BELT CLEANING

A DESIGNER'S POINT OF VIEW

By Graham Shortt and Paul Nel
Anglo American Corporation of South Africa (Ltd)
Central Technical Office : Mechanical Engineering

1. INTRODUCTION

The purpose of this paper is to present some aspects of belt cleaning that are often overlooked by conveyor designers and which could lead to operational problems that last the life of the conveyor. The application of belt cleaner types, the material of construction, the cleaning action and their compatibility with given conditions will be discussed, from the point of view of a conveyor designer in the South African mining industry. Belt cleaners have applications for materials that range from run of mine ore down to microscopic tailings, through the spectrum of hard rock, shale, coal and clay.

Much has been said and written over the years regarding the cleanliness, or otherwise of conveyor systems. Since the concept of a belt conveyor for handling bulk materials was introduced, the problem of spillage and carry-back has been one which has vexed both conveyor designers and especially operators. The need for a universal, inexpensive, effective and efficient belt cleaner has led to the design of a plethora of cleaners, of varying degrees of success. The lives of the cleaners were not always of any significant duration. The result is that there are many salvage yards, on mines, plants and factories, that have served as the final resting place for these devices.

In many cases, the user's approach to belt cleaning is purely commercially driven, short sighted and based entirely on economic considerations. This implies that the selection of a particular type of cleaner is often based on the lowest cost, rather than the suitability or efficiency of the cleaner system. Belt cleaners, of the human type, are a treatment of the symptoms, rather than the illness. If we have to employ unskilled labour to lash the spillage back onto the system, then the original system must be seen as partly deficient and in need of attention. Manual belt cleaning must be intermittent and often the response to a cleaning problem occurs only after the damage has been done. Hence the need for mechanical, automatic and continuous belt cleaning and dribble handling.

2. WHY CLEAN BELTS?

Why do we need to clean the belt in the first place? The answer to that question lies in a combination of practical and economic considerations, some of which are discussed here briefly.

2.1. The concept of belt conveyors as a means of handling bulk materials, implies that the material is handled as few times as possible. If the belt is not cleaned, then carry-back *will* occur, by the nature of things. This carry-back will either stick to the return idlers, the pulleys on the return strand, (or both), or fall off the inverted belt. Irrespective of the material normal angle of repose, or the dynamic surcharge angle, the angle on the underside of the belt for sticking material will be zero; hence the carry-back. The material build-up causes accelerated wear of components such as idlers and pulleys, makes training of the conveyor more difficult, reduces system availability and impacts on the overall safety of an installation.

In addition to the spillage which costs money to remove, there is the danger of accident, since the piles of material will obstruct access and maintenance work. It is extremely unpleasant in many locations under conveyors, and the maintenance personnel cannot be blamed for not always being able to reach some area of the belt again and again, in order to clean out a recurring pile of spillage. Indeed, some conveyors exist where the accumulated spillage has reached depths of more than 2,0 m. Of course it is impossible to maintain such systems.

Dirty conveyors result in a direct loss of product, which can be translated into money. For example, the higher concentrates of gold occur in the slimes and fines. It follows then that fugitive material on unclean conveyors means that the plant is literally dumping gold.

There is also the possibility that the material that is recovered from the piles underneath the conveyor could result in product contamination. Consider, for example, the image of the company that sells a pocket of cement with some bits of wire, rocks or rusty bolts in it.

The conveyor itself, which is no small investment, will be damaged by the build-up of spillage. Not only will the belt be damaged, but the life of the idlers, the pulleys and even the structure will be adversely affected by spillage.

Finally, there is the simple *cost* of cleaning up the mess, as labour is becoming more and more expensive.

3. CARRY-BACK IDENTIFIED

The determination of the amount of carry-back on a conveyor, is almost as subjective as determining the length of a piece of string. The amount of carry-back is dependent on many factors, these being influenced by the material type, the size of the material, the speed of the conveying system, the capacity of the system, the presence of moisture and many others. Several cleaner suppliers have attempted to place some sort of value on the carry-back, not only to advertise their cleaner effectiveness, but also so that an appreciation for the economic benefits of clean conveyors can be obtained.

3.1 Incurred Costs

The usual approach is to assume that a regular film of material passes around the terminal pulley and is deposited in some way onto the ground behind the pulley or terminal in question. If we accept that the majority of conveyors handling bulk materials will be loaded to about 80% volumetrically and will have a surcharge angle of about 15° then, using a nominal 1000 mm wide belt, the material width on the belt will be about 750 mm, that is about $^3/_4$ of the belt width. If the material film is considered to be just 0,1 mm thick over this width, then the amount of dribble or carry-back that must be handled will be given by the following expression

$V = 750 \times 0{,}1 \times 10^{-6} \times 3600 = 0{,}27$ m³/h per m/s of belt speed per metre width of belt. That in turn implies that a 1200 mm wide belt, running at about 1,6 m/s (a fairly typical plant conveyor) would be shedding $1,35 \times 1,2 \times 1,6 = 0,52$ m^3/h of dribble - no small amount. If the bulk density of the dribbles is assumed at 2,0 t/m^3, then we are looking at 1,04 tons per hour of material build-up, for every hour that the conveyor operates. That translates to about 6 200 tons of material per year, given 20 hours per day, 6 days per week and 50 weeks per year. No wonder then, that carry-back seems to accumulate at such a great rate, and that manual labour seems so unwilling to lash the stuff back onto the belt. If we employ one unskilled labourer to clean up this mess on a full-time basis, and the minimum wage is set at R1500 per month, the cost will be a minimum of R18000.00 per year to clean each conveyor. Consider too, the restricted space available in conveyor haulages underground, and the importance of clean belts and structures becomes even more obvious.

Of course, the calculations above are academic and are dependant on the parameters as set out. A less obvious cost of carry back is the cost of plant downtime. This is very much greater than the labour costs related to cleaning and a balance needs to be reached to suit individual plant needs. The rate of carry-back accumulation may vary as widely as the applications of conveyors and the materials handled.

3.2 <u>Areas of Spillage</u>

Spillage from conveyor systems occurs at various points on the conveyor. These points may be generally identified as :-

- at the loading points, as a result of poor chute design or maintenance, leakage of material at the skirts, run-back of material loaded at a steep angle, flood loading of the conveyor, or uncontrolled loading.

- along the belt as a result of wind, poor tracking, damage to the belt edges or the structure itself, poor splices, or longitudinal slits.

- at the discharge end as a result of poor design, shallow chutes and skirts, material splashing, skirt leakage, chute blockages or poor maintenance.

- on the belt underside as a result of carry-back of material adhering to the belt, combined with poorly adjusted or non-existent belt cleaning.

The first three items may be relatively easy to identify and (possibly) relatively easy to correct. The fourth area of concern is the underside of the conveyor. While it may be easy to identify the fact that the conveyor is spilling, it is another matter entirely to correct the problem in a lasting and economical manner.

4. TYPES OF BELT CLEANERS

Belt cleaners have developed over the years, and have followed the development of the conveyor itself.

4.1 Simple origins

The most common type of belt cleaner was the simple block of wood, placed across the belt and slightly clear of it. Any material larger than the gap between the block and the belt was removed, to fall into some collection chute underneath. The advantage of this cleaner was only that it was easy to make. If material became jammed between the block and the belt, the belt cover was very rapidly removed, and the belt absorbed power would climb appreciably, since the jammed material acts as a brake. The block could be located further back from the head pulley, in such a way that it can "ride" on the conveyor belt. While this may improve the jamming aspect, the poor efficiency of this type of cleaner led to its very rapid discontinuation (see Figure 1).

