and size of the Mill etc. and hence are not considered here.)

2.3.5 CONVENTIONAL CANE CRUSHING MILL
It may be noted that out of the above, the power consumed in Cane handling, Cane Preparation, Rake Elevator, Donnelley Chute etc. is same, irrespective of the type of Mills installed. We would therefore not refer to these here in details.

We would, therefore, discuss and consider the factor of power and most important, the loss of power that unavoidably occurs in a conventional Mill in various items which are mentioned below, since this is an extremely vital factor concerning the conventional three roller mills. To consider these one by one and in order –
2.3.5.1 Trash Plate for Dragging Bagasse from Feed Roller to Discharge Roller.

This is the most critical and damaging item, so to say, in the design and construction of the conventional cane crushing basic Three Roller Mill, as discussed previously.

Fig. 2.26: Power loss in the Trash Plate.

As seen earlier, the Trash Plate does not take part in efficiency generation or performance of the cane crushing mill except for providing a sort of a bridge for dragging or transporting the bagasse mat - which is under pressure - from the feed roller to the discharge roller. While doing so, substantial or large chunk of power - say about 25% - is consumed by the trash plate, which is a waste of power in reality.

Besides being responsible for wastage of precious power, the trash plate also contributes to other problems which would be discussed in appropriate section. It is for this reason that in many discussions and seminars the trash plate is described as a “Devil” in a conventional cane crushing mill of three roller type.
2.3.5.2 **For driving the Under Feed Roller, if provided**
The Under Feed Roller is a cast iron roller, similar to the Mill Roller, and as discussed elsewhere, as per the latest practice followed in the Mill Section, the diameter of the Under Feed Roller is nearly same as that of the mill roller itself. As per the established principle the Under Feed Roller being of Cast Iron variety, there will be power consumption - this is, though, marginal – say up to about 10% or so depending upon design. This would also depend upon the setting of the UFR and the designed surface speed etc., as in case of the Mill itself.

2.3.5.3 **In the closed Pressure Chute of the Pressure Feeder System, if provided**
As in the case of the Trash plate, the Closed Pressure Chute also acts as a conduit only for transporting of the bagasse mat from the pressure feeder rollers to the mill feed nip. The bagasse mat is being pressed forward by the pair of pressure feeder rollers through the closed pressure chute and in the process the frictional resistance has to be overcome. This consumes about 15% - 20% power. The surface speed of pressure feeder system is about 25% to 30% more than that of the Mill Roller, which also attributes to the generation of friction.

2.3.5.4 **In the T.R.P.F. System, if provided**
Power is spent for the operation of the pressure feeder system rollers and also for creating necessary pressure on the bagasse mat by the pressure feeder rollers. Power is spent in this operation.

It is to be noted that the surface speed of the pressure Feeder Rollers is about 25% to 30% more than that of the surface speed of the mill rollers creating pressure on the bagasse mat and creating force feeding effect by creating higher density of the feed mat.

This consumes about 10% power.

2.3.5.5 **In the Rollers of the G.R.P.F. System**
As stated earlier, the G R P F System employs Cast Iron Rollers similar to the Mill Rollers. We have also seen that the Mill normally requires a Feeder
Roller for creating better density of the bagasse feed. Same principle is applied to the G R P F system also and the two GRPF Rollers are fed by a similar third roller for further improvement in working. This G R P F system is called the G R P F with Under Feed Roller. Thus in this system there are two sets of C. I. Rollers, three in the Mill and three in the Pressure Feeder system and the Mill is called a Six Roller Mill. The GRPF Rollers being provider of “Passive” feed to the bagasse mat, it requires more power which is about 25% to 30% of the Mill drive power.

<table>
<thead>
<tr>
<th>2.3.5.6</th>
<th>Due to change caused in the setting during operation, because of lifting of the Top Roller</th>
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<tbody>
<tr>
<td></td>
<td>Once the mill is accurately set with carefully calculated feed and discharge settings for a desired feed rate, for efficient operation of the Cane crushing mill - for any type of cane crushing mill for that matter – what is most essential is a constant feed rate of the cane to suit the desired crush rate. However practically this is the most difficult thing to achieve - no, next only to impossible thing to achieve. There are of course many types of systems and equipment devised to achieve this target, but one must say, without much or without desired success. It is the typical behavior of the bagasse and practical problems of controlling and executing the cane unloading and preparation operations that is responsible for this phenomenon. Since it is not possible to control or to maintain the feed rate, there is obviously only way out to provide necessary flexibility in other equipment - in the cane crushing mill. This has been attempted by</td>
</tr>
<tr>
<td></td>
<td>a. Providing hydraulic loading system which would provide some flexibility to accommodate slight variation in the feed rate.</td>
</tr>
<tr>
<td></td>
<td>b. Providing allowance for “lift” or “free floating” of the top roller of the cane crushing mill.</td>
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</table>

While the (a) and (b) above do provide the necessary flexibility it also causes some efficiency and power loss.

