CHAPTER – 1

PRESENT SCENARIO OF THE EXTRACTION TECHNOLOGY
ABSTRACT:

This chapter deals with the various stages of progress and trends in the cane extraction technologies and the present popular practices generally followed in the cane sugar industry across the world.

It must be understood that the juice extraction is the first stage of operations in the sugar manufacturing process. It is also the most important stage in the process, for the simple reason that the extraction influences not only the production but other parameters related to crushing operations and working of the other stations of the cane sugar factories. And ultimately it is responsible for quantifying of the profitability of the sugar factory. It is also important on account of the fact that the Juice Extraction Station or the Milling Station is the costliest station in the sugar factory and has a pretty long life too. Therefore, selection of the Mills becomes extremely critical and important. This is particularly so, since overall progressive production planning or capacity of the sugar factory itself is a very tricky affair and requires a careful and studied approach considering long life of the plant.

1.1 HISTORY OF CANE CRUSHING

Sugar itself is known to mankind from ages and particularly known to us – Indians – since the Vedic era. The cane crushing, therefore, has a very interesting and long history. The cane crushing is the first stage of sugar production and like other histories of mankind; everything must have been a manual process before the engineering was invented and employed. In the early stages of entry into mechanics by the mankind, the obvious method was the one which employed animals, particularly oxen, for driving the cane crushing equipment. In this, two wooden rollers were placed vertically and driven by animal power. It is interesting to note that this system is still found in operation on the streets of India, where cane juice is popular and readily available as an energy drink, particularly in summers, when the cane is readily available, being the season of the cane. This system obviously has the capacity limit, which did not matter in the good old days when the sugar industry was perhaps a cottage industry
and when the sugar was produced in chunk forms on the farms themselves, perhaps.

With introduction of the “Wheel” forming solid base for “movement” and of development of engineering and mechanization, the form of this wooden equipment slightly changed and it was made horizontal instead of vertical and later wooden rollers getting replaced with metal ones. Steam engine drive was employed with advancement in engineering and equipment design and thereby enabling industrial output of larger scales. With further progress, and with availability of various options, different types of drives were introduced and absorbed by the industry.

Sugar is produced from Cane as well as beet. References of production of sugar from cane are available in Vedic religious literatures abundantly but not about beet sugar. Beet sugar has apparently made a late entry in the field of sugar. It could also be due to the fact that beet is not a tropical crop. The characteristics of the Beet and the Cane are totally different i.e. as the name suggests the cane is like stick while the beet is a bulbous root. Also cane is a fibrous material and remains so even after crushing, while beet turns into pulp when crushed and most important is the fact that the cane fibre after crushing has substantial fuel value or calorific value imparting it the qualities of useful fuel, while the pulp of the beet remaining after juice extraction, on the other hand, does not have any such quality or usefulness as fuel.

Beet sugar production is about 22% of the total global sugar production. Thus the cane sugar production is about 78% of the total sugar production of the world. Also, cane is a tropical crop while beet is grown in Europe and similar cold continents. It must be noted here that lately successful attempts have been made to develop beet cultivation in India. It is felt that beet may be used as a secondary raw material for sugar production after end of the cane season.

However, the sugarcane and sugar has been known to India from the age old Vedic period. It is said that the sugar is the gift of India to the world.
Vedic period can be said to be the period before about 3,000 years of the Christian era.

The organized sugar factories, is a comparatively a late development. It is said that the first sugar plant in India was established by the French people at Aska in Orissa in 1824. Not much is known about this factory except that it was maintained by Late James Fredrick Vivian Minchin and that it stopped its operation around 1940. However, the first vacuum pan process sugar plant was set up at Saran in Marhowrah in Bihar in 1904. By 1931-32 there were 31 sugar factories in India all of which were in the private sector. The total production of sugar at that time was only about 1.5 lakh tonnes, whereas the consumption was about 12 lakh tonnes. To meet the domestic demand of sugar, India had to import sugar mainly from Java (Indonesia) *

The beginning of this development can be said to be that of introduction of steam engine. The sugar cane crushing mills or extraction mills were driven by the steam engine. Also, the crushing capacities being comparatively smaller - say 800 / 1000 TCD only – which were constrained by the cumbersome drive provided by the steam engine, employed as a common drive. That is, the tandem of 4 mills and a crusher were all driven by a single steam engine only.

With the progress of modern technology, engineering expertise and strict control over material specifications, and like the trend of modernization of other industries, the cane sugar industry has also made immense progress during last decade or two. Nevertheless, it can be safely stated that there is still vast scope for further improvements, since, as per the proverb, “Perfection can never be achieved but it has to be always aimed at”. *

* From National Federation web site.