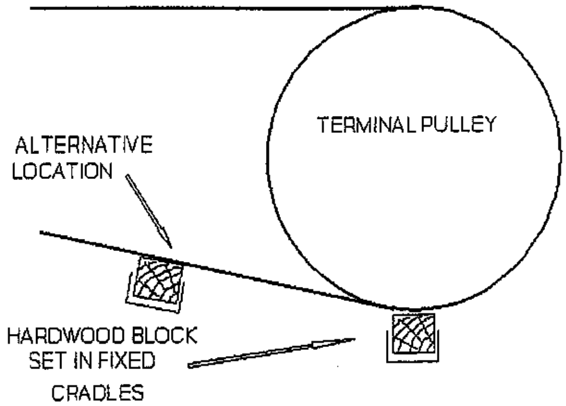

Figure 1

Of course, this type of cleaner was soon discarded. The blocks would break, splinters would damage the belt and they were extremely inefficient, because they were not designed to be adjusted.

4.2 Later Developments

The block cradles were replaced with counterweighted arms, so that the blocks could move against the belt. An additional refinement was the introduction of rubber blocks, in place of the hardwood blocks used previously. The advantage of the pivoted system is that it is relatively self-adjusting and, if maintained correctly, can be a very inexpensive and reasonably effective first-line cleaner (see Figure 2).

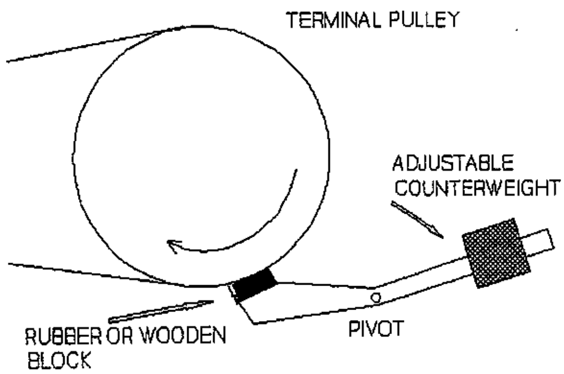

Figure 2

The pivoted type of cleaner is very useful for the primary cleaning of very wet or sticky material, particularly if the scraper is substantially proportioned. In this way, the scraper actually acts as a sort of primary discharge device, rather than a belt cleaner as such. In some gold mining operations, particularly with the modern methods of cleaning out stopes with high pressure water, the material often reaches the surface and underground conveyors, well mixed and having the consistency of wet concrete. A single cleaner operation is therefore obviously insufficient. The major disadvantage of the solid block lies in the fact that the conveyor belt surface does not wear evenly. The profile of a belt will soon take on an uneven shape (as shown in Figure 3), as a result of skirtboard wear, uneven loading, and the concentration of load at the surfaces where the belt flexes in the idler cradles. The wear, while it is uneven across the belt, is equally uneven along the length of the belt. The result is that the solid block will not contact the belt over the full surface, at every point on the belt, neither will it wear into a pattern across the line of the belt, as a result of the uneven and unpredictable wear. This will therefore allow a good deal of fugitive material to pass beyond the scraper, to be deposited on the structure, the idlers and the floor behind.

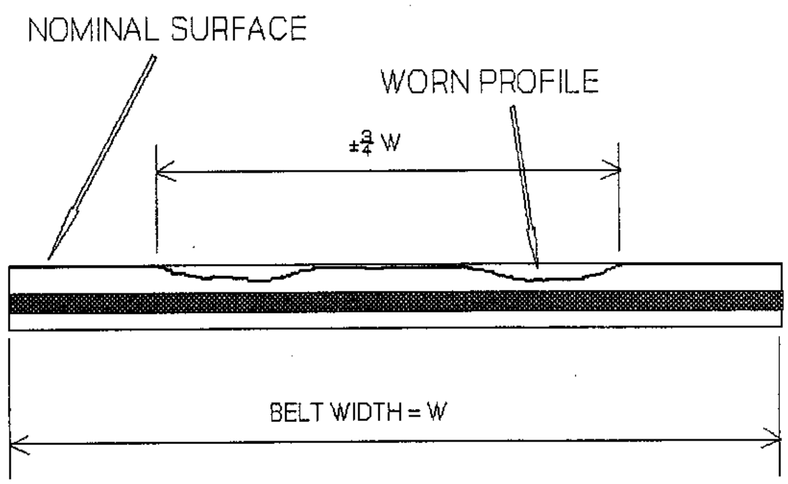

Figure 3

Unfortunately, blocks of rubber wear out and are more expensive to replace than strips of old conveyor belting. The result is that this type of primary scraper fell into disfavour, partly because the function of this type of scraper, namely to act as a first-line primary discharge device, was lost and partly as a result of the very high maintenance requirements.

5 MODERN SCRAPERS

Modern scrapers are available for virtually any application. These scrapers range from relatively simple units that are devised and built on site, to sophisticated units that can automatically vary contact pressure to suit loading conditions, sense direction of travel and give early warning signals of wear.

5.1 Home-made Scrapers

Virtually every mine has an artisan who has had a great deal of experience with belt cleaners and has finally decided to make his own scraper, since the commercial units "don't work". The foreman is extremely happy with this scraper, because his conveyors appear to be a good deal cleaner than they were before. The scraper usually consists of a single blade, sometimes two blades in series, clamped between two pieces of angle and supported with the remains of a commercial cleaner's mounts, or a home-made spring or counterweight adjustment system. The blade material consists of one or more strips of conveyor belting sandwiched between the angles. The scraper runs smoothly until the artisan goes on leave. Suddenly the belt cleaning problem has raised its head again, and no-one appears to be able to isolate the problem. The problem, is of course, that the artisan adjusted his scrapers *every day*. In that way the scrapers deliver their best and are quite useful. Indeed, it was only in the late '70s that commercial scrapers really gained a foothold in the South African markets. What this serves to illustrate, is that *all* scrapers, provided that they are properly adjusted and maintained, will clean conveyors. The degree of cleaning is determined by the finer technologies of the cleaners, but the effectiveness of the scraper will stay directly in proportion to the maintenance of the installation. Other factors such as material selection, rate of wear, ease of adjustment and so on, represent the essential difference between home-grown units and the undoubtedly high-technology units on the market.

5.2 Primary Scrapers

The idea of a primary scraper led to the development of the so-called "doctor " blade, which usually consists of a profiled blade, either in a single piece, or segmented across the line of the belt. This device is placed in such a way that it acts as a knife, to provide a primary cleaning action on the conveyor belting. See Figure 4. Unfortunately, these scrapers suffer from the same problems associated with the earlier blocks, in that they are subject to rapid wear, and are often difficult to adjust. As a result of the uneven wear on the conveyor surface, coupled with the concentration of material in the centre three-quarters of the belt, the centre blades in a multi-bladed system will tend to wear more rapidly than those running on the outer, relatively clean surfaces of the belt. The result is that, in order to maintain the cleaning action of the centre blades, the operators adjust the system inwards. This has the effect of placing the outer blades under a good deal more pressure than normal, with the resultant accelerated wear, belt surface damage and increased drag on the system. The nature of the knifing action, since it is opposed to the belt motion, tends to draw the blade into the belt surface. While this may be advantageous from a cleaning point of view, it also exposes the belt to damage from the scraper itself, since, under certain conditions, the blade will tend to overturn into the belt. In addition to this, belt splices, particularly mechanical clips, can do a great deal of damage to the cleaner blades, and subsequently to the belting itself. Early models of the doctor blade were equipped with tungsten carbide tipped blades and, indeed, many are still provided with hard metal blades. Of course, the damage to some conveyors was horrific, which led to some interesting geometric shapes, in an attempt to make the scrapers more belt-friendly.