On one side mill engineers calculate the necessary settings of feed and discharge openings and trash plate profiles and settings, all to the accuracy of nearest millimeter; they are also required to provide for the lift of the top mill roller. In the process what happens to the calculated setting of the feed, discharge and trash plate? (Mill setting is calculated
taking into account the desired lift of the Mill Top Roller) These are naturally disturbed and do not hold good during the lift of the top mill roller during crushing operations. So there is a dilemma. One has to set the mill openings accurately to achieve the desired crush rate and efficiency. However these mill settings go awry since the top roll to lift or float has to be provided. The geometry of the mill rollers does not allow constant settings, as the openings get altered in different proportions. Also, in the whole process, the calculations of the power for the mill go haywire and power loss becomes unavoidable. However, this appears to be an unavoidable phenomenon, as practiced faithfully by the cane sugar factories all over the world.

2.3.5.7 Re-absorption

We have seen that the Trash Plate is called a “Devil”. However we must note that there is also another Devil, which cannot be seen but the damage could be experienced, and that unseen “Devil” is nothing but “Re-absorption”.

In the process of milling of the cane, the bagasse mat suffers tremendous pressure of loads on the rollers and resultant compression which forces the liquid – the juice – to escape and get drained causing “extraction”. Here we must note the composition and behavior of the bagasse mat which comprises of millions of fibres of cane bagasse, entangled together. This bagasse mat, under tremendous pressure, tends to form a hard and solid mass which does not allow the juice to escape or the juice cannot find a path to escape. As we know, the liquid - the juice – is incompressible, it cannot be compressed, and therefore beyond certain limit, the liquid can no more bear the pressure and tries to find a path to escape. However the bagasse fibres, forming solid wall or mass, do not allow the juice to escape. In the meantime the bagasse mat approaches the exit of discharge roller opening, and with the entrapped juice which is under tremendous pressure and which is trying to find an escape path comes out or escapes along with the bagasse mat. The lubrication provided by the juice layers on the surfaces of the Mill Roller grooves helps the process. Therefore the juice, instead of getting drained, gets out forcefully with the exited bagasse and gets mixed with it. Therefore the
extraction efficiency is reduced and the power expended for extraction is wasted.

### 2.3.5.8 Transmission loss – in Mill Drive System

The drive of the mills is provided in different types and manners. There is the main source of energy or drive which is at a given speed. The Cane Crushing Mill being equipment working at very slow or reduced RPM, the speed of rotation of the source has to be reduced to suit the RPM of the Mill roller. This being done or achieved in stages, there is loss of energy or loss of power in the process. Let us take a review of the various types of drives in use or opted.

#### 2.3.5.8.1 Steam Engine Drive

The initial industrial drive was a steam engine drive, which we know was even employed for driving public or personal vehicles like buses, trams and even cars also besides driving all sorts of mechanical equipment. The Cane Sugar industry could not be an exception and the cane crushing mills of earlier days were driven by the steam engine drives. Not only that even smaller equipment like various pumps were also driven by steam engines. Since the steam engine occupies hell of a lot of space on account of its design and therefore even a tandem consisting of 4 nos cane crushing mills was driven by a single steam engine only. This arrangement, therefore required the consecutive mills being placed closer for enabling placement of the complicated open gearing arrangement so that the single steam engine can drive all the four mills. Therefore any modification or attachments to mills, after installation of the original Mill Tandem was almost impossible.

There had to be open gearing system after the Steam Engine, truly called the gear-train, which itself required large space for number of huge gearing, making the scene almost fascinating and impressive.

Sometimes the arrangement was also split, by providing two steam engines, if the Mills were of larger size.
The efficiency of the steam engines is only about 50%, the lowest in the range, it may be noted.

2.3.5.8.2 Steam Turbine Drive
The efficiency of the steam turbine is about 70%, depending upon the steam parameters like steam pressure and temperature etc. Further, the steam turbine drive necessarily involves high speed gear box and low speed gear box, besides open gearing system for onward reduction in the output speed. This is followed by a tail bar coupling for connecting to Mill roller. The gear boxes, open gearing and the tail bar system also contribute to power loss, it may be noted.

However the steam turbines offered ready convenience by making it possible to provide common drive for Mills and later on even individual drive for the Mills. The steam turbines also occupied much less space and the layouts of mill tandems were no more complicated or huge like the steam engines. This also considerably reduced foundations and millhouse buildings.
Electric Motor Drive

The electric motors are highly efficient and claim efficiency of about 95% or so. After the electric motor there is a Helical Gear Box followed by one stage only of open gearing as against two stages of open gearing in case of steam turbine drive.