These changes of conceptions have now brought the number of Mills in a milling tandem down to maximum 5 from earlier 6 or 7. Also there is now significant attention to the otherwise considered minor parameters, like Re-absorption factor, temperature of imbibitions water, strict maintenance of mill roller arcing, feed control and related systems etc. Induction of
efficient lubrication systems, careful choice of couplings for various drives to reduce loss of energy in transmission, careful maintenance of top roller lifts of the mills etc. are also paid attention to. Of course the major factors like mill settings, mill roller speeds, selection of appropriate mill feeding systems, careful attention to design, maintenance and working of Donnelley chutes, Tramp iron removing systems, and most important, ensuring desired Preparation Index, are also paid attention to, without which none of the modern Milling Parameters can be touched even distantly.

It is to be noted that the Cane Extraction Technology, with the vast improvements as available, has to be carefully and purposefully selected to serve the goals of the final product and other parameters like plant capacities and available raw material that is type, variety and characteristics of the Cane. In addition, the scope for future capacity projections and last but not the least, the commercial or financial planning, are also other equally important or more important aspects.

1.2 EVOLUTION AND DEVELOPMENT OF MILL DESIGN

Considering the supreme importance of Mill design, it would be very much interesting to study and take a review of Evolution and Development of the Mill Design.

In the pre-historic or medieval times, when only the wheel was known to the mankind and all means of energy were powered by human or animal power inputs and when the metal still perhaps, was not fully developed, a cane crushing mill having vertical placement of two rollers were used, rollers being made of wood.
Figures 1.1 and 1.2 above show, perhaps, the earliest juice extractors. These were made entirely of wooden materials.

On the background of present days of fast progress of technology, we easily throw away old handsets or computers etc., since new, vastly improved designs are available. It is therefore surprising that we are able to see these cane sugar extractors working on Indian roads, even as on today, without much change in the original technology, proving the utility and wisdom of the older technologies.
The next stage was perhaps of introduction of a heavy mill (Fig. 1.3), where the rollers were metallic and placed horizontally instead of vertically, as shown.

Fig. 1.3: A Typical earlier Roller Mill.

Further development was with the Mill with a slanting Headstock (Fig. 1.4) to facilitate Mechanized operation of feeding with a mechanical conveyor for a large size cane extraction operation. Due to increasing expectations with regard to capacity as well as performance of the cane crushing mills, there were attempts to improve or modify upon the design of the mill. The mill therefore, was complemented by addition of a third roller (Fig. 1.5) which was perhaps considered to act as a feeder roller. Perhaps with satisfaction of availing desired improvement with the addition of a feeder roller for the erstwhile two roller mill, attempts were continued for further improvements in the design of the mill that was available those days.

Fig. 1.4: An earlier Two Roller Mill with Slanted Headstock.
The natural culmination of these efforts to improve the Mill was the now established design of a conventional Mill which is having a trash plate, as we will discuss and see later.

![Fig. 1.5: A Mill with a Feeder Roller.](image)

There were also progressive improvements in the design of the headstocks. The top roller was given pressure to deliver force for extraction of juice from the bagasse mat. In the earlier versions this pressure was delivered by sometimes incorporating heavy springs (Fig. 1.6). This was later replaced by oil and air pressure application.

![Fig. 1.6: Spring Loaded Top Roller.](image)
Although the cane sugar industry is claiming roots in the Vedic period and dates back to more than 3000 years, in those good old days the production of sugar was not on the industrial scale as we see today. There was a greater Philip for the development of machines in and about the 17th century, the outlook of the cane sugar industry also took a new turn around the same time - it can be said safely. As was the trend in the other sectors of industry - manufacturing and engineering - the establishment, growth and emergence of cane sugar manufacturing in the industrial sector was also finding its origin in the Western Countries, particularly after the availability of steam engine as drive for equipment in general.

We have seen earlier that the previously known equipment employed for cane juice extraction, though not on industrial scale, was a vertical cane crushing mill, having wooden rollers and driven by humans or animals.

The same equipment was employed in the slightly modified form when the wooden rollers placed vertically earlier, were turned in 900 to be placed horizontally in the improved version, as we have seen earlier.

