BELTCON 1

BELT CONVEYORS - DESIGN, OPERATION AND OPTIMIZATION

PAPER B2

LOADING, DISCHARGING AND CLEANING OF BELT CONVEYORS

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SUMMARY

MATERIAL CHARACTERISTICS : definition of angle of repose, angle of surcharge and flowability.

LOADING THE BELT; Flow of material through the load chute. Optimising belt wear. Skirtboards. Belt speeds. Impact

DISCHARGE : Simple discharge. Plows. Trippers

BELT CLEANING : Scrapers. Rotating belt cleaners. Water sprays.

1. INTRODUCTION

The succesful operation of a belt conveyor requires that the conveyor be loaded properly and that the material carried by the belt be discharged properly.

Ideal loading exists when the material is placed centrally on the belt at a velocity equal to that of the belt.

Ideal discharge implies that all the conveyed material is discharged at the desired point and in the desired direction.

In practice ideal conditions are seldom achieved resulting in excessive belt wear, spillage and pollution which lead to higher running costs. In this paper various aspects of loading, discharging and cleaning, considered important in achieving the ideal, are discussed. Attention is focused on the effect that various loading and discharge conditions have on the life of the belting.

2. MATERIAL CHARACTERISTICS

The characteristics of the material to be transported impose many of the conveyor design limits and it is therefore important that accurate appraisal of these characteristics is made. The most important are, angle of repose, surcharge angle, flowability, abrasiveness and bulk density.

Some of these may need definition.

2.1 Angle of repose- This is the angle which the surface of a normal freely formed pile of the material makes to the horizontal. Obviously this angle is important in determining the profile of a stockpile.

2.2 Angle of surcharge- The angle to the horizontal which the surface of the conveyed material assumes. The surcharge angle is about 5° to 15° less than the angle of repose because of the tendancy of the material to slump as it is conveyed.

2.3 Flowability - The flowability of the material determines the cross-section of the material load on the belt. It is measured by the angle of repose and angle of surcharge together with size and shape of the material particles, roughness or smoothness of the surface of the particles, proportion of fines to lumps and moisture content.

The flowability of the material and the relationship to other material characteristics is illustrated in table 2.1.

	GROUP 1	GROUP 2	GROUP 3	GROUP 4
FLOWABILITY	very free flowing	free flowing	average flowing	sluggish
SURCHARGE ANGLE	5^o	10^o	20^o - 25^o	30^o
ANGLE OF REPOSE	Up to 19^o	20^o - 39^o	30^o - 39^o	40^o or more
CHARAC - TERISTICS	Small rounded particles, uniform size. Either very wet or very dry.	Rounded dry. polished particles of medium density	Irregular, granular or lumpy of medium density	Stringy, fibrous, interlocking and irregular size
EXAMPLES	Wet concrete, cement, dried peas	Grain, crushed quartz	Most ores, stone, coal	Damp clay, wood chips, bagasse, shredded asbestos.
COMMENT	Difficult to handle in terms of inclines, spillage.	Easier materials to handle		Difficult to handle in terms of chute blockage.

TABLE 2.1 FLOWABILITY OF MATERIAL

3. LOADING THE BELT

Loading the material onto the belt involves many considerations. Possible the two most important are first, placing the material centrally on the belt and second, ensuring that the material is fed in the direction of belt travel and at a speed as near as possible to that of the belt.

Delivering the material at a different velocity to that of the belt creates turbulence in the material at the loading point. A build-up of volume could form at this point negating all the care taken in designing a chute to cater for the required volume.

