

BELT VS CHAIN-SLAT BAGASSE CONVEYORS FOR BOILER FEEDING

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Abstract

Every mill in Southern Africa feeds at least part of its bagasse as fuel into boilers from a conveyor.

There has been much debate as to the relative merits of belt conveyors with ploughs vs. chain-slat conveyors with gates for this application. There are experienced engineers in strong support of each alternative. In many cases, the strength of the support for one type is due to bad experience with a poorly designed or under-capacity conveyor of the other. Unfortunately, the majority of conveyors in the industry are less than ideal designs, despite the “red line” importance of these conveyors for reliable sugar mill operation.

This paper addresses common faults in the designs of both types of conveyors and suggests key features for good designs, including some which are seldom incorporated. Practical operating tips are given.

In conclusion, a listing is given of some relative advantages and disadvantages of each conveyor type for this application.

Introduction

There have been many dramatic changes to the requirements for boiler bagasse feeding over the 36 years of the author's experience in the Southern African sugar industry:

- Heavy duty shredders have greatly improved cane preparation.
- Diffusers have reduced the comminution of bagasse previously done through long milling trains.
- Improved mill roller roughening techniques have increased the comminution in the mills which remain.
- Cane varieties have changed (no varieties as ‘tough’ as N50/211 are now approved for use).
- Few wide, open-mouth furnaces, such as the stepped grate, horseshoe or Eisner types, are left in service.
- Multiple small, labour-intensive boilers with minimal automation have been replaced by a few large, highly mechanised units.
- Modern compact, highly rated furnaces generally require high bagasse feed rates through relatively small openings into long, enclosed boiler feed chutes.
- In 1964, many mills' bagasse reclaim systems were manually loaded from a store or from piles kept on the boiler firing floor; now nearly all have high capacity mechanised systems.

- In 1964, the highest Southern Africa factory crushing rate was 216 tch, with no others reaching 200 tch. In 1999 (a “slow” season), the highest was 532 tch, with six mills (including two in Zimbabwe) crushing at over 400 tch. Bagasse conveyors are accordingly very much larger.

These changes have caused all factories to spend substantial sums on new boiler bagasse conveyors. Few of these have proved entirely successful immediately, except as engineers' training equipment!

All factories currently use either belts with ploughs or chain-slat conveyors with gates for supplying bagasse into their boilers, although other systems (e.g. pneumatic) are theoretically possible. Characteristics of the two common systems are discussed below.

Belt Conveyor Systems

Chain-slat conveyors were almost universally used in 1964. In his Cane Sugar Handbook of that year, Meade stated, “the bagasse is carried directly from the mills to the boilers by carriers of the drag type...”(Meade, 1964), with no mention of belt conveyors. Subsequently, cost considerations and higher capacity requirements encouraged engineers to try to feed bagasse into boilers directly off belts. Some installations involved each discharge being taken off from the head of one of multiple conveyors (see Figure 1), but the finer bagasse from modern shredders made it feasible to plough off from belts and this is the system now generally used.

In the ploughing zone, the belt is normally contained within a flat-based trough. Because of the downward pressure under the ploughs, aero-belts cannot be used in this zone.

The ploughs are usually of steel, with inverted angle, flat angle or tee cross-section. They sometimes incorporate a wearing strip of high density plastic or polyurethane. The ploughs may be fixed, but most are pivoted round an anchor which may be at the discharge end or suspended from above the conveyor, usually at the upstream end of the plough. Some installations – first seen in Australia – involve ploughs supported at both ends across the belt, which are lowered into the bagasse flow as

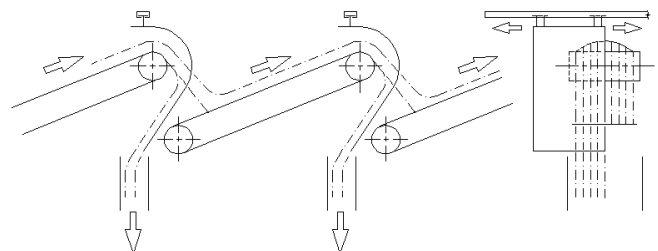


Figure 1. Feeding from multiple belts.

required. The majority of ploughs are straight, but the most successful of those known to the author is a design curved forward towards the discharge end, introduced in 1985 by the Felixton II design team under Robin Renton (hereafter referred to as the 'Renton' plough) (see Figure 2). It is interesting to note that Conveyquip incorporate a parabolically curved plough in their patent for use in other bagasse applications (Anon, 1999) (see Figure 3). Komati mill also uses curved ploughs. The curvature initiates bagasse movement along the plough at an acute angle of approach; by the stage where the plough is more square to the belt travel, the bagasse on the plough already has a component of momentum across the belt.