With the availability of steam engines to drive the equipment this cane crushing mill was further improved to contain mill rollers made of metal, either fabricated or made of cast iron. Also for gaining strength for enabling improved capacities, a heavy framework to position or incorporate the mill rollers was used. This framework was earlier of fabricated form but later on cast steel was employed for ease of manufacturing as well as for the reason that the sizes of the cane crushing mills went on increasing to attain desired larger capacities of cane crushing. This head stock in either form was accommodating the two mill rollers, centers placed vertically. Later on with the incorporation of cane carriers to feed the mills, these rollers were placed with a slight angle with the horizontal and the headstock of the mill was accordingly of slanted
design. Incidentally the similar design of the headstock is followed even today for the conventional and contemporary other mill designs.

As designs of the cane preparation equipment were improved over the period and better and better cane preparation was obtained, there was a need for further improvement in the mill designs, that in the mill rollers itself and also in the basic design of the cane crushing mills.

The fabricated cane crushing mill rollers were provided with different kinds of teeth or surface strips welded for providing better grip on the cane blanket. As was the case of the cast iron cane crushing rollers, these were provided with different kinds of grooves. These arrangements were necessitated for allowing better grip on the cane mat of the prepared cane and also for improved juice drainage.

The design of the Mill Head Stock was also strengthened with making it from Cast steel, which continues to be in use even as on today.

With continuing attention for improved performance and higher cane crushing capacities, there was an obvious need for further improvement in the design of the cane crushing mills. Therefore rollers were placed in triangular pyramid pattern. However in doing so, there was unavoidable gap between the two bottom rollers and transport or carrying of the bagasse mat from the feed to the discharge rollers of the cane crushing mill, was a problematic thing and some sort of a bridge was needed to be provided so that the bagasse mat can safely and efficiently travel from the feed roller to the discharge roller of the cane crushing mill. This was provided in the form of what is now known as a “trash plate”. This more or less perfected the design of the three roller mill, which we would call as a “conventional cane crushing mill”.

This design appears to have been based on Rousselot’s Patent of 1871.*

* (Ref. Modern Milling of Sugar Cane by Francis Maxwell -1932)
The design of the Three Roller Mill is in use even these days, for quite some time, however the need for further improvement was always there and therefore a number of slight improvements in the basic design of the mill were introduced over the period of time.

The most important and fundamental of these were the introduction of a 4th roller for improved feeding of the bagasse for better juice extraction operation.

These 4th rollers were intended to press the bagasse blanket and thereby to obtain improved density of the bagasse mat for feeding to the Mill Feed Nip.

However before the 4th roller, as we see today, was formulated the design went through different stages of trials and developments. The earliest introduction perhaps was a 4th roller placed under the bagasse mat (please refer figure 1.8)
The 4th Rollers were also of different types, like, fabricated with strips, or CI, diameters also being different.

![Fig.1.8: 4th Roller (Feeder Roller) Placed Under the Bagasse Mat.](image)

However since this was not found to offer satisfactory results or performance, an “overfeed roller” was introduced and tried (Fig. 1.9).

![Fig.1.9: 4th Roller (Feeder Roller) or Over Feed Roller.](image)

Even different positions and locations of these rollers were tried.
As the sketch indicates, this roller was placed over the bagasse mat. In addition to this, also for pressing the bagasse mass towards the feed rollers, an “Oscillating frame” was also incorporated.

Both types of above rollers and other attachments, though tried at different settings and positions did not find much use or utility and soon search continued for a further better arrangement.

Also tried was a pusher system as shown in figure no. 1.10 above. In this system a mechanically driven reciprocating drive was installed with a pusher arrangement. The intention was to push the bagasse mat in the nip of the feed rollers of the cane crushing mill. The reciprocating pusher arrangement created the necessary force to push the bagasse mat. However the system was not seen to have continued much longer on account of perhaps inadequate results.
After trials, a feeder roller, made of Cast Iron material, now recognized as an “Under Feed Roller” was introduced. Initially the diameter of the Under Feed Roller was kept limited to about 50% only of the Mill Roller diameter (Fig. 1.11).

Satisfied with the improved performance and results, with the installation of a Cast Iron under Feed Roller of 50% dia., efforts were made to upgrade this type of roller with larger diameters and soon the Under Feed Rollers provided were upto 100% dia of the Mill Rollers.

Fig.1.11: Under Feed Roller of 50% Dia.

Fig.1.12: Under Feed Roller of 100 % Mill Roller Dia.
For further obtaining even better results and performance, attempts were made to install such Under Feed Rollers even of bigger dia than the Mill Rollers themselves and dia of upto 110% - 120% Mill Roller diameters were tried.