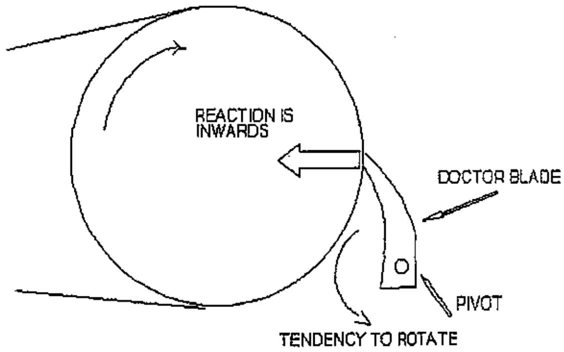

Figure 4

5.3 Secondary Scrapers

Once again, there are as many designs as there are suppliers of secondary scrapers. That is not necessarily a bad thing, though, since most of the scrapers available in South Africa today follow the same basic principles. One area of great disagreement, however, is the attitude of the scraper blade with respect to the belt surface and the direction of travel. Suppliers each have their own ideas with regard to the blade attitude and each supplier will provide argument to support their product. The conveyor system designer is presented with three basic attitudes :-

- A vertical blade, at 90° to the belt surface (Figure 5a). The blades can be supplied as continuous items, or as individual blades, either overlapping in two rows, or in a line next to one another. In truth, the arrangement of the blades across the line of the belt is fairly common for all types of cleaners. The action of the blade against the belt implies that the blade does not stay normal to the belt and bends backwards in sympathy with the belt. The result is that material accumulates in the "valley", which impairs the scraping action and reduces the effectiveness of the scraper. The result is that the operator adjusts the blade more heavily into the belt, which, of course, exacerbates the problem, apart from increasing drag on the system. Of course, if the blade is substantially thick, then the deflection will be reduced. Unfortunately, the leading edge of the blade will wear into a convex pattern, which will have the same result as a deflected blade.

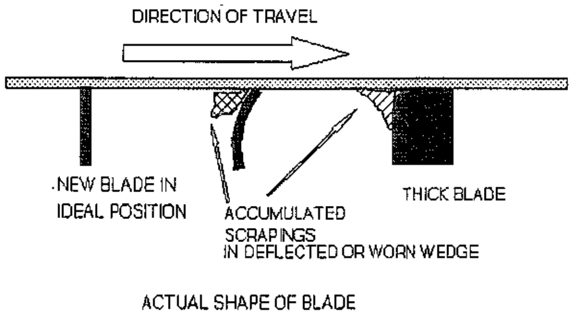

Figure 5a

- The blade inclined at a negative angle, with respect to the belt travel (see Figure 5b). While this arrangement does reduce the danger of belt damage as a result of the sharpening action of the belt on the blade, the material *must* accumulate in the valley, in exactly the same way as it does with a deflected vertical blade. The result is an impaired cleaning action and increased scraper pressure on the belt.

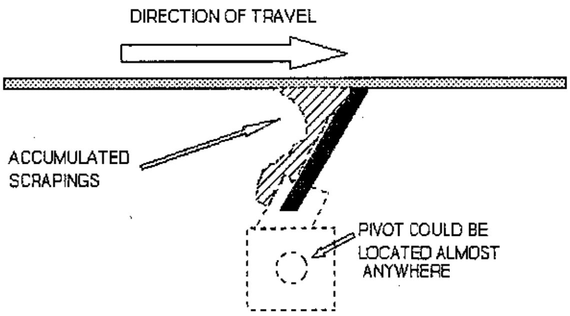

Figure 5b

In addition to the accumulation of scrapings in the wedge, the actual material cleaned off the belt must stop, change direction, and be forced to move down the slope of the blade. In the mining industry, blades in this attitude have not remained in place for very long.

- The blade inclined at a positive angle with respect to the direction of travel of the belt (see Figure 5c). In this attitude, the scraper blade acts as a knife and slices the material of the surface of the belt, rather like a potato peeler. While the action of the scraper blade in this attitude is very efficient and requires the least pressure between the blade and the belt, the abrasive action of the material against the blade tends to sharpen the leading edge of the blade to a razor sharpness. This can have a very deleterious effect on the surface of the conveyor, particularly if the system is equipped with mechanical splices.

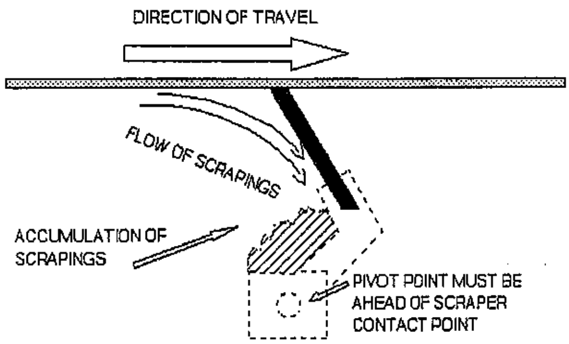

Figure 5c

The pivot point of the blade, either single blade or individual blades, must be located ahead of the point of contact with the belt. This is required in order to ensure that the blade moves *away* from the surface of the belt when it is struck by an obstacle, such as the belt splice. If the pivot point is located behind the point of contact, then the scraper blade will be pulled into the belt surface as it rotates backwards.

5.4 Belt Scrapers and Belt Splices

Most belt cleaners are considered to be running on a smooth, regular, uninterrupted surface. In practise, we encounter the case of mechanical splices. The splices can not only damage the cleaners themselves, but, if the cleaners are supplied with hard metal tips, for example, the action of the scraper against the splices can do a great deal of damage that is not always recognised. The situation becomes worse as the belt speed increases. Most mechanical splices leave a small ridge at the splice edge, the design of the splice notwithstanding. This ridge was soon recognised by the belt cleaner manufacturers, and the result was the location of the scraper blade pivot ahead of the point of contact, in order to allow the blade to be knocked out of the way by the splice itself, as indicated above. The effectiveness of this is impaired by excessive blade pressure, which is a common fault on most installations. In one instance, the mine was experiencing belt breaks, which occurred just behind the splice. The belt was of the solid woven type, with a pivoted staple type of splice. The belt breaks were occurring about 0,5 m behind the splices. After observing several cycles of the belt, the cause of the belt breaks became quite obvious. The belt speed was about 3,5 m/s, which is not normally considered excessively quick on an underground trunk conveyor in a coal mine. As the splice struck the scraper installation, the blades would deflect backwards and downwards, to clear the splice. Since the blades were mounted in an elastic mounting, they returned with a bang, with all the accumulated spring energy stored in the deflection. The result was that the blades were all slamming into the belt surface, which, by this time, had advanced about 0,5 m. The result was that the scraper was gouging out the belt carcass until such time as the tension in the system overcame the weakened carcass, and the belt broke. There is no simple solution to this problem, other than to suggest a different type of material for the scrapers, or to use an entirely different cleaning concept.

5.5 Relative Speed

A point to consider is the speed of the cleaner, relative to the surface of the belt. As with scraping paint from surfaces, the faster the scraper moves, the less efficient the scraping action becomes. It is reasonable to assume that the same principle applies to scraping belt conveyors. If the relative speed of the belt with respect to the scraper can be reduced, then the scraping action should improve and dynamic damage at splices, as described above, would be reduced. One method of achieving this would be to mount the scrapers on a short chain conveyor, which is mounted so that it runs parallel to the belt line. In this way, there can be more than one scraper in contact with the belt at any time. (See figure 6).

If the chain is driven at a speed slightly less than the speed of the belt, so that the relative linear speeds of the belt and the chain differ by about 0,5 m/s, then the scraping action would improve dramatically.

