BAGASSE STORAGE AND DETERIORATION

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ABSTRACT

Sugarcane bagasse is now a major source of fiber for pulp and paper making. Its storage and handling is a critical factor in the resulting pulp yield and quality. The causes of the deterioration and the methods of storing and handling the bagasse to minimize this degradation are discussed. Essentially each mill will require its own best system due to the site specific conditions involved. This selection of the most suitable handling and storage system is one of the most importance aspects of a successful bagasse pulp mill project.

A. BAGASSE DETERIORATION

The deterioration of wood, straw, and bagasse fiber is caused by the attack of cellulolytic micro-organisms on the cellulose. Under dry or anaerobic conditions, the attack is much less and can be minimal. Wood submerged in fresh water, for example, will last for many years with little deterioration and the preservation of wood in the pyramids and tombs in the deserts of Egypt, where relative humidity is as low as 4%, is quite remarkable. However, under all conditions, the deterioration of straw and bagasse fiber is more rapid than wood because of the more open and reactive structure of straw and bagasse. The deterioration of bagasse is especially rapid because of the presence of sugars and because the cane is broken up, and consequently presents a large surface for attack by micro-organisms.

As Cusi has noted in a paper on the storage and deterioration of bagasse (1) the presence of residual sugars and other water solubles makes bagasse a very fertile substratum for the growth of all kinds of micro-organisms. The sugars in bagasse are broken down by aerobic bacteria, facultative anaerobes such as yeasts, and anaerobic bacteria into carbon dioxide and water, or alcohol and water, depending on prevailing conditions, with the release of a considerable amount of heat, especially under aerobic conditions. Continuing and side reactions also produce a variety of organic acids.

Since bone dry bagasse contains 8 - 11% sugar and water solubles, this attack on sugars and water solubles by micro-organisms, which results in a substantial weight loss in the bagasse, is practically impossible to prevent if the bagasse is stored, as the attack will occur under aerobic or anaerobic conditions. However, the attack on sugars and water solubles does not result in any fiber damage and is beneficial as pulping chemicals will not be consumed by these substances and also black liquor viscosity is reduced. Because the residual sugars and water solubles are of no value to a pulp mill, bagasse for pulping is frequently purchased on a "sugar-free" or "water solubles free" basis; that is, the weight of sugar and water solubles, is not included in the weight of bagasse purchased.

Some cellulolytic micro-organisms that feed on cellulose will be present under all circumstances. Their number and severity of attack will depend on prevailing circumstances and conditions. They attack pith first and fiber only later, and, if the attack is limited, even the attack on the cellulolytic micro-organisms can be beneficial; for the attack of the cellulolytic micro-organisms loosens the bagasse structure, and the limited deterioration of bagasse thus tends to make depithing easier and more complete.

There is, however, no doubt that the strength characteristics and yield of bagasse pulp will decline if bagasse storage conditions are such as to promote any serious fungal and/or cellulolytic bacterial attack on the bagasse fiber.

Fungi require air and moisture for growth, and bacteria, both aerobic and anaerobic, also require moisture for growth. Thoroughly dried bagasse will not deteriorate appreciably.

The rate of deterioration also depends on temperature. Within particular culture temperature tolerance limits, warmer temperatures will result in faster deterioration.

Under aerobic conditions, deterioration is rapid when the moisture content of bagasse is over 25% as fungi and cellulolytic bacteria need moisture for growth. Under anaerobic conditions, the rate of deterioration is much slower, but it can proceed relatively rapidly at temperatures over 40°C due to attack by thermophylic cellulolytic micro-organisms provided there is sufficient moisture and the pH is high.

However, provided there is sufficient sugar available, lactobacilli (anaerobes that form lactic acid) will also grow under moist anaerobic conditions at higher temperatures (40 - 50°C); and the growth of these bacilli will create an acidic environment which will inhibit the growth of thermophylic cellulolytic micro-organisms.

There are many factors that affect deterioration - method of bagasse storage, type and size of piles, and climatic conditions. It is not readily possible to apply data from one operation to another without considering all factors.

In the case of storage of bagasse in bale form, it is not possible to attain anaerobic conditions. The trick, in this case, is to allow the bagasse bales to dry to 15 - 25% moisture content as rapidly as possible so that fungi and cellulolytic bacteria stop growing or, at best, grow only very slowly.

Bale size is of course a factor. Large bales dry more slowly and get hotter in the interior. If the bales are very large, the slow drying and the heat accumulation in the bales will promote the growth of thermophylic cellulolytic micro-organisms and deterioration of the bagasse in the interior of the bale becomes extensive.

If the climate is hot and relatively dry, and the bales are relatively small, rapid drying can be accomplished by spreading the bales over the ground, or small bales can be hand piled allowing each layer in the pile to dry before placing the next layer.

Where the climate is not so dry somewhat larger bales can be stacked in a pattern (such as used by Cellotex (2)) with internal air channels. The breakdown of the residual sugars and water solubles by yeast enzymes and aerobic bacteria generates sufficient heat to drive off the moisture through the air channels. The air channels also permit the rapid dissipation of heat so that the temperatures do not rise to levels where sugar fermentation by yeasts decreases and the growth of thermophylic cellulolytic micro-organisms is favoured.

The air channels are essential. For if moist bagasse bales are stacked into a pile without air channels, there will still be enough air within the pile to permit attack on the bagasse fiber by aerobic cellulolytic micro-organisms; the moisture will be retained, thereby promoting a continuing attack; and as there is no air circulation, the temperature of the pile will rise quite rapidly and degradation by thermophylic cellulolytic micro-organisms will intensify.