However it was observed in many such installations that bigger diameters of Under Feed Rollers created problems like overflowing of juice over the top roller and thus reducing extraction efficiency and also loss of drive power, since large quantity of juice was getting mixed up in the discharged bagasse. Such rollers were also costing more due to the increased dia and were adding to maintenance cost of the mill. Considering all these factors the Under Feed Rollers of upto 100% dia of Mill Roller were accepted as reasonable.

These rollers were sometimes even installed on a different headstock or were installed in suitably designed brackets welded on the main headstocks.

Thus the basic Mill was improved from vertically placed two mill rollers to horizontal placement of the two mill rollers. This was eventually improved with provision of the third roller thus the Cane crushing Mills were having three rollers, as we see even today.
The natural eventual step for the Mill Engineers and designers was strengthening this design of a three roller mill, where the mill rollers were placed in a pyramid fashion and the trash plate being added to act as a bridge to carry the bagasse mat from the feed roller opening to the discharge roller opening.

This design was further upgraded to include a feeder roller, similar to the mill roller itself, placed as a 4th roller and called as an under feed roller, as discussed above.

This is the basic design of a standard cane crushing mill and the same is used all over the world even up to now with slight modifications etc.

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<th>1.4</th>
<th>SPECIFICATIONS OF CANE CRUSHING MILLS EMPLOYED IN INDIA AND ABROAD</th>
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Specifications of the cane crushing mills in India and abroad are dictated mainly by-

1.4.1 CRUSHING CAPACITY DESIRED

The crushing capacity of a cane crushing plant is recognized on the basis of cane crushed per hour (TCH) or cane crushed per day (TCD), both in metric tons of cane crushed. While it is generally on per day basis, for calculation purposes and design point of view it is generally on TCH (cane crushed per hour) basis.

The working of cane sugar factories obviously depend upon supply of cane which is the raw material. This cane is grown by the farmers and the area from which the cane could be made available to the factory is said to be the ‘command area’ of the particular factory. The period of the operation during which the factory produces sugar is known as the length of the ‘crushing season’.

The average quantity of a particular variety of sugar cane grown in the fields in the command area is known from experience which is called ‘yield of sugar cane per acre’. Knowing the acreage of the command area and...
average yield of the cane, the estimated total quantity of cane available per season from the command area is calculated. The average length of the cane crushing season is also known from which the quantity of cane to be crushed per day is arrived at. This is the TCD capacity of the factory (Tonnes Cane crushed per day). However the Mill capacity is generally recognized in terms of TCH (Cane per Hour) for design purposes.

A Cane Sugar factory is a giant and complex affair having installations / equipment with different kinds of materials, types and designs; and all these work continuously round the clock for 24 hours. There is comparatively a large season when the factories are not producing sugar, called “off season”. During this period intensive maintenance and repairing activities are well planned and carried out most scrupulously, so that there should be minimum stoppages (down-time) during the crushing season operations. However there are always some or other kind of troubles, mechanical or process snags and stoppages do occur. As a matter of practice some reasonable margin or allowance for such unavoidable stoppages due to breakdowns etc are provided for and this is an important factor for determination of crushing capacity, particularly of a cane crushing mill. In this consideration the crushing capacity of the plant is calculated on 22 hours basis that is the length of the working day is considered to be 22 hours only.

Let us take an example. Suppose a plant is to be put up for crushing capacity of 5,000 Tonnes of cane per day. Therefore the crushing capacity in TCH is considered to be 5,000 ÷ 22 hrs = 227 say 230 TCH or 230 tonnes of cane to be crushed per hour. This is taken into account for design of different equipment in the cane crushing or cane milling station. It must be noted that the aim or target is always to work the factory at this crush rate (TCH) continuously for all the 24 hours of every day.

In addition to the above, there are also other factors which influence the design like fibre Content of given cane and cane variety etc.

This is most important factor since this influences the actual quantity of
material that is to be handled by the various sections of the Mill house. Thus we can say that the actual work load is determined by this factor of fibre content in the cane. The fibre content in the cane is expressed in terms of percentage. Thus the cane may have fibre of 13% to even 20% of cane. Since the fibre load on the Mill is proportional to the % fibre content, the Mill has to be accordingly designed or selected, particularly with respect to the provision of the size and drive power of the concerned cane crushing Mill.

### 1.4.2 EFFICIENCY AIMED AT

This can be further classified in the following parameters –

#### 1.4.2.1 Efficiency Target

Targeted efficiency is a most important factor which would influence design of crushing mill. While it is easy to aim at maximum possible efficiency, one has to take a pragmatic and realistic view of the target of efficiency. In all these cases optimization, therefore, is very important.