There was also choice of either D.C. Motors or the A.C. Motors to chose from.
This drive made the mill plant layouts much simpler and convenient besides being economic.

![Electric Motor Drive for Mill](image)

**2.3.5.8.4 Foot Mounted Planetary Gear Box**

A foot mounted Planetary Gear box installed after the electric motor, completely eliminates requirement of any open gearing and thus reduces wastage of power in the gear train and also saves lot of space and foundations required for the open gearing.

It also reduces costly inventory of items like, open gearing, shafts and bearings etc. Besides complicated maintenance of such open gearing and lubrication etc. is also saved. Therefore, even elsewhere such gearings were previously installed, these are removed gradually and replaced with Planetary gear boxes.

![Foot Mounted Planetary Gear Box](image)
### 2.3.5.8.5 Hydraulic Drive

On account of high flexibility offered this is a convenient and better drive, however the high costs and critical maintenance have reduced popularity of this drive. Further, because of the element of high transmission loss in the configuration and gearing system etc., this system does not deliver economy desired in power consumption.

![Fig. 2.31: Hydraulic Drive.](image)

### 2.3.5.8.6 Shaft Mounted Drive

This system completely eliminates the foundations required for the drive system like the electric or turbine drive, and also reduces width of the Mill House building thus reducing cost of the civil works. In this system the entire drive system that is the electric motor and the planetary gear box are all installed on the shaft of the Mill Roller directly and totally eliminates the open gearing and coupling etc. along with the power loss on that account.

![Fig. 2.32 : Shaft Mounted Drive for Mill with vertical motor.](image)
In this system two options of motor installations are available. In one alternative the drive motor is attached to the shaft mounted gear box vertically to save the space. This is a preferred arrangement since the bending movement on the mill roller shaft is considerably reduced.

In another option the mill Drive motor is attached horizontally only along with the shaft mounted Gear box, if sufficient space and clearance is not available for installation of the motor in vertical position as in the previous arrangement. In this arrangement since the motor gets placed away from the centre of the mill roller shaft the bending movement on account of motor placement stands increased and the shaft has to be accordingly designed.

Selection of these depends upon space availability or constraint.

### IDEAL EXTRACTION PROCESS WITH REGARD TO POWER CONSUMPTION

While considering the ideal process it is essential to consider the suitability of the process with regard to below points.

#### EASY AVAILABILITY

Comparing the Diffuser System and Mill System, the Mill system and components are easily available indigenously and can also be maintained and repaired locally. However the main components of the Diffusers like chains etc. have to be imported and therefore heavy inventory has to be maintained. Mills therefore are convenient on this account.
2.4.2 **EFFICIENCY**
The efficiency of the Diffuser system, primarily on account of high degree of PI, say upto + 90%, delivers RME claimed upto +97%. As against this the Mills require lower PI of + 85 and deliver RME of 96%.

2.4.3 **POWER CONSUMPTION**
As stated elsewhere, the Cane handling and preparation section for both sections is common except for the fact that on account of requirement of high degree of preparation index of the Diffuser System the power consumption of this section is more than that of the Mill Section.

However, the Diffuser itself consumes very limited amount of power since it has only a multiple of pumps and drive of the diffuser itself consuming less power. However since the Diffuser requires minimum two nos of Mills with GRPF etc. the consumption of this Tandem is more than 50% of the similar capacity mill tandem.

Considering high requirement of preparation section delivering + 90 PI and at least half of the Mill Tandem for the Diffuser, this Author feels that there is not much difference in power consumption of both the systems, in case the power saving efficient Mill Tandems are considered.

Considering the strides made by manufacturers lately and availability of highly efficient and power saving Mills, it can be safely said that soon the consumption and efficiency of the Mills will be equal to that of the Diffuser System.

2.4.4 **SUITABILITY FOR FURTHER EXPANSIONS**
On account of design constraints, the Diffuser section does not have much scope for expansions.

On the contrary the Mill Section has tremendous scope for expansion to be carried out in future, either in one stroke or step by step, depending upon planning of cane farming and other targets. Therefore Mills are far superior on this account.
2.4.5 CAPITAL COST

Capital cost of Mills is almost same as compared to Diffuser System.

However, considering the other factors the Milling system is preferable over the diffuser system.

In view of the various factors influencing the power saving in the mill drives, we may conclude that in existing conventional three roller mills, the ideal configuration would be a conventional three roller mill with a GRPF with Under Feed Roller (A Conventional Six Roller Mill) with shaft mounted drives.