In all of the above cases, fungal and aerobic cellulolytic bacterial attack on the pith and fiber will continue until the bagasse moisture content drops to 20%. After this condition stabilizes and further fungal and bacterial attack on the fiber is minimal.

More recently in an effort to reduce bale handling and storage costs, a sugar mill in Brazil developed a storage system using a bio-chemical catalyst to promote accelerated but controlled fermentation of the residual sugars and water solubles in bagasse to dry very large bales (600 kg) to a moisture content of 20%. This system called the "BAGATEX-20", is currently in use to bale excess bagasse for power generation in public utilities. However, as Acheson (3) has pointed out, there are some distinct advantages if the BAGATEX-20 process is used to store bagasse for pulp production. Because of the rapid drying by controlled fermentation, the deterioration of the bagasse during the drying period is reported to be minimal with no appreciable loss of brightness.

If the climate is very humid and wet, no matter how the bagasse bales are piled, deterioration will be more rapid unless the piles are protected or under sheds. The addition of borax, fungicides and the like may also be of help.

In the case of bulk storage, there are two types of storage; storage in moist bulk piles and storage in wet bulk piles.

Moist bulk piles are piles of bagasse at roughly 50% moisture content. Loose, moist bulk piles contain considerable quantities of air and will retain moisture, thus fungal and aerobic cellulolytic bacterial attack on the fiber will continue. Also, as there is no air circulation, the pile temperature will rise; favouring rapid thermophylic cellulolytic bacterial attack on the fiber. Deterioration of bagasse in such piles is rather rapid, even though fungal attack may be suppressed by the high carbon dioxide content in the pile from the breakdown of the sugars.

Deterioration can be reduced by compacting the piles and several pulp mills have adopted compacted moist bulk storage. However, sufficient air remains to result in significantly more deterioration than in wet bulk piles. In countries that have a long cane crushing season and storage requirements are relatively short term in the case of lower pulp for lower grade papers, moist bulk storage could be advantageous as corrosion problems are far less.

Wet bulk piles are saturated with water which displaces the air, and, if in addition, the pile is compacted to improve anaerobic conditions in the pile, fiber deterioration can proceed only by the attack of anaerobic cellulolytic micro-organisms.

Under anaerobic conditions at temperatures below 30°C, the attack on bagasse fiber by cellulolytic micro-organisms is insignificant and only fermentation of sugars by yeasts occurs. The anaerobic fermentation of the sugars and water solubles at low temperatures by the yeasts produces primarily, alcohol, carbon dioxide and heat; though some organic acids are produced as well. As the temperature rises above 30°C due to the anaerobic fermentation of the sugars, the activity of the yeasts declines and the activity of thermophylic cellulolytic micro-organisms increases but still remains relatively insignificant up to about 40°C.

Above 40°C the activity of thermophylic cellulolytic micro-organisms will increase and can increase rapidly at temperatures approaching 50°C unless the pH of the bagasse pile is low. A low pH inhibits the growth of thermophylic cellulolytic micro-organisms.

An acidic environment which inhibits the growth of thermophylic cellulolytic micro-organisms can be created at this stage by bacteria that convert sugars into organic acids at relatively high temperatures (temperature levels at which thermophylic cellulolytic micro-organisms are also active) provided that enough sugar is available for the growth of these acid forming bacteria; largely, lactobacilli. An acidic environment can also be created simply by addition of acids.

In the Ritter process, which is basically a wet bulk storage system, a bacterial culture (largely lactobacillus) is deliberately added to the bagasse to promote more rapid fermentation, a rapid decrease of sugars and water solubles, and a resultant rapid decrease in pH due to the formation of lactic acid, which results in the better preservation of the bagasse and bagasse brightness. Molasses may also be added to assure that the growth of lactobacilli is predominant when temperatures are reached that would favour the rapid growth of thermophylic cellulolytic micro-organisms (50°C).
If a bacterial culture is not added in advance, yeasts and anaerobic bacteria will enter the system by themselves, multiply and break down the sugars and water solubles into alcohol, carbon dioxide, and organic acids. The only difference is that the fermentation takes more time, the desirable drop in pH does not occur as rapidly as with the Ritter process, and, consequently, there is the danger that the thermophylic cellulolytic micro-organisms could become dominant with serious degradation of the bagasse. This can be overcome by adding formic or sulphuric acid to the water used for building up the wet pile so that the pH will be low enough (3.5 - 4.5) to inhibit the growth of thermophylic cellulolytic micro-organisms.

Early acidification will hinder the development of anaerobic cellulolytic micro-organisms and favour the growth of lactobacilli even if the residual sugar content of the bagasse is relatively low.

In wet bulk piles, fiber deterioration is minimal within the pile where anaerobic conditions prevail. Deterioration is limited to the outer surface of the pile. Obviously, as the surface of the pile increases as the square, whereas the volume increases as the cube, large piles will have a much smaller surface area compared to the volume and, consequently, the percentage of deterioration is smaller.

Thus, in the case of wet storage piles, the important factors in reducing the degrees of deterioration are:

1) thorough wetting of the pile and compaction to create the highest anaerobic state possible;

2) maximum pile size to minimize the deterioration on the surface;

3) early or rapid acidification.

The extent of deterioration on the surface of a wet bulk pile also depends on climatic conditions. If the climate is wet, so that the whole pile can be readily kept wet, surface deterioration is limited to 15 - 30 cm at the end of a 4-month storage period. If the climate is very dry and there is a considerable loss of water at the surface, the zone of deterioration can move inward and losses may be higher. It should be possible to offset this by providing a continuous spray of recycled water.