It is a fundamental principal that efficiency of any equipment is directly proportional to the force or drive power applied. In case of the cane crushing mill, the pressure is applied on the bagasse blanket by the top roller hydraulic arrangement. Obviously higher the pressure better would be extraction efficiency. To deliver this higher efficiency and to suit the higher hydraulic loads, proportionately higher amount of drive power for the mill has to be provided. As stated above, one has to aim at an optimum figure of the desired efficiency so that realistic and reasonable extraction efficiency would be available without requiring excessive drive power. After all drive equipment and power, both have factor of costs, affecting the profitability.

#### 1.4.2.1.1 Factors affecting efficiency target

The extraction efficiency also depends upon various other factors, which are also equally important and have to be duly considered or taken into account while planning for attaining the efficiency target set for the plant, like –
1.4.2.1.1 **Imbibition**

As stated above, while targeting the Imbibition % and Temperature, optimization as stressed earlier has to be carefully considered for balanced results.

1.4.2.1.1.2 **Number of compressions**

The numbers of compressions in a three roller mill are fixed – 2 nos, and cannot be altered or increased. However by providing external attachments like the Pressure Feeder Systems, additional compressions can be generated.

1.4.2.1.1.3 **Juice drainage**

The juice drainage influences the extraction efficiency of the cane crushing mill. Juice drainage arrangement can be improved by providing suitable grooving arrangement for the mill rollers.

Also by providing other means like Lotus type Roller etc., the juice drainage of a cane crushing mill can be improved.

All these factors i.e. (a), (b) and (Sc) are a subject of the present thesis and would be discussed in appropriate chapters.

1.4.2.1.2 **Number of Mills in a Tandem**

It is a primary knowledge that the efficiency and also capacity of a Milling Plant would depend upon the number of cane crushing mills in a tandem and will be proportional to the number of Mills in a tandem. Again, here also “optimization” is extremely important, as elsewhere. The cane crushing mill is a capital intensive item and the capital cost of a plant is dominated by the cost of the Mill Station. Therefore careful assessment with respect to financial benefit due to the desired number of mills in a cane crushing station and profitability aimed at, has to be ascertained while arriving at the conclusion.
In any cane sugar plant the provision and planning for future development is another most important aspect. This, again, is primarily based on projections of growth of the cane cultivating area in future and resultant availability of cane. The time period of such projections of future developments is very important, because depending upon the time element or interval element, provision and planning of future development of the Mill Equipment are to be planned. These could have different variants such as provision of a larger size first mill in first stage and another larger size mill as a additional last mill, increasing length and / or cross section of existing cane carrier, and resultant replacement of all preparatory equipment to suit new width etc. It must be noted that there is no fixed formula or method for providing specifications etc for such projects and only highly experienced engineers or executives can suggest an appropriate set of future planning to suit future target.

Depending upon such careful planning for future projections, the design and size of the mill/s to be installed in the first instance or 1st stage has to be decided.

The requirement of drive power for the cane crushing mill would depend upon the projections of the future and design selection of the present provisions. In all these deliberations, the consideration of engineering implications and also cost implications are very important and require not only close studies but also substantial previous experience and exposure of such projects.

Sometimes, the foundations or certain equipment could be conveniently made or provided in future even at the cost of scrapping already installed ones. But some other cases may be such that it would be excessively costly and time consuming or also cumbersome to carry out such replacement in future and would be convenient as well as saving substantial expenditure if these are suitably implemented in the initial stage only.

Consideration of all these factors is critically important and also essential
in overall planning of the Plant and which would affect engineering, production and also financial planning including profitability. It must be noted here that individual ideas of planning may differ based on targets and resources planning.

| 1.5 | REVIEW OF VARIOUS ATTEMPTS MADE FOR IMPROVEMENTS IN THE DESIGN OF CANE CRUSHING MILLS EARLIER IN THE WORLD |

The cane crushing Mill is a “centuries old” equipment and it is quite natural that it has undergone improvements.

1.5.1 EARLIER IMPROVEMENTS

Following are the early improvements in the Design of the conventional cane crushing Mills

1.5.1.1 Improvements in the Headstocks

In the design of the cane crushing mill headstocks many improvements were incorporated with experience or as a matter of necessity.

One of the most important factor was placement of the pyramid of the Mill Rollers in a angular slant (Fig. 1.14 a and 1.14 b) -

![Fig. 1.14 a: Different Headstocks with Angular Displacement](image)
As established earlier, the design of a conventional Mill (as a Mill with three rollers and a trash plate) was firmed up and accepted universally as standard design. The Under Feed Roller was either installed as an integral part of the Mill, as we will see later here, or the same added later, as per the convenience.