Fixed ploughs have generally not been successful, although at the former Mt. Edgecombe Mill they worked reasonably satisfactorily feeding very fine milling tandem bagasse from a lightly loaded belt into the last boiler along the line. Most ploughs are actuated by pneumatic cylinders, called by proximity sensors measuring the bagasse level in a boiler feed chute. The Mt. Edgecombe ploughs were eventually converted to pivoted, weight-actuated against a choke-fed chute. The Renton ploughs followed this development and are either spring- or weight-loaded against a full chute.

Some features of well-designed belt and ploughs systems:

- A belt of adequate width for the duty.
- A belt speed of not more than 1,1 m/sec.

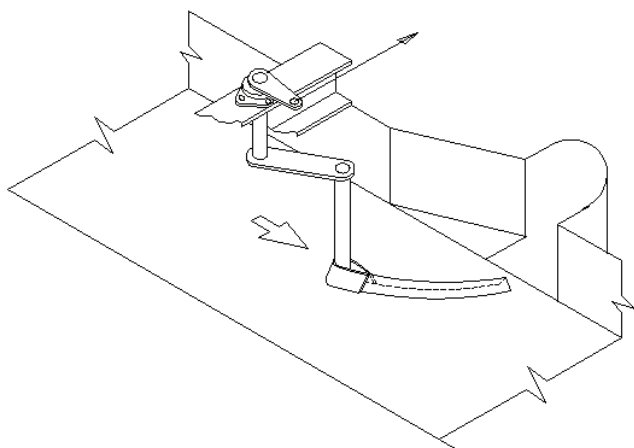


Figure 2. The 'Renton' plough concept.

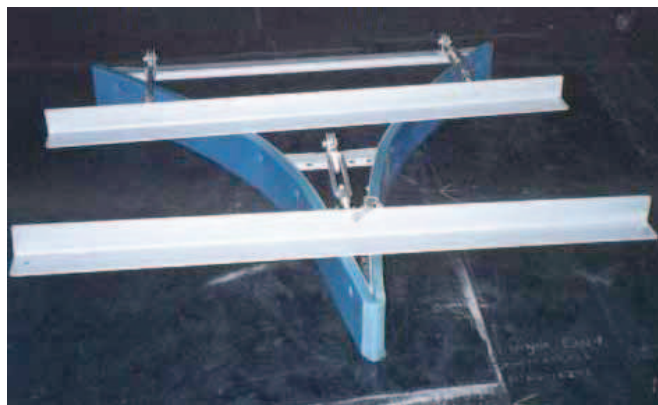


Figure 3. Conveyquip parabolic diverter plough.

- A belt of correct construction for the purpose, with respect to both carcass and covers.
- The belt installed such that the edges try to curl down, not upwards, to prevent bagasse ingress under the edges. With conventional dual cover belts, this requires having the thinner cover on top, contrary to usual conveyor practice.
- A cross-stabilised weave (at 10% cost premium) helps to prevent the edges curling upwards.
- A "friction backed" belt can be used to reduce friction drag. This is a belt with no cover over the fabric carcass on the underside. For such belts, one ply more than usual (e.g. 5-ply instead of 4-ply) should be used to maintain adequate strength once the bottom ply wears.
- A belt splice of not less than 1,5 m (preferably 2,0 m), with the top cover splice trailing.
- Every pulley (including the head- and tail-pulley) and every idler square to the conveyor centreline.
- If the return is on idlers (i.e. not also in a solid trough), good training arrangements to ensure accurate feed into the trough. Note that training these belts is made more difficult by their slow speed.
- Head- and tail-pulley diameters of not less than 600 mm and snubs not less than 400 mm.
- A bagasse clearing scraper on the tail-drum to prevent bagasse build up which can cause tracking problems; alternatively, a self-cleaning tail-drum of slatted perimeter around a double-coned core.
- An appropriate belt tensioning device which maintains correct tension and alignment under all operating conditions.
- A good scraper arrangement immediately after the head-pulley to minimise dust off the return.
- Ploughs preferably of the 'Renton' type as used in Felixton and in 1999 trials at Malelane. These are pivot-mounted, curved in shape and of a cross-sectional profile which allows excess bagasse to flow over the plough. They can be tensioned by adjustable springs, counterweights or pneumatics. When properly positioned and tensioned, these ploughs maintain full boiler chutes. (The most common types of plough in the South African industry are actuated on-and-off by low- and high-level sensors in the boiler chutes. This not only requires instrumentation that sometimes fails, but creates dust blow-back from the windage associated with the falling bagasse. Choke-fed chutes are also preferred because they provide constant density to the boiler bagasse feeders.)
- Any protrusions into the bagasse flow, such as suspended pivot arms and the leading end of ploughs, should be generously rounded (radius > 30mm) to prevent chokes building up from 'wrapping' of bagasse fibres.
- A trough under the belt either of 3Cr12 (polished before first use) or of mild steel lined with rubber-backed UHMWE (ultra high molecular weight ethylene).