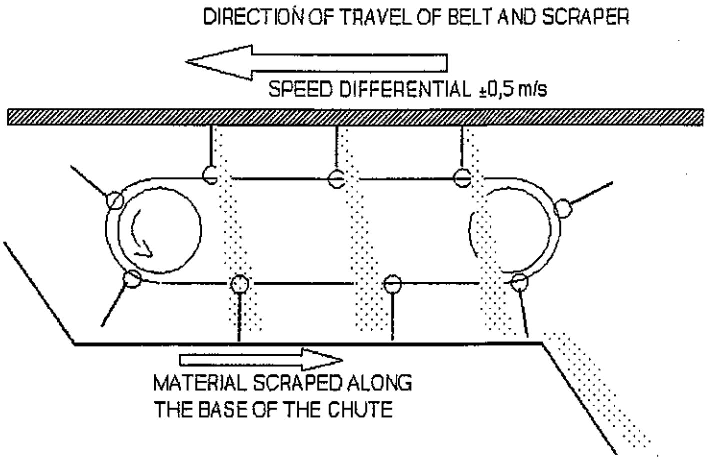

Figure 6

5.6 Scraper Blade Materials

The relative speed between the belt and the scraper blade implies that there will be a build-up of heat in the blade (and the belt), and that this heat is a contributory factor in accelerated blade wear. The solution is to specify a material that can

- withstand the hammering that it is likely to sustain from the material, the belt splices and so on
- withstand the heat that will be generated by the sliding contact between belt and blade
- have an economic life, so that the blade does not have to be replaced too often
- be friendly to the belt surface and the splices
- provide a good scraping action with minimum pressure, in order to maximise blade life, minimise additional belt tension and prevent shaving the cover off the conveyor surface.

In most cases, a combination of scrapers with different materials could be used. Often materials such as polyurethane can be combined with soft metal as a central reinforcing. This allows the larger footprint of the polyurethane blade and the softer steel, while not likely to damage the belt (since it is encased in the polyurethane, will retard the rate of wear of the blade. Combinations of ceramics with steel backing or UHMWPE faced steel or rubber have also been successfully used in places.

5.7 Adjustment, Friction and Belt Pull

For plain rubber or polyurethane compound blades, the counterweight spring adjustment system on the cleaners should be designed to give a contact pressure of about 20 kg/m belt width. For a coefficient of friction of 0,5 (rubber on rubber), we can expect an additional belt pull of about 1,0 kN/m of belt width per cleaner blade set. For steel and ceramic blades, the additional pull per blade set will be about 0,35 kN/m of belt width. Other values that have been suggested for the additional belt pull of the cleaners are between 2 lbs/in and 145 lbs/in width, with a suggested value of 5 lbs/in width, from CEMA. This translates to between 0,35 kN/m to 5,4 kN/m, and suggested value 0,875 kN/m, whilst ContiTech suggests 1,5 kN/m width.

A selection of materials available today from most suppliers are summarised in Table 1. The list is by no means exhaustive, but serves only to illustrate the most common materials. Most commercial scraper suppliers have an ongoing development program to identify suitable materials.

TABLE 1 - SCRAPER BLADE MATERIALS

MATERIAL TYPE	SPEED RANGE	REMARKS
Ceramics	< 3,0 m/s	Suitable for some types of mechanical splices. Prone to chipping if subject to impact. Best when combined with steel backing plates. Extremely high temperature tolerance.
Hard Steels	< 3,0 m/s	Tungsten Carbide tips. Not suitable for mechanical splices. Low rate of wear if properly maintained. Becomes very sharp. High temperature tolerance.
Softer Steels	≤ 2,0 m/s	300WA plate. Blades are usually supplied in 150 mm widths and between 3mm and 6 mm thick. Higher rate of wear. Subject to sharpening. Tolerates mechanical splices and medium temperatures.
Polyurethane	1,5 m/s - 2,5m/s	Splice type not normally important, except for wear. Usually used on primary scrapers or belt driers after washing. often combined with steel reinforcing. Wear rate dependant on thickness and pressure. Low temperature tolerance.
Neoprene ±60 Shore	up to ± 2,5 m/s	Most common blade or block in use on South African mines. Wear rate dependant on thickness and pressure. Often combined with steel reinforcing. Wide temperature tolerance, but less effective at high speeds.

An interesting idea is that the material for the scraper on a given system that is most likely to give the best cleaning action, would be made from the material that the belt is carrying. An example would be an interesting method used to clean bagasse conveyors. A simple rolled steel angle was placed just clear of the belt and its fasteners, facing the direction of travel (see Figure 7). As the bagasse adhered to the angle, it built up and eventually filled the angle. The result was a very clean belt.

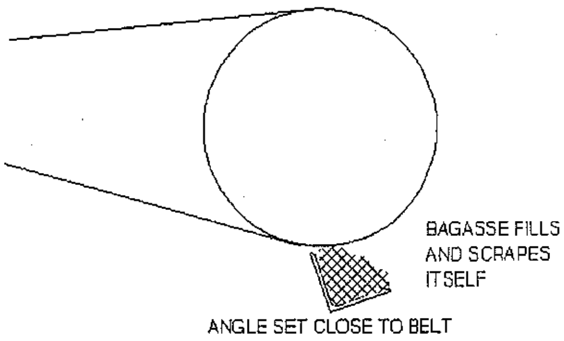

FIGURE 7 BAGASSE SCRAPER

A second, more frightening example is the case of a run-of-mine transfer conveyor on a gold mine. The cleaner was not operational, and the material carry-back was squeezed a little drier at each idler, until such time as the adhesion between the belt and the material was broken. This occurred closer to the tail of the conveyor, inside the totally enclosed gantry. The result was that the material built a stalagmite across the width of the idler and all the way up to the idler from the floor of the gantry. The material on the belt was then scraped off by the build-up underneath the conveyor. This in turn resulted in a plug of material, 800 mm high and 1100 mm wide, advancing along the length of the gantry, until the underside of the belt was a solid plug of material. The additional mass on the gantry, (figured at about 30 tons), caused the gantry to collapse, although the belt was clean. In this case, no-one was injured, but this incident serves to illustrate two things; (1) that effective belt cleaning, at the source is essential and (2) that most probably the best material to clean a belt is the burden itself.

5.8 Commercial Scrapers

The wide variety of scrapers on the market today can prove very confusing, since they all seem to claim similar results in tests. Often the tests are carried out in laboratory conditions, with the result that the scrapers soon fail when faced with real-life situations.

Different types of scrapers and their locations are identified in Table 2 below. This table lists only the types of scrapers that are used most often and is in no way intended to imply favour of one supplier over the others.

TABLE 2. COMMERCIAL BELT SCRAPER SELECTION

STYLE OF SCRAPER	CONDITIONS
Single row, sprung blade	Used where the material is relatively dry
Offset sprung blade	Used where the material is wet
Double row, Offset sprung blade	Used where the material is very wet and sticky and where maximum cleaning is required
Pulley scraper (single plain blade, sprung blade or commercial type)	Used as a "doctor" blade to pre-clean the belt at the pul). Used where the material loading is high and the material is wet.

Typical commercial scrapers are sketched below.

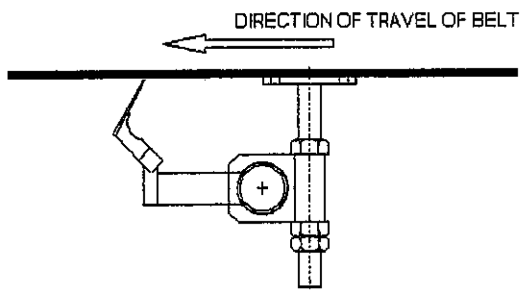

Figure 8 SINGLE ROW SPRUNG BLADE

The single row sprung blade scraper is useful for lighter loads, or as a primary scraper, in conjunction with other scrapers (see Figure 8). The blades have a gap of about 5 mm between them and are set in a single row.The gap between the blades does allow some slimes to escape. The scrapers can be located anywhere on the return strand, even upside down, as return strand ploughs. The belt must be supported on the clean side, usually about 150 mm ahead of the scraper.