1.5.1.2 Improvement in Pressure on Top Roller

However, Engineers have never been satisfied with what has been achieved or available and with a constant quest for betterment and improvement on what is available, continuous attempts were made by all concerned to improve upon the available design of the Three Roller Mill which we call – a conventional Mill.

As we will see, this is the most fundamental design of the cane crushing Mill and all developments in future have been revolving with improvements of this basic design. It must be noted though that each such improvement has only fuelled further quest for improvement over the period.
In such further improvement, the pressure on the top roller was delivered by means of hydraulic pressure in combination with a suitable type accumulator.
The earliest accumulator was of a deadweight type. In this arrangement a vertical cylinder in which a plunger moves was provided. This plunger carried heavy cast iron weights which were supported by the pressure of oil in the hydraulic system. However this system proved to be too cumbersome and response of the system was also too sluggish. Also due to its size the accumulator had to be placed away from the Mill which required lengthy piping which created resistance for flow of oil denying rapid response to changes in pressure.

The air - oil accumulator was introduced in about 1940, and replaced the deadweight type of accumulator. These could be placed alongside of the mills and connected by piping etc.

In America Edwards developed the idea of placing the air chamber close to the Mill cap and several manufacturers followed the design.

Fig. 1.17: Top Roller Loaded with Hydraulic Pressure.
The next to come, therefore, was the Edwards type, which is in use even today. This design totally dispensed with any mechanically moving parts and readily provided convenience and advantages.

Being easy to operate and use, and convenient to maintain, this had been the most popular system so to say.

1.5.1.3 A Four Roller Mill

We have earlier seen that a necessity was felt for a feed roller for the three roller conventional cane crushing mill for improvement in feeding as well as capacity and an under feed roller was introduced with the three roller Mill, and was readily accepted globally. However there was a choice of installation of the Under Feed Roller for any Cane Crushing Mill at a later date, after the Mill was installed and commissioned. Also many designs were available, as an upgrade of the three roller mill design, wherein the Under Feed Roller was installed in the Mill configuration as an integral part of the mill itself, and in that case the Mill was called a Four Roller Cane Crushing Mill.

Also various types of such Under Feed Rollers were also developed and thus offered a wide choice for selection depending upon goals set by the Mill Engineers.
1.5.1.4 **Horizontal / Vertical displacement of roller setting**

Also in the conventional head stocks, many improvements for convenience as well as improved convenience were incorporated like the provisions for either horizontal displacement of the two bottom rollers of the cane crushing mill to facilitate setting of the Mill rollers or these were sought with displacement of the Mill Rollers vertically. Each of these were naturally having own conveniences, advantages or disadvantages. The selection was, in fact a matter of liking of a particular system.

With the satisfactory role of the function of the Under Feed Roller in improving feedability and efficiency of the Three Roller Mill, there was search for obtaining further benefit and advantage with suitable
modifications in the mill design of the conventional cane crushing mill. A better system was the need of those times.

Fig. 21: Typical Headstock with Vertical Setting

1.5.1.5 Pressure Feeder Systems
This quest for better feedability and efficiency of the three roller Mill resulted in development of Pressure Feeder Systems for the conventional Cane Crushing Mills. In these systems minimum two rollers in a pair were employed. These rollers were placed in separate head stocks for heavy duty systems, away from the mill head stock and were placed before the feed and top mill roller on the feed side. The intention of these rollers was to press the bagasse mat, after receiving it from the mouth of the Donnelley Chute, for improving feed rate of the mother Mill. The bagasse mat thus duly compressed, was transported from the pressure feeder rollers to the feed nip of the mill by providing a fabricated closed pressure chute. Since pressure was developed in the bagasse mat, the pressure chute was adequately designed to bear this pressure by providing structural stiffening arrangement from outside of the pressure chute. Also, since incorporation of the closed pressure chute which was bearing tremendous pressure, and was naturally adding to frictional resistance in the system, was provided with a stainless steel lining from inside of the pressure chute of the pressure feeder system to reduce such frictional
resistance. Further to avoid chocking of the bagasse mat inside the closed pressure chute and reducing resultant stoppages or damages, or both, the closed pressure chute was provided with a converging angle. That is, the width of the closed pressure chute at the pressure feeder rollers was less and increasing at the discharge end or near the feed nip of the Mill. However this provision of the converging angle obviously reduced the pressure on the bagasse mat built in the system, but that was accepted as a lesser devil.