3.1 Flow of material through the load chute

The speed of the material as it leaves the load chute is related to the velocity of the material entering the chute, the chute angle, the fall, the material density and the flowability of the material.

i.e., $V_1 \sim V_2 . H . \sin\alpha . F . D$

where V_1 - exit speed

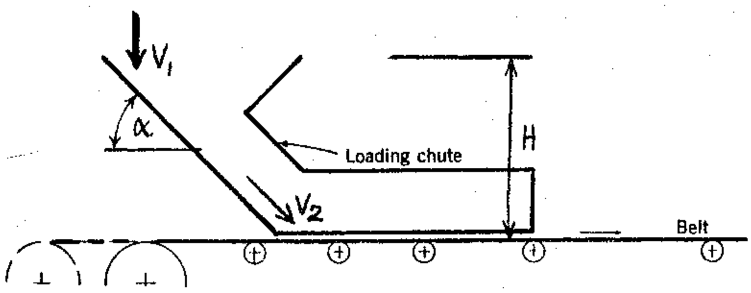
V_2 - entering speed

H - vertical fall

α - chute angle

F - flowability factor

D - material density



There is no published data on the flowabilty factor for various materials. This factor is dependant on the material characteristics stated in section 2.3 and also on the chute dimensions relative to the material size. For this reason the influence that the above values have on the exit velocity of the material is discussed but no attempt is made at formulating an exact relationship.

The component of velocity in the direction of belt travel is $V_2 . \cos\alpha$

To increase the material speed the chute angle must approach 90^o, but angles above 60^o result in a rapid decrease in the forward speed. Conversely, decreasing the chute angle has the effect of increasing the material speed in the direction of belt travel but the material would flow very slowly through chutes with angles less than 30^o. Optimum chute angle is therefore from 30^o to

60°. Heavier materials would flow more quickly through the chute making a smaller chute angle possible, while light materials require a steeper angle. Lumpy materials tend to tumble and bounce in steep chutes thereby impeading the material flow. So, while it is desirable to increase the chute angle for light materials, if they are lumpy the chute angle should be limited to prevent this tendency.

In many instances the material may enter the chute at a very high velocity. An example is where a crusher is positioned in the chute. A low chute angle would limit, and could possibly retard, the material speed but unless the exit velocity is close to that of the belt this is not recommended practice as will be seen later. An alternative means of limiting high lump velocities is to hang baffle bars or chains in the path of the lumps.

3.2 Optimising belt wear rate

Most of the wear and tear of the belt takes place at the loading point. The rate of wear is dependent on the velocity difference between the material and the belt as well as the angle at which the material strikes the belt.

At any given angle the wear rate is linearly dependent on the velocity difference as depicted in diagram 3.2.1. However, the relationship between rate of wear of rubber and the angle of impingment is not linear as seen in diagram 3.2.3. It is seen that the wear rate rises rapidly up to an angle of about 22° where it is immeasurably high. The wear rate then decreases rapidly for angles from 22° to 50° after which the slope of the curve starts to flatten until an optimum rate at 90°. It is desirable to keep the angle above 50° since small changes in angle have less serious consequences in terms of wear rate. A 50° angle represents a wear rate of 3. In terms of a moving belt the impingment angle is the effective angle taking into account the direction of travel of the material and the difference in speed between the belt and the