Deterioration of bagasse fiber is minimal within a properly designed and properly operated wet bulk storage system for periods of well over one year. In the case of the Ritter system, it is claimed that bagasse can be stored for up to 18 months without serious degradation of bagasse fiber.

In Peru, where only short-term storage is required because of the long cane crushing season and mills have no chemical recovery, weak black liquor is sometimes sprayed onto moist bulk storage piles to neutralize the acids formed; largely to prevent corrosion of the storage slab and equipment. As the storage time is so short, little damage is done. The use of black liquor on long-term storage piles is detrimental.

The formation of organic acids by fermentation and/or the addition of acids to wet bulk storage piles creates corrosion problems. Slabs under wet bulk storage piles made of concrete will be subject to corrosion and will need to be resurfaced rather frequently. Asphalt surfacing has been proposed, but the danger is that particles and fragments of asphalt may enter the pulp mill which is decidedly detrimental. Epoxy resin and other plastic coatings can be used to protect the concrete but are expensive. The use of sulphur concrete for wet storage pile slabs is another solution.

The choice of the type of storage depends on the number of sugar mills involved, transport distance, means of bagasse delivery, and the length of the cane harvesting season. If conditions are such that either of the two basic long-term storage systems (bale storage and bulk storage) may be used, the wet bulk pile system is to be preferred as handling costs are lower and storage losses are lower especially if the bale system uses smaller bales. Also in most cases, bagasse in bulk piles can be stored for longer periods of time without appreciable deterioration. Only the BAGATEX-20 system is comparable in this respect.

Salabar and Maza (4) have pointed out that wet bulk storage is beneficial in many respects which has been confirmed by several mills. Thus, in the case of wet bulk storage, it is preferable to "age" or "condition" fresh bagasse by storage for a period of 2 - 4 months before use in a chemical pulp mill as the use of "aged" bagasse results in:

1) better final pith removal

2) better pulp quality and uniformity

3) higher unbleached pulp brightness

4) better pulp drainage characteristics

5) lower chemical consumption

6) less foaming

7) lower wash water consumption

8) higher weak black liquor concentration

9) lower black liquor viscosity

Both in the case of conventional baled storage (the BAGATEX-20 bales are an exception) and wet bulk storage, the unbleached chemical pulp brightness decreases on prolonged storage (more than 6 months). The darker pulp obtained because of prolonged storage is, however, as easy to bleach as unbleached chemical pulp from fresher bagasse.

The situation is somewhat different if RMP, TMP, CMP or CTMP (the so-called "mechanical" bagasse pulps) is to be produced from bagasse that has been stored for a considerable length of time. To maintain the desired opacity, peroxide bleaching is required for these pulps. However, the stored bagasse may darken to the point where peroxide bleaching will no longer brighten the "mechanical" bagasse pulps to acceptable levels of brightness.

For this reason, the Ritter bulk storage system, which has the least drop of brightness is favoured for mills producing "mechanical" pulps for the production of newsprint. However, the best solution to the brightness problem in bagasse newsprint mills is probably the use of the BAGATEX-20 bale system.

If the bagasse is properly stored by either of the two basic long-term storage systems, there is little, if any, deterioration of pulp strength properties; and, as mentioned above, in the case of chemical pulping, "aging" improves pulping operations. Improperly stored bagasse can deteriorate quite rapidly with serious loss of pulp strength properties.

B. BAGASSE HANDLING AND STORAGE

In all cases, bagasse for pulp production should be moist depithed as soon as possible and stored before deterioration starts when bagasse leaves the sugar mill. Preferably the bagasse should be moist depithed at the sugar mill whenever feasible. Bagasse is moist depithed at the pulp mill only if the bagasse comes from many very small sugar mills; mills too small to justify moist depithing at the sugar mills.

Bagasse may be brought to the pulp mill in bales or in bulk form and may be stored in bale or bulk form.

If the bagasse has arrived at the pulp mill in bale form and has not been moist depithed at the sugar mill, it is dry and wet depithed after reclaim from storage.

If the bagasse arrives in bulk form and has not been moist depithed at the sugar mill, it should be moist depithed before bulk storage.

Bagasse bale sizes range from a moist weight of 30 to 800 kg. The lightweight bales were developed for manual handling; handling of the heavier bales must be either partly or entirely mechanical.

There were problems with the very large bales (400-800 kg). Deterioration was often extensive, especially at the centre of the bales, as the heat from fermentation could not be dissipated fast enough and moisture could not escape readily. Attempts to produce large bales with holes in the middle for the escape of heat and moisture did not result in any great improvement.

As mentioned previously, this problem has been overcome by BAGATEX-20 system for the rapid drying of large bales (400-800 kg) from 50% moisture to 20% moisture. Drying time to 20% moisture content is 20-25 days, as compared to the usual 70-100 days for the drying of large bales. Furthermore, the process is reported to stabilize the bagasse so that there is no deterioration or loss of brightness for up to two years storage.
In the case of small bales, baled bagasse storage piles or ricks are built up with the same type of bale stacking conveyors and cranes as used for small straw bales.

In the case of larger bales, cranes fitted with bale clamps that can lift several bales at a time are used to lift bales off trucks and to put them on the piles.

Very large bales are handled by crane and large wheel forklifts.

Baling is, however, costly, and storage and handling costs are high. Also, bale storage involves a very considerable and unpredictable fire risk; even more so, if the bagasse bales have been stacked moist with air channels to promote drying. These same air channels will promote faster combustion, and, once a fire starts in such a pile, it is virtually impossible to extinguish.

Today, baling is used only if transportation distances are very large (in excess of 100 km), the bagasse comes from many small sugar mills, or the BAGATEX-20 system is used to preserve bagasse brightness for the production of mechanical bagasse pulps.