This pressure feeder system has two varieties or types, one a Toothed Roller Pressure Feeder System popularly known as TRPF System and the other, Grooved Roller Pressure Feeder system popularly known as the GRPF System. As the name suggests the TRPF System has Toothed Rollers which are fabricated type in M.S. construction while the GRPF System has Grooved Rollers which are made of cast iron, similar to the Mill Rollers.

### 1.5.1.5.1 Heavy duty Pressure Feeders

For the ease of maintenance and upkeep, these pressure feeder rollers, of either type, are placed in a heavily built headstock, generally of Cast Steel, similar to the Mill Head Stock only, which was sometimes specially designed to be of hinged or tilting type (Fig. 1.22). This made the pressure feeder roller removal and maintenance easy and convenient as well as time saving. Also the entire assembly could be conveniently placed on the civil foundation at a suitable distance from the Mill Head Stock. Such arrangement necessarily required sufficient distance between two consecutive Mills, it may be noted. In absence of such distances or space, the arrangement could not be installed.

![Fig.1.22: Typical TRPF / GRPF System Arrangement.](image)
Later on for further improvements, one C.I. Under Feed Roller was added to the GRPF System. This system then is called GRPF with UFR system.

![GRPF System with Under Feed Roller](image)

**Fig.1.23: GRPF System with Under Feed Roller (GRPF+UFR).**

The GRPF System delivers what is called passive feed, just like in the case of the Cane Crushing Mill itself, as against this; the TRPF delivers positive feed due to its construction with teeth on the surface of the pressure feeder rollers. This makes significant difference in power consumption of both these systems and we shall appropriately refer to these in due course. The GRPF System obviously requires substantially more power as compared to the TRPF System. However, performance of the GRPF System is considered to be much better than the TRPF System.

The TRPF / GRPF systems earlier described, were called heavy duty pressure feeder systems and normally were provided with separate drives for such systems when these were installed on existing Three Roller conventional cane crushing mills at a later date. When these were installed as original equipment along with the installation of the mill itself, the drive power of the mill was suitably provided to cater for additional drive power demanded by the pressure feeder systems.
Later on, particularly in India, light duty pressure feeder systems were developed. In these, the separate headstock for the pressure feeder systems were eliminated and the pressure feeders were installed on the headstocks of the conventional mills by providing required structural support and brackets on the mill headstocks only. This considerably reduced the requirement of spaces between consecutive Mills. Another factor was length of the pressure chute provided in the design of such systems.
Since the length of the pressure chutes in these light duty pressure feeder systems were comparatively less than the heavy duty pressure feeder systems and settings were also not critical, these light duty pressure feeder systems consumed less power. Naturally the performance of these systems was also inferior. Usually these light duty pressure feeder systems were driven from the mill roller drive power only by providing suitable chain drive arrangements.

**1.5.1.6 Headstocks with integrated Pressure Feeder Systems**

In further Development of the pressure feeder systems, again in India, integrated mill headstocks were developed wherein the pressure feeder systems were incorporated as an integral system only by providing specially designed arrangement so that the pressure feeder systems could be installed in the main headstocks only, as an integral part and supplied with original mill only (Fig 1.25 and 1.26).

The specialty of the integrated five or six roller mills was that, the pressure feeder rollers were placed near to the mill rollers thereby the length of the pressure chute was substantially reduced. Due to this the power requirement of the pressure feeder systems, whether TRPF/ GRPF (five roller mill or six roller mill) was reduced further. In these mills also the pressure feeders could be driven by chain drive only.

![Fig. 1.26: Integrated Five Roller Mill.](image)

(Three Roller Mill with Trash Plate integrated with TRPF system)
Improvement being a constant process, further improvements in the design of the cane crushing Mill Headstocks was introduced when the Constant ratio mills were designed. It may be noted that setting is made in any three roller Mill to establish a certain ratio between the feed opening and discharge opening while operating. This ratio naturally varies according to the position of the particular Mill in the Tandem, and is calculated to suit the required crushing rate and other parameters etc. However, the feed rate of the cane bagasse mat is, unfortunately, never constant or to be precise, cannot be maintained accurately and varies from minute to minute of the operation of the Mills. These variations naturally result in repeated rise and fall of the top roller according to the changes undergone. Thus the ratio of openings changes accordingly and affects the extraction efficiency and working of the Mill. In a typical design of the constant ratio Mill (Fig. 1.27), where the top roller of the Mill is fixed in a cap which pivots about an axis situated on the delivery side of the Mill and is located in such a way that the feed opening opens or closes by an amount approximately double the change in the delivery opening. The ratios of the variations are adjusted in such a way the ratio set between feed and discharge opening is maintained or there is only a very slight variation between the set ratio and actual ratio.
1.5.2 **FURTHER IMPROVEMENTS WITH NEW TECHNOLOGY**

In view of seeking further improvement in the conventional GRPF + UFR systems already installed on the Conventional Mills, many factories employed very interesting modifications. However it must be noted that such a modification was possible only lately, after the new TRF system was successfully and widely installed in many sugar factories.