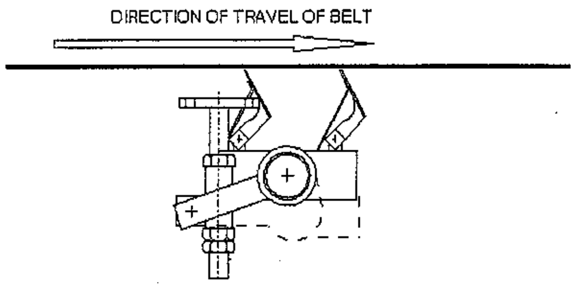

Figure 9 DOUBLE ROW OR OFFSET

The double row or offset scraper is nearly always used as a secondary cleaner and follows a primary scraper (see Figure 9). The double row of blades overlap, which should give a completely clean surface. The belt must be supported on the clean side, usually about 150 mm ahead of the leading scraper.

Primary scrapers are used on the pulley surface to scrape the belt (see Figure 10). They can also be used to scrape the pulley face itself, as in the case of snubs and bend pulleys running on the dirty side of the belt. The blades are often made reversible, which does help with the economics of replacement.

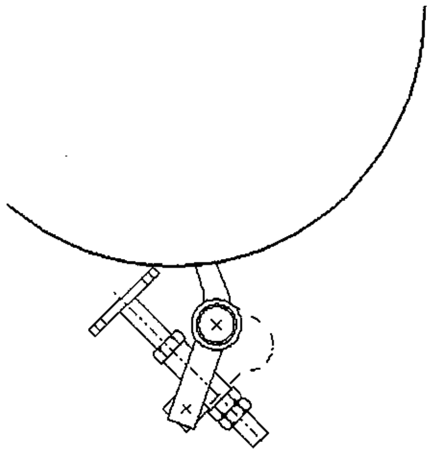

Figure 10 PRIMARY SCRAPER

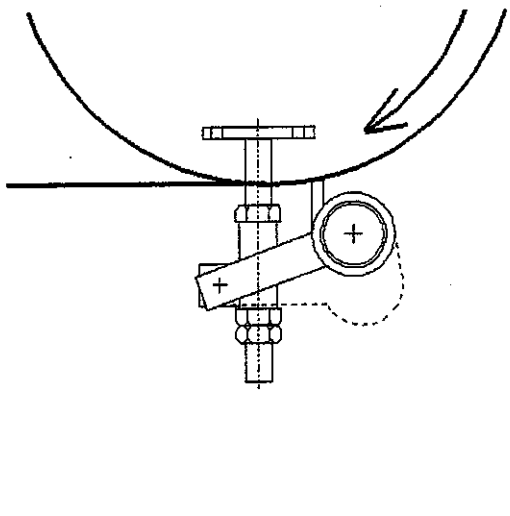

Figure 11 PULLEY SCRAPER

Pulley scrapers are similar to the primary scraper, except that the scraper should be aligned in such a way that the scraping action is tangential to the pulley and opposing the direction of rotation (see Figure 11).

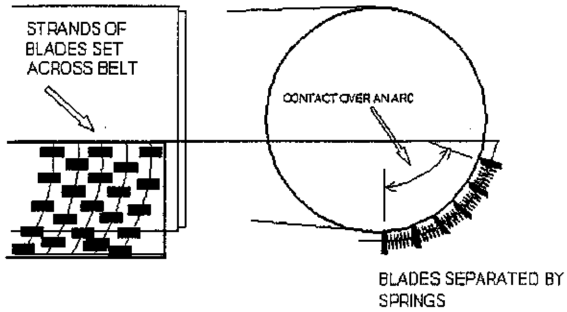

FIGURE 12 WHIP TYPE SCRAPER

Whip type scrapers are really only useful for very light loads, and for conveyors that will only ever have vulcanised splices (see Figure 12). On one installation, we installed these scrapers on 600 mm wide conveyors in a sampling plant. Unfortunately, the belts were mechanically clipped with plate fasteners. The scrapers lasted about 2 hours.

6. OTHER TYPES OF BELT CLEANING

Of course, scrapers are not the only type of belt cleaner, even though they may be the most widely used. Other common belt cleaning devices are :-

6.1 Rotating brushes.

Rotating Brushes are usually made of rubber fingers or stiff nylon bristle, on a spindle and rotate against the direction of travel of the belt (see Figures 13 and 14). Brushes work reasonably well with very dry, free flowing material. They are less effective with material that has a tendency to bind, or material that is wet and sticky. In this case, the brush simply fills up with the fine slime and soon becomes a solid, very uneven roller. This roller then proceeds to strip the cover off the conveyor, or severely detrains the conveyor, since the surface is so uneven. Because the brush rotates at a speed different to the conveyor, it can act as a kind of squeezer, but usually acts as a rotating cover stripper, because the rotation of the brush is opposite to the direction of belt travel. The brush speed can vary according to the material being handled. Usually, the brush speed is set to a speed where it will self-clean by centrifugal force. With higher belt speeds and the brush rotating opposite to belt travel, the relative speed of the brush tips becomes very high and the rate of wear accelerated appreciably. If the brush rotates in the same direction as the belt, then the brush should run at a peripheral speed greater than the belt speed. A suitable difference would be about 2,5 m/s. For example, a ϕ500 mm brush on a conveyor running at 2,0 m/s would have to rotate at a speed given by

$$n = \frac{60 \times (S + 2,5)}{\pi \times d} = 190,0 \ rpm$$

which is not excessive. Higher brush differential peripheral speeds, up to 6 m/s are used on drier materials, while the lower speeds would be used for the more sticky material.

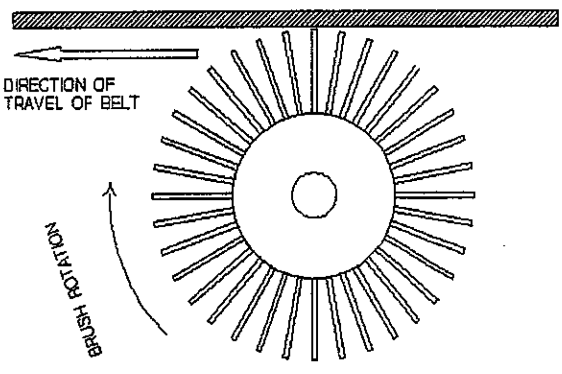

FIGURE 13 ROTATING BRUSH

An interesting variation would be to make the fingers from a softer steel, (Figure 14), and to pivot each finger on the rotating cylinder. The brush is then mounted in such a way that the fingers are trailing the direction of rotation, and they act a little like rotating paint strippers. Suitable for drier and more granular materials, these brushes are less prone to clogging and display the same belt and splice friendliness as the conventional radial brushes. Brushes are uncommon, though, since they can become rather expensive and they do require additional maintenance and a separate drive.

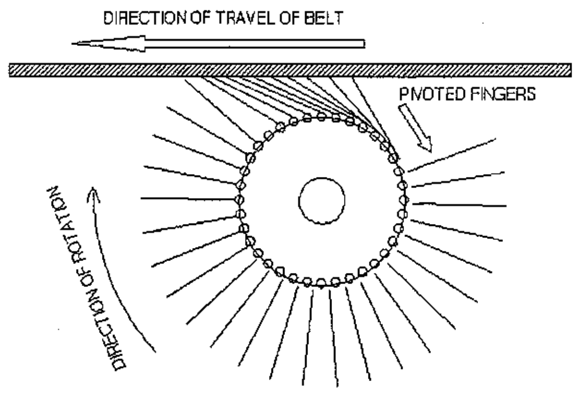

FIGURE 14 PIVOTING BRUSH

6.2 Piano Wire

Piano wire can be stretched across the line of the belt, usually about 1 mm clear of the belt surface for removing clay and similar materials from the belt by a slicing action similar to a cheese slicer strung with a guitar string. This type of cleaner has never been successful in the general mining environment. The wires are subject to frequent breakages, depending on the material being sliced off. Piano wire is definitely not suitable for belts with mechanical clips, but have been used on steel belts in the food industry and similar installations.