- An overall design that allows for belt replacement and splicing to be as easy as possible.
- A closed circuit television (CCTV) system to enable monitoring from a floor-level control centre.

Chain-slat conveyors

As already mentioned, chain-slat (scraper) conveyors are the traditional and most common means for distributing bagasse to boilers. Even in the latest edition of Hugot's Handbook, he states that bagasse conveyors "are generally of the scraper type. When they are not also acting as distributors, they can well be of belt type" (Hugot, 1986).

Over the past 36 years, changes have had to be made to chain-slat conveyors to accommodate the much higher tonnages and to supply bagasse into modern boilers through multiple enclosed chutes to feeders of relatively small cross-section (in contrast to the old wide, open chutes which poured uncontrolled quantities into horseshoe or stepped grate furnaces)

The most robust chain-slat bagasse conveyor in the South African industry is probably that in the Umfolozi boiler house. This carrier is a twin deck unit (i.e. bagasse conveyed on both decks in opposite directions), is 55 m long and 2500 mm wide with 2240 x 300 x 80 hardwood slats carried by double AS2 attachments on Ewart 09063 chain. Because of the heavy bagasse loads on both decks (up to 180 tph), it is (uniquely) driven by two identical 90 kW electric drives through David Brown QRA 69 gearboxes, one at each end of the carrier. This conveyor has proved to be mechanically very reliable, but the concept of dual drives would not normally be recommended. It adds complications in requiring exactly matched speeds, complex starting arrangements and careful chain tensioning through adjustment of the entire drive and sprocket assembly at one end.

Despite their widespread use, many installations - including new ones - are troublesome, unreliable and costly to maintain. This is invariably due to unnecessary design deficiencies. Whereas a factor of safety of 5 is adequate for a well-designed conveyor, a factor even of 9 may be insufficient for one of poor design.

Some features of well-designed chain-slat systems:

- A carrier speed not more than 0,8 m/sec.
- A robust chain from a reputable supplier, operating at a maximum working load well within the supplier's recommendation.
- The chain preferably not of the roller type. Rollers add to chain cost and weight and often jam from bagasse ingress. With sliding on slats, rollers are unnecessary. Either a block link (see Figure 4) or a cranked link (offset sidebar) bushed rollerless type chain (see Figure 5) is preferred. Block link chains require a longer take-up adjustment but have higher strength (64 000 kg vs. 50 000 kg) and do not require welded-on attachments. Hardened alloy steel components are preferred to stainless steel for bagasse duties other than where still 'steaming' from diffuser dewatering mills (cheaper and longer wearing in a low corrosion environment).

- With cranked link chain, slats preferably mounted on the chain on side attachments (AS2), welded to the chain by the chain supplier. (The alternative "C3" type attachments are more likely to pack with bagasse.) On heavy duties, extra thick or double AS2 lugs, welded only longitudinally to avoid weakening the sidebar. Slats mounted on the lugs by HT bolts with Nylock nuts. Note that cranked-link rollerless chain must be operated with the wide side forward to minimise bush-on-sprocket wear (see Figure 5).
- With block link chain, slats mounted by attachments which pass through slots in the blocks. This avoids any welding on the chain.
- An inspection authority (e.g. Lloyds) appointed to check chain manufacture: materials, dimensions, welding and heat treatment.
- Sprockets of minimum 15 teeth for cranked link or 8 teeth for block link chain; head- and tail-shafts square to carrier; teeth of head-sprockets aligned with each other; one tail-sprocket 'floating' rotationally. A bronze bushed mounting is usually used for the floating sprocket, but this sometimes seizes; mounting on sealed roller bearings is an alternative.
- An adequate length adjustment facility and also a sufficiently long hanging catenary section immediately behind the drive sprockets to ensure natural tensioning.
- Other than over the catenary section, the chain-slat assembly sliding on the slats, with suitable wearing pads if necessary (depends on slat design).
- Slats pitched as close as possible without risk of bagasse bridging between slats. This is usually about 900 mm to

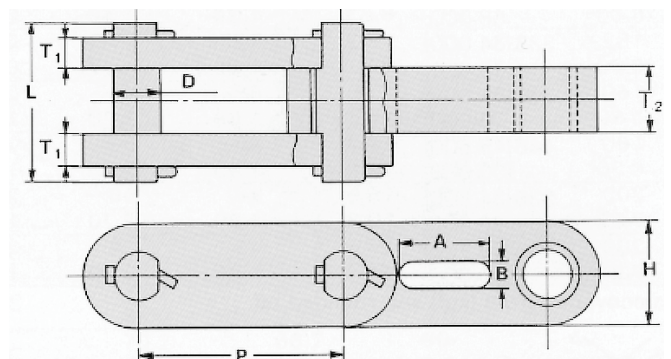


Figure 4. Block chain with slot attachment.