![Diagram of Conventional GRPF with TRF](image)

Fig.1.28: Conventional GRPF with TRF.

Thus in the modified system of GRPF + UFR, the installed UFR was discarded and replaced by the *newly developed T R F system roller*. At each of such modification, substantial improvement in the function of the conventional GRPF system was reported.

1.5.3 **CONSTANT RATIO MILLS**

A constant ratio or Auto set Mills were developed by leading Mill Manufacturers abroad, as shown in fig. 1.29. The specialty of this design was that it did not require change of Mill settings to take care of change in feed rates or crush rates and it would automatically adjust itself for the changes.
Theoretically though these and other designs of the Constant Ratio Mills or Auto Set Mills were introduced with great fan fare, particularly abroad and highly elevated expectations of the cane sugar industry, when experienced during actual operations in sugar factories, these could not be said to have delivered desired results and success. Therefore not many installations are available and in fact, in most of the factories, where these and such Mills were installed, hardly any reference is now available. There are many reasons perhaps, some of which are also commercial besides reasons of technical and practical dissatisfactions.

In another development on the same lines, in India also a similar Mill was developed, with slightly different mechanical arrangement as shown in the sketch (Fig: 1.30).
One reason also was that for these mills, pressure feeder systems could not be incorporated due to typical design and configuration of the headstocks and thus improvement or Upgradation in capacities was not possible.

### 1.5.4 OTHER IMPROVEMENT

Since the cane crushing mill is the juice extraction equipment, it follows that enough and easy path be made available for the cane juice to escape out of the equipment. This is also called free and fluent juice drainage. Various provisions made towards this are –

#### 1.5.4.1 MESSCHAERT GROOVES

The base of the normal grooves provided in the Mill Roller surface of the cane crushing mill provides a path for the juice to drain out and escape when bagasse mat is pressed between the surfaces of the two adjacent mill rollers. Study of the juice drainage through the grooves of the Mill Rollers show that there is a tendency of the fibres of the bagasse to form a sort of a bridge at the bottom of the grooves so that on compaction of the bagasse, the flow of the juice out of the grooves is actually resisted and the juice drainage is affected reducing extraction efficiency of the mill. To get over this problem, a solution was found where a deep groove, called The Messchaert Groove, refer sketch, is provided at the bottom of the main groove where the bagasse fibres cannot reach and hence escape path for the juice is readily available, improving the extraction efficiency.
of the Mill. The Messchaert Grooves can be provided for the bottom rollers of the mill only where these provide good results.

![Messchaert Grooves](image)

However such grooves cannot be provided for the top mill rollers because there will not be possibility of juice outlet as in case of the bottom roller of the mill. Also the top roller of any mill delivers or provides the necessary pressure on the bagasse mat for extraction of the juice. This roller therefore is highly stressed and sometimes it is seen to be breaking while working, The Messchaert Groove is likely to weaken the roller.

1.5.4.2 **LOTUS ROLLER**

However there is a need to provide some arrangement for easy juice drainage for the top roller of the mill also. The solution was the Lotus Roller. In this, the roller of cast Iron, similar to the other mill rollers, is provided with a number of radial drainage holes from the root of each groove and are placed at regular intervals around the circumference. These holes drain the juice into axial channels which are running across the width of the roller, and out of contact with the cane are being milled. Specially designed hardened plug with small orifices are inserted into the inlets of the radial drainage holes to obstruct large particle of bagasse from blocking the passages provide
These rollers found satisfying the expectation in general. However, as per the conventional practice followed, such a Lotus Roller is cannot be provided for the last mill. The reason is that the bagasse gets well “prepared” while reaching the last Mill of the Tandem and becomes finer. This increases the chances of chocking or blocking the holes and the whole purpose being defeated. Also cleaning the provided piping becomes very difficult task. Therefore it is strongly advised not to provide the Lotus type Top Roller for the conventional last Mill.