6.3 Belt Washing

For the usual sort of materials that are extracted from South African mines, belt washing is still probably the most effective method of really cleaning the belt. For primary crushed material, fines with high clay content and tailings, belt washing is preferred. The belt washing should consist of one or more banks of sprays, arranged so that the spray is angled against the direction of travel of the belt (see Figure 15). The sprays should be designed to give an overlapping spray pattern, to cover the whole width of the belt. All spray banks should be equipped with both manual and automatic isolating valves. The automatic valve closes on power interruption or belt stoppage, to eliminate flooding and wastage, while the manual valve can be used to isolate the system for maintenance. Consideration should be given to closing the valves when the belt is running empty.

The advantages of belt washing are that *all* the material is cleaned off the belt, including the slimes, and the resulting slurry can be thickened to return the concentrates to the process. The water can be recycled to be used again for washing, depending on the type of sprays fitted. The major disadvantage is simply the supply of water, especially in the drier parts of the country. Underground, there is the added disadvantage of storage of water and the disposal or recycling of water in the confined and limited spaces available. The nozzle diameter must be carefully selected, to minimise the risk of blockage, especially when unclarified water is recycled for belt cleaning purposes.

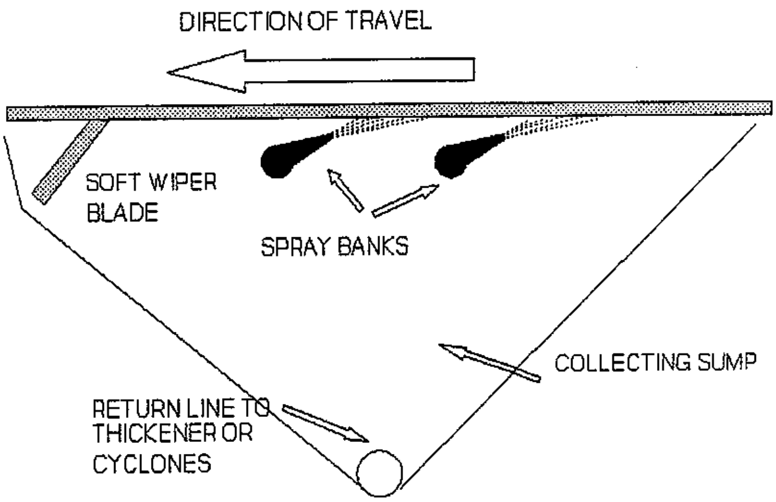

FIGURE 15 BELT WASHING

The amount of water required really depends on the nature of the material. For sticky materials such as Kalahari clay and Kimberlite, spray banks delivering about 50 ℓ/min of water per spray bank, per meter of belt width, at a pressure of 200 kPa, with ϕ2,5 mm bore nozzles set at a distance of about 150 mm from the belt line and angled at about 30° to the belt line, will give a very clean belt. The initial scrapers will still be required at the head end of the conveyor. The advantage of the spray bank is that it need not be located directly behind the discharge chute, while this is the better location.

If air, at about 50 kPa is injected into the water spray at the same time, then the cleaning action will be enhanced and the drying wiper blade at the sump exit will not have to work so hard. Again, the disadvantage is the cost of compressed air, the availability of water and the facility to handle the slurry.

6.4 Belt Turnovers

The practice of turning over the belt on the return strand is only really useful on longer conveyors (about 1000 m centres and up). The turnover, while it is not strictly a belt cleaning device, does allow the return strand of the conveyor to run with the "clean" side facing down. As a result, the incidence of fines accumulating at each return idler is eliminated. The length of the turnover is dependent on the method used to turn the belt over (see table 3). The most common method within my company is to use a series of mangle rolls to force the belt over in stages and is defined as a *guided* turnover. Points to note here, are the design of the lower bearings in the rolls that are inclined at vertical. Fines mixed with slurry seep down the roll as it is squeezed off the belt surface. This then collects in the bearing as no existing bearing seal will provide adequate sealing. The result is that the bearings soon fail and become a high frequency consumable. A better arrangement would be to use a heavy series flat belt idler, since the bearings are enclosed on the roll end pressings and will be above the supports and the slurry path.

The types of turnover are defined as

(i) Unguided — Where the belt is constrained between horizontal rolls at each end of the turnover and simply rolled over.

(ii) Guided — Where the belt is forced into a turnover length by means of a series of mangle rolls, usually set at increments of either 30° (a 6-stage turnover), or 45° (a 4-stage turnover).

(iii) Supported Where the belt has horizontal mangle rolls at each end of the turn over and is equipped with a series of rolls set on a central pipe support, inside the belt turnover.

TABLE 3 - RECOMMENDED BELT TURNOVER LENGTHS

TURNOVER TYPE	BELT WIDTH W (mm)	MIN TURNOVER LENGTH	
		FABRIC BELTS	STEELCORD BELTS
Unguided	≤ 1200	10·W	-
Supported	≤ 2400	10·W	15·W
Guided	≤ 1650	15·W	22·W

6.5 Air Blowers

The use of air blowers should be restricted to areas where spillage and carry over of fines cannot be tolerated under any conditions. Air blowers to be used on conveyors carrying dry material, or in conjunction with dust extraction, should be sized in conjunction with the dust collection requirements. Pulsed air blowers are particularly useful on pocket side-wall conveyors, or belts with profiled surfaces, where conventional scrapers are not suitable. On conventional belts, air blowers are usually used in conjunction with and in addition to other forms of belt cleaning, such as rappers, scrapers etc. This form of belt cleaning is not common in mining.

6.6 Belt Rappers

The belt driven rapper, while often considered outmoded, is an effective means of cleaning the majority of chips and fines from the surface of a conveyor. The rapper, combined with a squeezer must, however, be considered as a means for cleaning chips only. The slime on the conveyor can only be removed by means of properly adjusted belt scrapers, or, where conditions permit, by means of belt washing.

The principle of the rapper is that it excites the portion of belting into its natural frequency of vibration, thereby ensuring that the belt oscillates with maximum amplitude. This amplitude implies a maximum vertical velocity on the belting which effectively throws the particles from the belt surface. The major disadvantage of the rapper is the fact that the vibration is at a relatively low frequency and gives rise to a considerable noise, especially if it is not properly tuned.

The natural frequency of vibration of the portion of belt is dependant on the tension in the portion of the belt under consideration, the belt mass and the support distance.

Thus : $$F_n = \frac{1}{2} \cdot L \sqrt{\left[\frac{T}{B}\right]} \quad Hz$$

Here	F_n	=	Natural frequency of vibration	Hz
	L	=	Distance between supports	m
	T	=	Belt tension at point under consideration	N
	B	=	Belt mass	kg/m

The imposed frequency is given by the rotational speed of the rapper and is dependant on the belt speed, the rapper pitch circle diameter and the number of studs fitted to the rapper.

Thus, $$F_i = \frac{S \cdot n}{\pi \cdot d} \quad Hz$$

Here	F_i	=	Imposed frequency	Hz
	S	=	Belt speed	m/s
	n	=	Number of studs on the rapper	
	d	=	Pitch circle diameter of the studs	m

By setting the imposed frequency equal to the natural frequency of vibration, we obtain resonance, with the belt vibrating at maximum amplitude and velocity. This provides sufficient energy to clear all the chips from the surface of the belt.

Thus $F_n = F_i$

$$\text{ie.}\quad \frac{1}{2 \cdot L} \sqrt{\left[\frac{T}{B}\right]} = \frac{S \cdot n}{\pi \cdot d}$$

Manipulating the equation, we can say

$$L = \frac{\pi \cdot d}{2 \cdot S \cdot n} \sqrt{\left[\frac{T}{B}\right]} \quad \text{m}$$

The tuned length so determined is the distance from the squeezer to the rapper, measured along the line of the belt (see Figure 16). The conveyor snub pulley may serve as a squeezer when there is little room. It is recommended that an adjustment be provided, again measured along the line of the belt, in order to fine tune the rapping action to achieve the best results. The adjustment may be figured at about 10% of the tuned distance each side of the rapper.