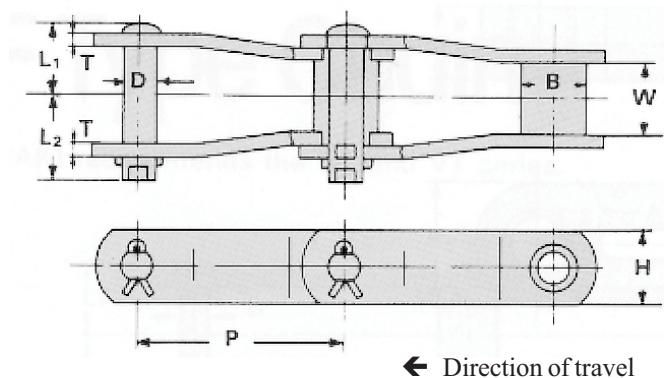


Figure 5. Rollerless chain.

1200 mm apart (every 8th 152 mm link on heavily loaded conveyors).

- Adequate deflectors at all bagasse feed points and immediately behind the drive sprockets, to prevent bagasse from being fed onto the chain.
- To enable adequate feed into modern small chute openings, a generous lead-in ramp preceding the bagasse gate into each boiler chute, allowing the bagasse to fall approximately 150 mm before reaching the mouth of the chute. The downstream cut-off above the chute by an angled plate to “knife off” the bagasse in the chute (see Figure 6). These design details are important for full chute feeding and to avoid shock loads on the slats.
- If a twin deck conveyor is used, a top deck which is sufficiently high above the lower deck to enable easy maintenance access. Bagasse transfer from top to lower deck via inclined slides to avoid dust creation.
- Deck(s) of 3Cr12 for long life.
- If necessary, chutes that can be isolated by tines (spiked rods) passed through the chute.

Operational comparison of belt and ploughs vs. chain-slat systems

The comparison that follows is based on a **well-designed** belt and ploughs system vs. a **well-designed** chain-slat and gates system, i.e. systems incorporating the above features.

Operational advantages of belt and ploughs:

- Can be an extension of a conventional low cost belt conveyor to the boiler area.
- Renton ploughs redistribute bagasse across the belt, so that chutes can be aligned along one side of the belt, provided sufficient distance is available between the boiler chutes (but note that one-side ploughs such as at Felixton cause belt tracking problems). Gates from a slat conveyor need to be staggered across the conveyor width.

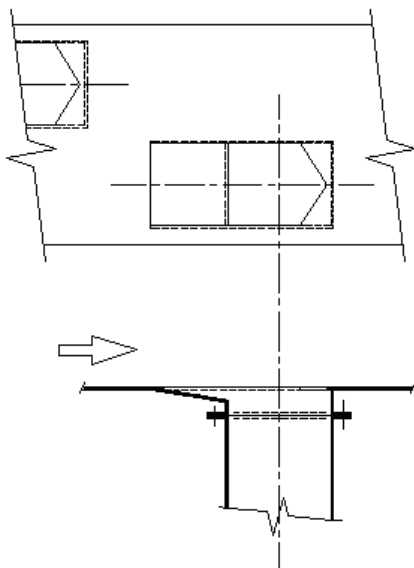


Figure 6. Bagasse feed gate arrangement.

- Is usually of lighter total mass, which needs less supporting steelwork.