The usual systems used today involve bulk handling, transportation, and bulk storage. The method of transportation depends on the location of the pulp and paper mill with respect to the sugar mill or mills. Ideally, the pulp and paper mill should be located adjacent to a sugar mill large enough to supply all the bagasse required. The moist depithed bagasse can then be supplied to the pulp and paper mill in aqueous suspension by pipeline or flume, or by belt conveyor.

If the distance to the sugar mill is considerable, the bulk density of bagasse may be increased by passing the bagasse through compactors, which are similar to balers except that no tieing is involved. The compacted bagasse is then loaded into high-sided railway cars or trailer trucks for transportation to the pulp and paper mills. Such bulk transport is generally economic for distances up to 100 km. The trucks or railway cars are dumped at the pulp and paper mill, and the bagasse is stacked into piles mechanically, pneumatically or hydraulically.

For the mechanical stacking of bagasse onto moist or wet bulk storage piles, a variety of drag-flight and belt conveyor systems have been used to build up piles to a height of 20-25 m. Drag-flight conveyors are used for steep inclinations and for relatively small storage piles.

Belt conveyors are used for horizontal transport of bagasse and small inclinations (12-15° or less). Fixed elevated belt conveyors, with or without travelling trippers or low-level belt conveyors fitted with mobile stackers, are used for large storage piles. The mobile stackers can be travelling stackers that can travel back and forth along the length of the belt conveyor and may have fixed or adjustable height arms. A tripper in the stacker diverts the bagasse to chain or drag conveyors on the arms which lift the bagasse onto the top of the piles.

Alternatively, the low-level belt conveyor bringing bagasse to storage can be fitted with a long-radius revolving stacker or a short-radius pivoting stacker that piles the bagasse into horseshoe-shaped or semi-circular piles (similar to those usedfor piling short pulpwood, but smaller and lighter in construction, or some of the chips storage systems). If a long-radius stacker is used,as was used at the Valentine Pulp and Paper Co. mill, a belt conveyor can be used to bring the bagasse to the top end of the stacker as the inclination is low. If a pivoting stacker is used, a drag-flight conveyor must be used on the arm as the inclination is usually steep.

In the case of moist bulk storage, the bagasse is constantly compacted as the pile grows. If wet bulk storage is used, sufficient acidified water should be added to the discharge chute as the bagasse is discharged from the belt conveyor to arrive at an 80% moisture content in the bagasse pile. The height of mechanically piled bulk storage piles may reach 25 meters. Bulldozers are used to compact and shape the piles. It is essential that the piles are well compacted to exclude air; otherwise, considerable deterioration of the bagasse can occur. The piles are then maintained at 80% moisture by water sprays. Belt conveyor systems are expensive but have a low power consumption. Protection against corrosion can be a problem if belt conveyors are used to reclaim bagasse from wet bulk storage.

In pneumatic systems, the bagasse is transported through pipelines to storage piles by means of positive air blowing systems similar to those used for piling wood chips. A fixed pipe system to which sections may be added as the pile grows can be used, or the pneumatic transport pipes can terminate on one or more pivoting booms at the piling area that can be raised or lowered to distribute the bagasse onto circular piles; again, a system similar to that used to pile wood chips, as described by Kopfmann (5). Water may be sprayed into the pneumatic pipeline just ahead of the discharge, or water may be added immediately after the bagasse is discharged. Power consumption is high but lower than for hydraulic systems.

In the hydraulic system, the bulk bagasse, as received, is fed into slushers where it is mixed with return water from the piles and clarified excess white water from the pulp mill. The bagasse is then pumped at 2.5 to 3.5% consistency through pipes (part permanent, part moveable) to a paved surface. The water drains away and a pile is built up. The delivery pipes are extended and adjusted to build up the pile. The water flows through the pile and is returned to the slusher.

Usually, there are three piles (one being built up, one being reclaimed, and one dormant), and piping is arranged in a loop about the piles. The piles are operated on a first-in, first-out basis.

Alternatively, the bagasse may be pumped to a mobile tower on rails fitted with a pipe on a boom at the top that builds up one long pile as the tower is moved to various positions along the track where it can be connected to a pipeline parallel to the track. (See Fig. 1) (4)

A variation of this, by the writer, is the pivoted adjustable height pipeline stacker. In this arrangement, the pipe supporting tower runs on a semi-circular track. The bagasse/water slurry is pumped to the stacker through a rotary joint; hence, there is no need to connect and disconnect the piping as the tower is moved. The pipe boom arm can be raised as the pile builds up; thereby allowing the pile to be build up without disturbance. The pile width can be extended by placing lightweight flume sections on the top; and, as the slab where the transport water is reclaimed is sloped to the pivot point, the distance the return water must flow is always the minimum. By also locating the slusher for reclaimed bagasse at the pivot point, the distance that reclaimed bagasse must be moved is also always the minimum. (See Fig. 2) Semi-circular piles can also be piled and reclaimed on a first-in, first-out basis.

When piling begins, the bagasse transport water should be acidified with sulphuric or formic acid. In a short time, fermentation of the residual sugars provides the organic acids that maintain a low pH in the pile, and further acidification is no longer required. A low pH (3.5 - 4.5) is desirable as the growth of microorganisms that attack cellulose is inhibited. Alternatively, a culture of lactic acid bacteria (Ritter system) can be added to the bagasse transport water to assure an even more rapid drop in pH and better preservation of brightness. Wet bulk piles reach a height of 20 meters or more, and are shaped and compacted by dozers.