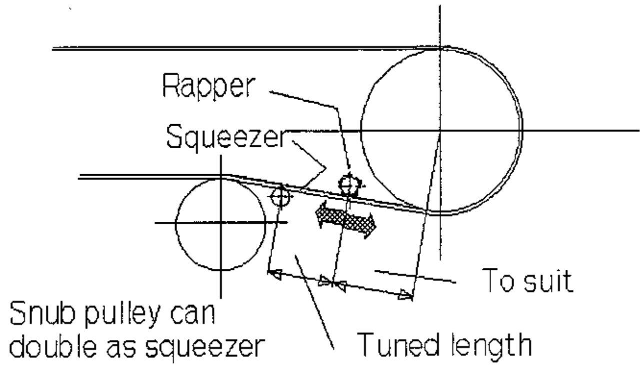

FIGURE 16. TYPICAL RAPPER AND SQUEEZER

The rapper is located such that the pitch circle diameter is tangent to the belt line. Under no circumstances must the belt be deflected around the rapper. That is, the rapper cannot be considered as a bend pulley, because the additional belt damping will destroy the rapping action, rendering the unit ineffective. The distance from the rapper to the head pulley may be figured as being equal to the rapping tuned length, but is not critical. Current practice is to make the rapper to head pulley distance about 2/3 of the tuned length.

The rapper is usually fitted with 5 or 7 studs, and very occasionally 9 studs. We use an odd number of studs to ensure the "hunting tooth" principle. In this way, the rapper is not likely to wear unevenly. The rapper base diameter is usually ϕ100 mm, ϕ90 mm or ϕ75 mm bright bar, with the studs usually ϕ16mm or ϕ20 mm bar. The rapper must be so designed that the pitch circle diameter of the studs is always tangent to the belt line. This is to ensure that the rapper will self start, being driven by the belt. Typical details of rappers and squeezers are given below (Figures 17 and 18).

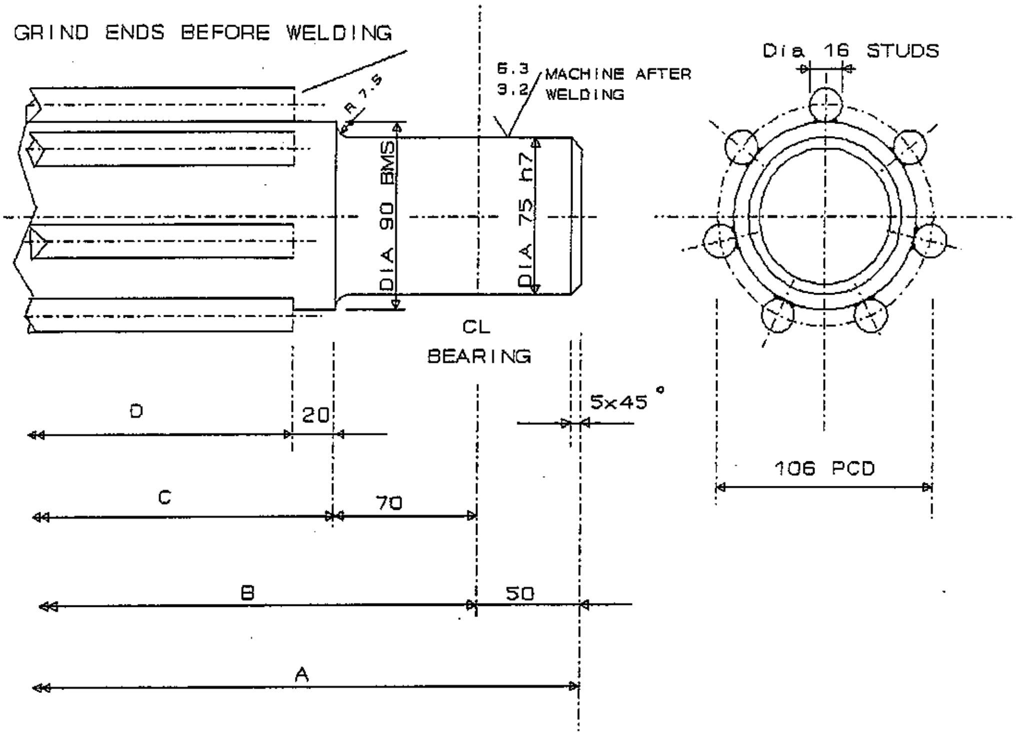

FIGURE 17. STANDARD 7-STUD ϕ106 PCD RAPPER

TABLE 4 : STANDARD 7-STUD ϕ106 PCD RAPPER

BELT WIDTH	A	B	C	D
600	940	840	700	660
750	1270	1170	1030	990
900	1470	1370	1230	1190
1050	1620	1520	1380	1340
1200	1550	1450	1310	1270
1350	1700	1600	1460	1420
1500	1850	1750	1610	1570

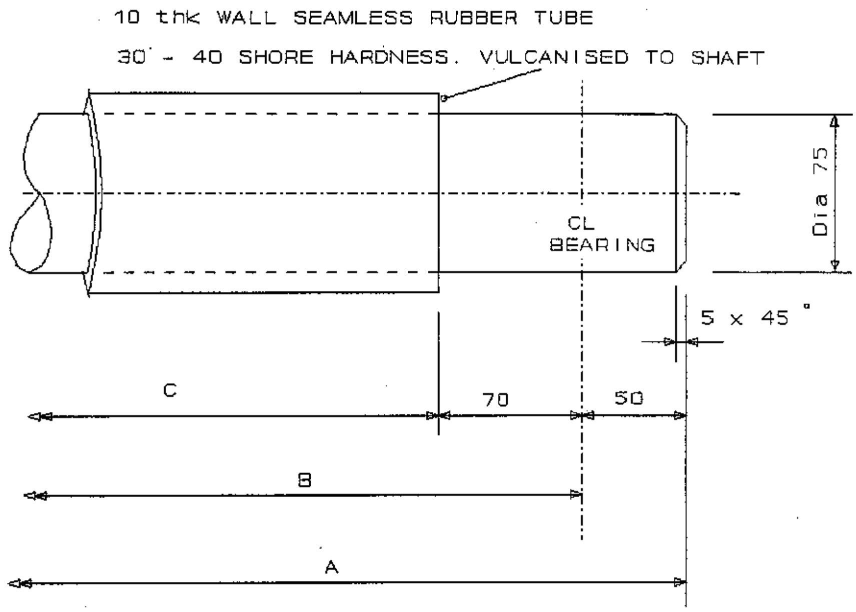

FIGURE 18. STANDARD ϕ75 SQUEEZER

TABLE 5 : STANDARD ϕ75 RUBBER COVERED SQUEEZER

BELT WIDTH	A	B	C
600	940	840	700
750	1270	1170	1030
900	1470	1370	1230
1050	1620	1520	1380
1200	1550	1450	1310
1350	1700	1600	1460
1500	1850	1750	1610

A useful set of formulae for determining the relationship between the base diameter and the number of studs on the rapper is given by

$$\alpha = COS^{-1}\left[1 - \frac{r}{R + r}\right]$$

Here R = Radius of base shaft and α = Half angular pitch (degrees)

The number of studs on the bar is then given by $n = \frac{360}{2 \cdot \alpha}$, rounded to the next higher *odd* number.

The selection of the base diameter will depend on the width of the conveyor. The ϕ90 mm rapper shaft is suitable for belts up to and including 1500 mm wide.

7. Ploughs and Return Strand Cleaning

In order to prevent spillage material from being trapped between the belt and the tail pulley, the return strand of the conveyor should be cleaned. The inner (or "clean" side) of the belting should be cleaned by means of a purpose made or commercial plough, which is designed to ride on the surface of the conveyor. In instances where there is sufficient access to both sides of the conveyor, the preferred V-form plough should be used.