Operational advantages of chain-slat systems:

- Virtually dust free (no return belt spillage, no dust creation over ploughs).
- Avoids moving parts, instrumentation and complexity of plough controls.
- Requires no adjustments (vs. precise plough fulcrum positioning and tension adjustments with ploughs).
- Better chute alignment than ploughs if chutes are so close together that ploughs have to alternate on either side of the belt.
- In many cases, can be used with advantage as a double decked arrangement to convey bagasse in both directions.
- Probably requires less power than a belt with ‘Renton’ ploughs.
- Chain or slat repairs are usually quick and by mill staff. Belt damage can be extensive (e.g. cut along length, worn edge or failed splice) and requires re-splicing by specialists, as belt clips cannot be used with ploughs. Belt outages are therefore usually of long duration (specialist’s travel to site and curing time).
- The typical chain conveyor problem of one chain jumping a tooth on the head-sprocket is much easier to rectify than a folded belt. The chains can be quickly realigned by packing a wad of bagasse (or wood) on the chain under the sprocket on the trailing side and advancing one revolution.
- Chain life with an appropriate chain is likely to be longer than belt life.
- Less vulnerable than belts to fires which occur in the boiler house.
- Perhaps most important: it is possible to design a chain-slat system which operates well from first start-up, whereas every belt and plough system known to the author has required extensive modifications and adjustments before reasonable reliability has been achieved.

Comparative costs of the systems

Capital costs:

The initial capital cost of a belt system (including ploughs and instrumentation) is normally lower by 15% to 30%. However, the direct (modifications) and indirect (lost production) costs of the initial operating period are usually substantial. If these are added to the capital cost, then it is probable that the chain-slat system is *cheaper*.

One of the better belt and ploughs systems is that at the outstandingly successful new Komati Mill. However, five years after start-up, the system is still not entirely reliable and small changes are still being made. This factory keeps excellent records of operations, maintenance and modifications. In May 1999, Hennie Jones compiled a report (Jones, 1999) of all problems experienced with their system and measures taken to rem-

edy them. This report is 29 pages long! A chain-slat system would probably have not warranted any report.

Maintenance costs:

The major maintenance items are belting and chains. Replacement belts are probably less costly than replacement chain. The cost of a replacement belt for a 30 m long x 2100 mm wide conveyor is approximately R60 000 and should last at least two to three seasons, i.e. R24 000 per annum. This compares with R117 000 for a replacement chain for an equivalent scraper conveyor which, with one R70 000 refurbishment (new pins and bushes) should last at least six years, i.e. R31 000 per annum.

Maidstone Mill has one belt and ploughs and two chain-slat conveyors feeding its boilers. They achieve an average of 2 years' life from their belt and 4-5 years before refurbishment from good quality rollerless chain. Overall, they consider the chain-slat conveyors less costly to maintain.

Operating costs:

Most belt-plough systems require either a full time operator or a CCTV monitoring system to warn of chokes or required control adjustments. Komati Mill still experienced an average of 79 chokes or incipient chokes per month during the 1999-2000 season, although by the 1998-99 season, only 10 incidents interrupted crushing and total downtime was contained to only 4,6 hours for the year. Even at Felixton, after 15 years, the plough-fed boiler chutes are liable to occasional chokes and mechanical "pushers" have been installed to clear these as they occur. The supervisory and choke clearing labour and lost production are all "operating costs". In contrast, most chain-slat systems are unattended; some are equipped with "broken slat" protection.

Conclusions

The overriding recommendations must be that, whichever type of system is selected, the design should be done by experienced sugar engineers and incorporate the principles set out above. Many installations of both types prove unsatisfactory because they do not follow the principles and/or because their designers have not experienced themselves the unique mechanical handling characteristics of bagasse. Designs based on successful wood-chip or oilseed husk installations are doomed to failure! Apart from the major principles set out above, there are many details that need to be right; these require bagasse experience. The report by Jones (1999) demonstrates clearly how important even small details can be in bagasse handling.

Experience is invaluable in detail design areas such as:

- Bagasse chutes: geometry (particularly at inlet), divergence angles, number and positioning of level sensors.
- Ploughs: positioning relative to chute, actuating forces and characteristics, angle to belt centreline, plough cross-section, gap between plough and belt, pivot design (position, offset, etc.), re-distribution ploughs.
- Belt scrapers: type, belt support over scraper, riddlings collection.

- Slat carriers: bagasse feed to carrier (no convergence under slats), slat attachment geometry, re-distribution after gates.
- Variability of bagasse quality: moisture, fibre vs. pith, burned vs. trash, sand.
- Prevention of bagasse build-up under both belts and chains.
- Chain sprocket design.
- Conveyor drive starting characteristics.

(Many items in this listing are referenced in the report by Jones (1999)).

Although there is no doubting the superiority of belts for general bagasse conveying, boiler feeding presents special problems. When asked which type of system they would select for this purpose, most engineers with experience of both opted strongly for chain and slats. On balance, this is also the author's view:

For a new installation, a chain-slat system is usually strongly recommended.

For replacing an existing unsatisfactory belt and ploughs installation, each case needs to be evaluated on its merits. The benefits of a more reliable system need to be weighed against the recoverable value of an investment already made.

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