Care must be taken to avoid many bends in the pipelines; otherwise, they will tend to plug. Pipeline velocities or bagasse/water slurries should be about 2.5 m/s and should not be lower than 1.75 m/s. For short lines, the velocity may be as high as 4.0 m/s. As the bagasse slurry dewaters readily, flow control by valves can lead to plugging of the pipelines; variable speed pumps should be used. Pipelines and pumps must be of stainless steel.

Large centrifugal traps can be installed both in the bagasse slurry transport line and in the return transport water line to remove stones and dirt, and pumps can be protected against large stones by gravity traps ahead of pump suctions. However, regardless of precautions taken, wear on pumps in hydraulic systems is high and standby pumps are required.

An alternative to using pipes is to build up the piles by an overhead flume over the length of the storage area at a height of 15 to 18 m. The bagasse slurry is pumped from the slushers to the flume which is fitted with a series of gates from which the bagasse slurry is discharged onto the appropriate storage area.

The flume has a slope of 1.5 to 2% and is usually equipped with gravity stone traps.

The flume supporting columns are frequently concrete as is the paving material used under the piles. Concrete is, however, subject to corrosion by the organic acids created by the fermentation of the residual sugars and other water solubles in the bagasse. A protective coating, such as epoxy resin, should be used to prevent corrosion of the wet bulk storage slabs and the concrete columns if used to support a fume. Asphalt is not very suitable, as pieces are usually picked up when the bagasse is reclaimed. Asphalt is difficult to remove before or after digesters and can cause many problems throughout the pulp and paper mill.

The wet bulk storage slabs at some bagasse pulp mills have rather elaborate systems of drainage trenches with covers for the collection of the return transport water that drains through the piles, as well as trenches for reclaiming the bagasse in aqueous suspension. Such trench systems are costly because of the form work required and even more so because of the corrosion protection required. A much simpler solution is to use as few trenches as possible and to use slopes and depressed areas to guide the return transport water to the collection tanks. Form work costs are then minimal and protective coatings are easy to apply.

Loose bagasse piles built up mechanically or pneumatically with moist bagasse are only suitable for short-term storage as sufficient moisture and oxygen remains in the pile for deterioration of cellulose to continue. However, if bulk piles of moist bagasse built up mechanically or pneumatically are moistened and compacted by bulldozers to limit the presence of air, deterioration is inhibited and bagasse can be stored for somewhat longer periods.

The piles built up hydraulically are wet and do not represent any fire hazard. Fires can start and smoulder in moist bagasse piles built up mechanically or pneumatically due to the heat generated by fermentation of residual sugars.

Although such fires are very difficult to put out, the hazard of a major fire is small. Dust from dry or moist bagasse operations can cause respiratory problems ("bagassosis"). These problems are largely avoided if the bagasse is handled hydraulically and storage is in wet bulk form.

Fermentation in wet bulk piles consumes the residual sugars in about one month. The acidic conditions and shortage of oxygen in dense wet piles inhibits the growth of fungi and other microorganisms such as clostridia bacteria that attack cellulose. Losses are, consequently, very low. Bulk storage piles give off an unpleasant odour due to the fermentation reactions. Also, wet bulk storage piles built up mechanically or pneumatically and maintained at 80% moisture content by water sprays will develop a very dark, foul, almost black effluent with a very high B.O.D. which can present a disposal problem in the case of mechanical or pneumatic bagasse handling systems. In the case of hydraulic bagasse handling systems, this effluent from the stored bagasse is combined with the bagasse transport water, and the problem is largely avoided.

The bagasse for pulping is recovered from bale storage by crane and truck. The bales are broken up in a bale breaker and fed to a wet depithing system. A tub grinder is required to break-up very large bales. The bagasse may be wet depithed in a hydrapulper and screening system, or a wet depither and washing system, to remove the residual pith, as well as stones and sand.

Bagasse may be recovered from bulk storage piles:

- mechanically by bulldozers and front-end loaders discharging bagasse into feeders and conveyors;

- or hydraulically by front-end loaders feeding a slusher from which the bagasse is pumped to the mill.

If the bagasse is reclaimed from moist or wet bulk storage mechanically, the bagasse is fed to a wet depithing system similar to that used for baled bagasse but without a bale breaker. If the bagasse is slushed and transported from storage hydraulically, the slushing and pumping releases the residual pith, and all that is required ahead of the digesters is a trap or a riffler to remove stones and sand, and a screen to effect the wet depithing by draining off the transport water and pith.

The dewatering drum or rotary drainer developed by the author can be used for draining water from a bagasse/water slurry and for wet depithing after bagasse storage. The discharge consistency is 10-12%. Its chief drawback is that some of the bagasse sticks vertically in the screen perforations and the unit must be cleared of impacted material periodically. This is, however, easy to do with a special tool.

If the dewatered bagasse must be elevated, a very simple solution is to use a drag-flight conveyor fitted with a perforated bottom (3-6 mm diameter holes) through which the water drains. This accomplishes both drainage and elevation in one step. Also, the unit is self-cleaning since the flights drag the bagasse across the perforations; shearing off or dragging out any bagasse that has stuck vertically in the perforations.
As elevation of the bagasse is not always necessary, a horizontal drag-flight drainer (see Fig. 3) can be used. This is essentially a short, horizontal drag-flight conveyor fitted with a perforated plate drainer bottom. The length and width, and speed and depth of the flights are selected to suit the dewatering capacity desired. The drainage widths range from 75 to 90 cm with flight depths of 20 to 30 cm. The speed is in the order of 30-45 m/min., and the overall length may reach 10 m. The flights which transport the bagasse across the perforated plates are fitted with rubber scrapers that keep the perforated plates clean.

The drainage water tray, under the perforated plates, may be divided into compartments to permit recycling of only a portion of the water with the balance going to sewer. The discharge consistency from the unit is about 15%.