Where access to the conveyor is limited to one side only, the single return strand plough should be used. In order to counteract the potential detraining effect of the plough, additional flat return idlers may need to be installed in the vicinity of the plough, to assist in the correction of the belt tracking (see Figure 19).

When the material is very sticky and wet, the installation of plain rubber blade scrapers, counterweighted to give a pressure of approximately 10 kg/m of belt width, should be considered. These scrapers should be installed just ahead of the idlers, for as many locations as required by the designer. Note that the return belt scraper is only

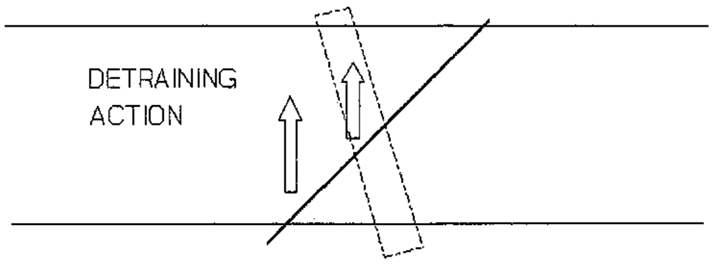

FIGURE 19. RETURN STRAND PLOUGH

used in conjunction with flat return idlers. When these scrapers are specified, they should be installed in addition to other belt cleaning equipment.

When a return strand plough is not specified, any spillage on the return strand may be shed (at virtually any convenient point along the return strand) by the installation of inverted Vee-form idlers, or inverted 35° idlers. Note that the normal transition distances for the local tensions should be applied at these installations, in order to minimise the edge stresses induced into the belting.

8. Dribble Chutes and Dribble Collection

Whichever belt cleaning method is utilised, the dribble should be handled by returning to the flow, or by removal to a separate handling system, as in the case of belt washing. In all cases the dribble collection chutes should be lined with a low friction lining material, to promote material flow and to minimise material build-up. The dribble chutes should be designed with steep sides, usually in excess of 70° to the horizontal. Because steep sided dribble chutes result in very high transfers, other separate means of handling the dribble may be specified.

8.1 Chain Scrapers

Chain scrapers are useful for relatively wide collection areas. The chain conveyor should be designed to be robust, with scraper blades that are sufficiently dimensioned to prevent overturning or bending under load (see Figure 20). The chain conveyor should be separately powered from the main conveyor and should be instrumented to continue running for at least 5 minutes after the main conveyor is stopped. The chain conveyor should be designed to slope towards the main chute body, for drainage. The chain scraper should be designed to be easily maintained. Because of the level of maintenance the specification of this type of dribble collector should be made with some care.

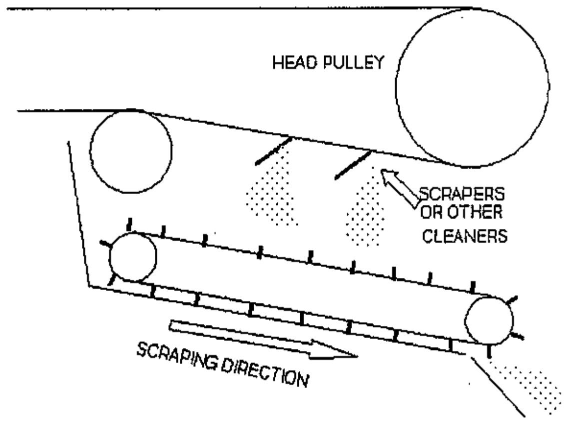

FIGURE 20 TYPICAL CHAIN SCRAPER

8.2 Screw Conveyors

Screw conveyors are useful for short collection areas (see Figure 21). They should not be specified where the material has a high clay content, or is very sticky. Ribbon screws are particularly useful to minimise build-up on the screw flights. Double *counter-rotating* screws are not recommended, while the double screw with sympathetic rotation is preferred for wider collection areas, in order to reduce headroom. The screw conveyor should be separately powered from the main conveyor and should be instrumented to continue running for at least 5 minutes after the main conveyor is stopped. The screw flight should be designed to be self-supporting, without the requirement for internal journal hanger bearings. The screw conveyor should be designed to be easily maintained and should be designed to slope towards the main chute body, for drainage.

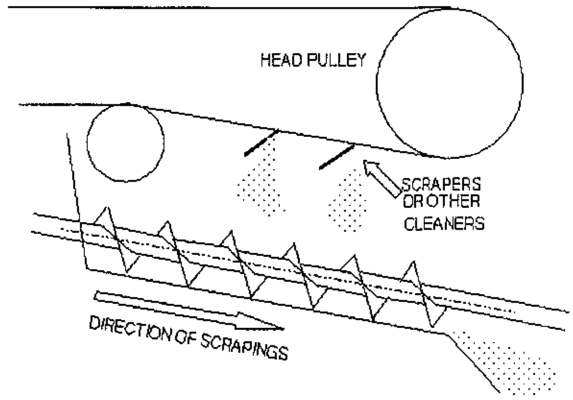

FIGURE 21 TYPICAL SCREW

8.3 Vibrating Feeders

Vibrating feeders should not be specified where the material has a high moisture and clay content. The feeders should be supported independently from the main chute body, on vibration isolating mountings. The system should be designed to be easily maintained. One of the major disadvantages of vibrating the dribbles, is that the material tends to pagg (that is, to build up, condense and firmly pack) more readily, if the feeder pan is at a fairly flat inclination. This form of dribble return is not common.

9. CONCLUSION

Although the materials handling industry in general and belt conveyor technology in particular has made tremendous advancements in the understanding of belt conveyors and their workings since the first Beltcon Conference in 1981, the same cannot be said for the operation of the conveyors in their locations. It is imperative to ensure that the systems that we specify so meticulously work in such a way that minimum maintenance is required, with the minimum personnel. Many mines and plants have contracts with specific belt cleaner suppliers, to keep their belts clean. While this approach is very useful, there is no real substitute for the training of the people that are going to operate the systems.

There is still no handbook on belt cleaning. The majority of publications relating to belt cleaning have been authored by representatives of specific cleaner system suppliers and must, therefore represent the views and philosophy of their respective companies.

An aspect of belt cleaning that must be addressed is the question of cost. Given the cost of labour and the possible costs of loss of production, the price of the commercial cleaner appears to be based on a comparison with the perceived potential saving, rather than an actual commercial cost.

The conveyor designer may be able to specify types of cleaners and systems that are most likely to work economically for given applications. The operating personnel must however be trained, to ensure the proper application of belt cleaning principles. In this way, the availability of the conveying equipment will improve, with the attendant improvement in productivity and profit.

10 ACKNOWLEDGEMENTS

The authors wish to thank the Anglo American Corporation Central Technical Office for permission to publish this paper. Thanks must also go to Dr Keith Wainwright for his valuable input and to Mr Albert Jacobs for editing the script.

11. REFERENCES

[1] Latimer, D. Canadian Mining Journal. *Selecting a conveyor belt cleaner.* May 1988

[2] Ringrow, G. Mining Technology. *Investment or Cost - The economy of efficient belt cleaning.* (Hosch) March 1994

[3] Swinderman *et al* Foundations. Martin Engineering Company. 1991

[4] SAIMH Special Program No 1. Proceedings of SAIMH conference. May 1989

[5] Rappen, A Bulk Solids Handling *Systematic cleaning of belt conveyors.* 1984

[6] BSH Bulk Solids Handling. Equipment Survey : Conveyor belt cleaning equipment. June 1988

[7] CEMA (4) Belt Conveyors for Bulk Materials. Fourth Edition 1994

[8] Page. J.L First International Chute Conference. *Examples of good and bad chute design.* Johannesburg 1991

[9] Goodyear Handbook of Conveyor and Elevator Belting. Metric Edition. 1976

[10] Rainer. A (editor) Conveyor Belt System Design. Contitech. 4. Revised 1990