Another self-cleaning unit which also permits washing of the dewatered bagasse is the "Circular Dewatering Table" (see Fig. 4). This is a patented design invested by J. Badiuk. The circular Dewatering Table is an annular tub with a perforated stainless plate drainage surface on the bottom, on which the slurry of bagasse fiber is dewatered. The slurry enters the tub from a headbox and is transported over the perforated plate by a series of paddles fitted with rubber or neoprene scrapers connected to drive arms projecting from a vertical drive shaft. The drained water is collected under the perforated plate and returned to the process. During the transport of the slurry, it can be dewatered and then washed a number of times if desired. The dewatered fiber, at a consistency of about 15%, then drops to a discharge chute located at about 320 degrees from the point of entry that passes through the perforated plate and the bottom of the tub.

The outside diameter of the circular tub is varied depending on the capacity required. The speed of rotation of the drive shaft depends on the application; dewatering or washing. For dewatering with series washing, the speed is 5 - 6 RPM.

Yet, another dewatering device consists of one or more inclined screw conveyors fitted with perforated troughs. The edges of the screw flights are fitted with nylon brushes that keep the perforations clean. Discharge consistency is 12 - 15%.

If the digesters are continuous, the wet depithed bagasse, with a dry fiber content of 12 - 15%, can be fed directly to the digesters, as the digester feed screw will press the bagasse to a dry content of 30 - 35%. If batch digesters are used, presses are required ahead of the digesters to reduce the water content of the bagasse to decrease steam consumption.

Fiber losses (as distinct from losses of residual sugars and dirt) are 6 - 12% for bale handling and storage; fiber losses in wet bulk storage piles are 2.5 to 5%.

The amount of insoluble material removed on wet depithing is usually 5 - 10%. If the bagasse has been stored in wet bulk piles, the material removed by wet "depithing" is fine dirt and about equal portions of fines and pith. If the bagasse is wet depithed immediately after moist depithing or the bagasse is from bale storage, the amount of bagasse fines removed will exceed the amount of pith removed; and it may be necessary to increase rejection rate to 15% to attain the desired degree of pith removal. The residual pith content after moist depithing should be in the order of 12 - 16% but is often as high as 18%.

Disposal of pith from wet depithing can be a problem. Wet pith is slow draining, especially wet pith from the wet depithing of bagasse stored in wet bulk piles. The simplest solution is to dump the wet pith into an old quarry or other depression, a large swamp or a desert area. Where this is not permitted or not feasible, other means of disposal must be applied.

Dumping the pith into irrigation systems is a good solution if the pith can be distributed over a large area and the irrigated land is ploughed regularly as the pith, being organic material, acts as a soil conditioner. If this is not feasible, then the wet pith must be dewatered and pressed before being trucked away for land fill or before incineration.

The best method for dewatering the wet pith is to pass the pith and water over DSM screens or gravity disk-type rotary strainers. DSM screens work well in the case of wet pith from a wet depithing operation immediately following moist depithing. The wet pith removed after long-term wet bulk storage tends to be slimy and DSM screens may blind. The gravity disk-type rotary strainers are better for thickening wet pith removed after long-term wet bulk storage. For final thickening to a high consistency, twin-wire sludge belt thickeners can be used. Unfortunately, belt thickeners currently available are unable to press wet pith to a moisture content low enough to sustain combustion; the moisture content remains at about 75 - 80% despite claims that moisture contents of 65 - 70% and lower can be achieved.

Land fill is not a good solution unless the pith is buried. Wet pith dries to a fine, light powder that may cause dust problems. Incineration of the wet pith may be the only solution.

If wet depithing is immediately after moist depithing, the thickened and pressed wet pith can be mixed with the pith from moist depithing and burned. This, of course, reduces the fuel value of the pith from moist depithing. If wet depithing is after wet bulk storage and the cane crushing season is relatively short, the wet pith must be incinerated separately. A fluidized bed reactor is a good but expensive solution.

Figure 5 shows a typical bagasse depithing, handling and wet bulk storage system.

CONCLUSIONS

Long-term storage of bagasse (in excess of 3 months), is required for almost all bagasse pulp mills. As moist bagasse is an ideal medium for the growth of micro-organisms, the deterioration of bagasse in storage can be rapid and extensive with a resultant loss of raw material, a loss of pulp quality, and a loss of brightness.

However, a variety of storage systems have been developed that have proven to be successful in reducing or avoiding high storage losses, and in maintaining pulp properties and reducing brightness losses.

The handling and storage system that should be used will depend on; local conditions, the number of sugar mills involved and their location with respect to the bagasse pulp mill. The selection of the most suitable handling and storage system is one of the most important aspects of a bagasse pulp mill project.

REFERENCES

1. Cusi, Dr. D.S., "Storage and Conservation of Bagasse", Progress Report No. 10, TAPPI, Atlanta, Georgia (1979).

2. Munro, Mr. T.B. and Lathrop, Mr. E.C., "Fiber Storage and Preservation", U.S. Patent 1,920,129 (1933).

3. Atchison, Dr. J.E., "The Bagatex-20 Process for Rapid Drying and Preservation of Bagasse and Large Bales by Accelerated and Controlled Fermentation", Progress Report No. 18, TAPPI, Atlanta, Georgia (1988).

4. Salabar, Mr. Juan and Maza, Mr. Francisco, "Ritter Biological Treatment Process for Bagasse Bulk Storage", Progress Report No. 2, TAPPI, Atlanta, Georgia (1970 revised 1975).

5. Kopfmann, Mr. K., "Storing Bagasse Under Hot and Arid Climatic Conditions", Progress Report No. 14, TAPPI, Atlanta, Georgia (1983).

Fig.1 – TRAVELLING TOWER HYDRAULIC BAGASSE STACKER

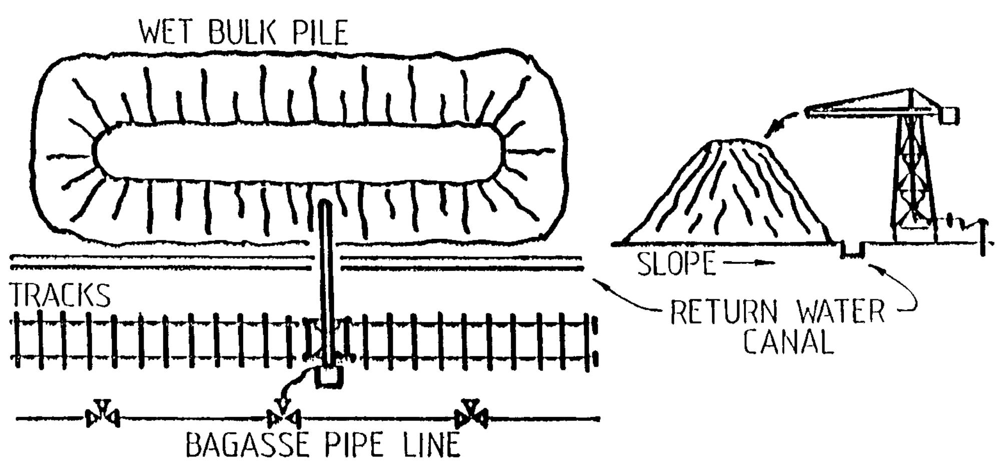

Fig.2 – ADJUSTABLE & PIVOTING HYDRAULIC BAGASSE STACKER

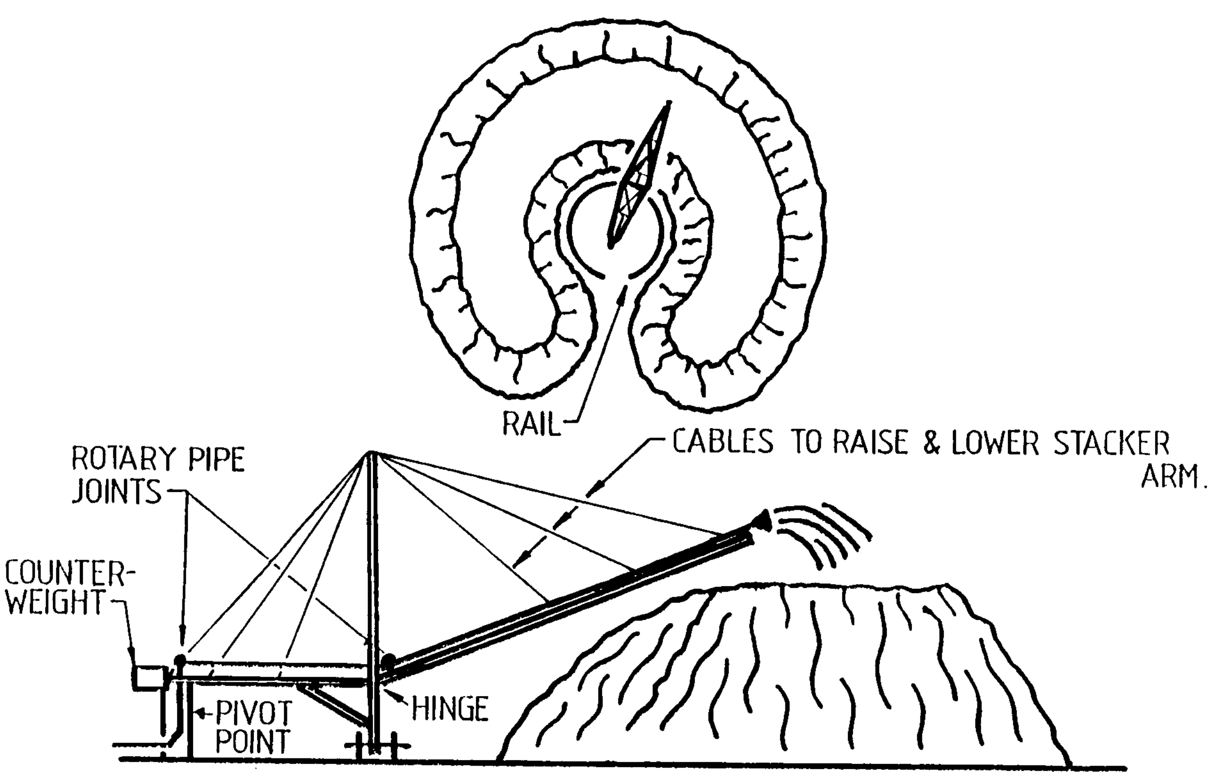

Fig.3 – HORIZONTAL DRAGFLIGHT BAGASSE DRAINER

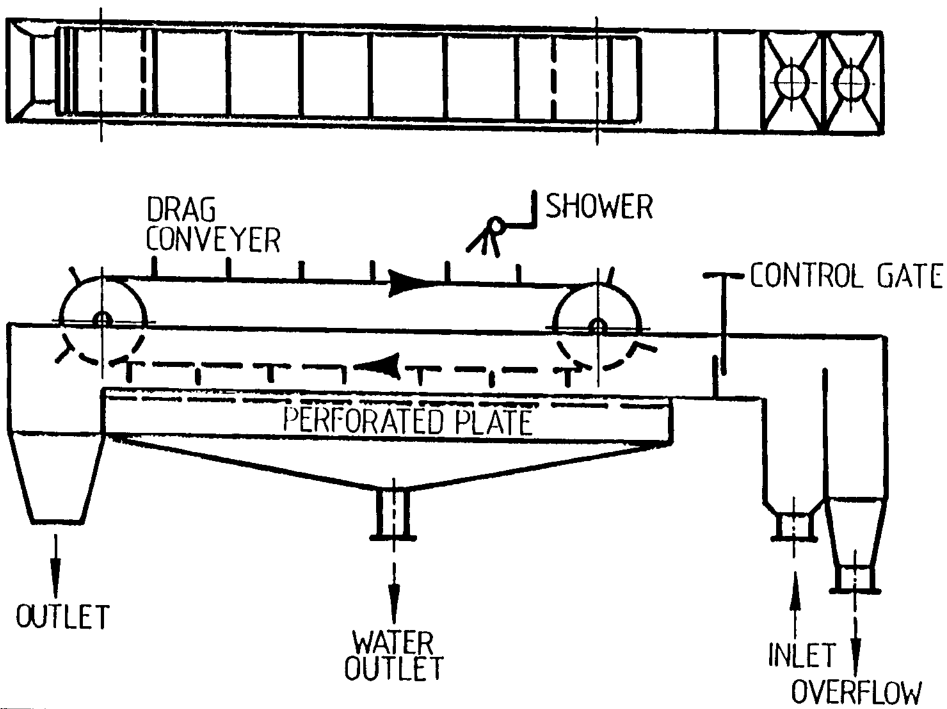

Fig. 4 - BAGASSE DEPITHING AND WET BULK STORAGE

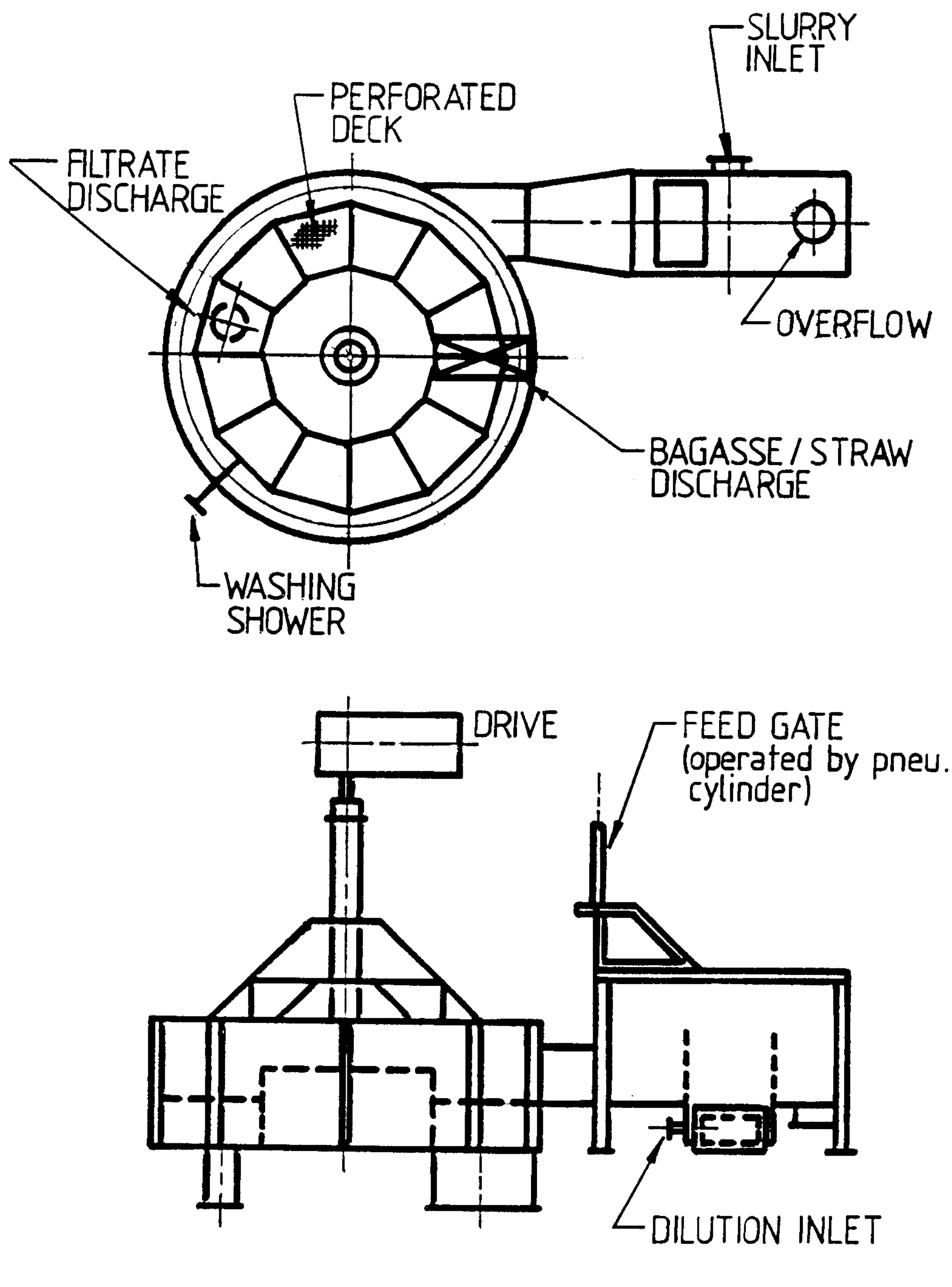

Fig. 5 - BAGASSE DEPITHING AND WET BULK STORAGE