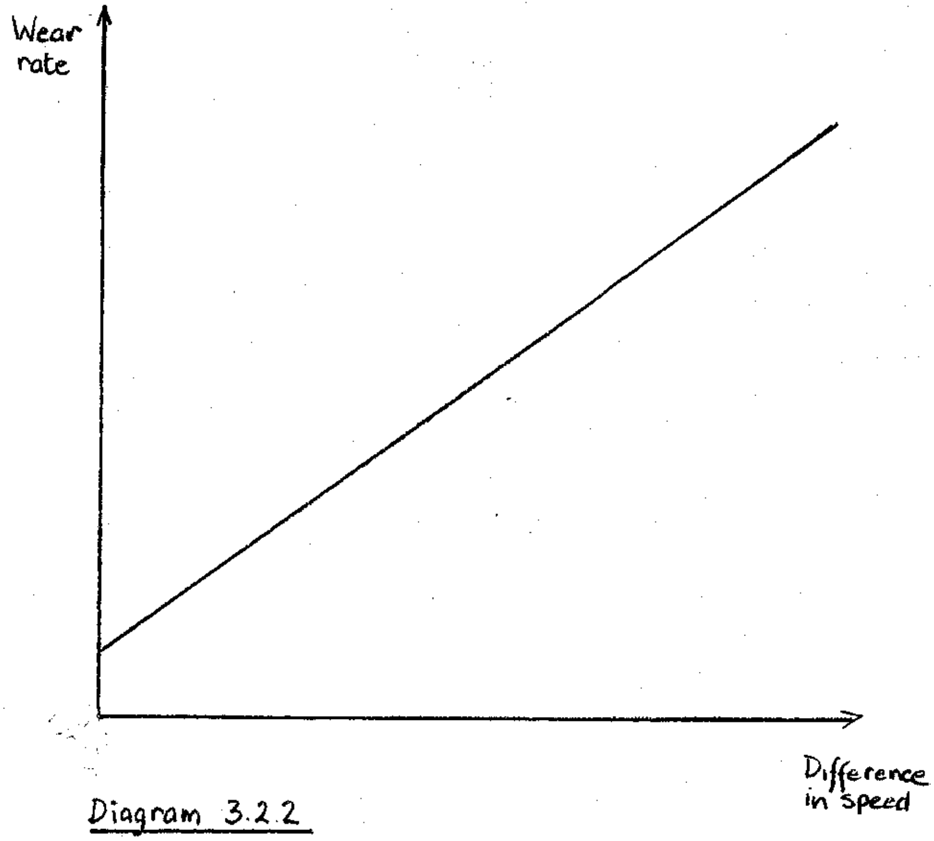


Diagram 3.2.2

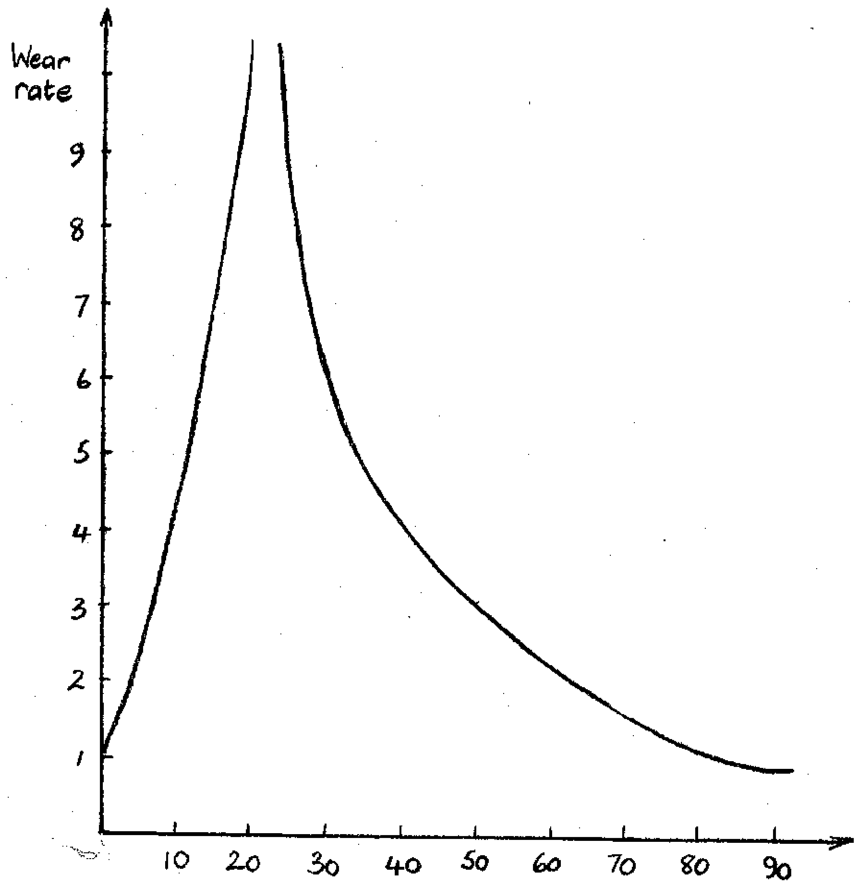


Diagram 3.2.3

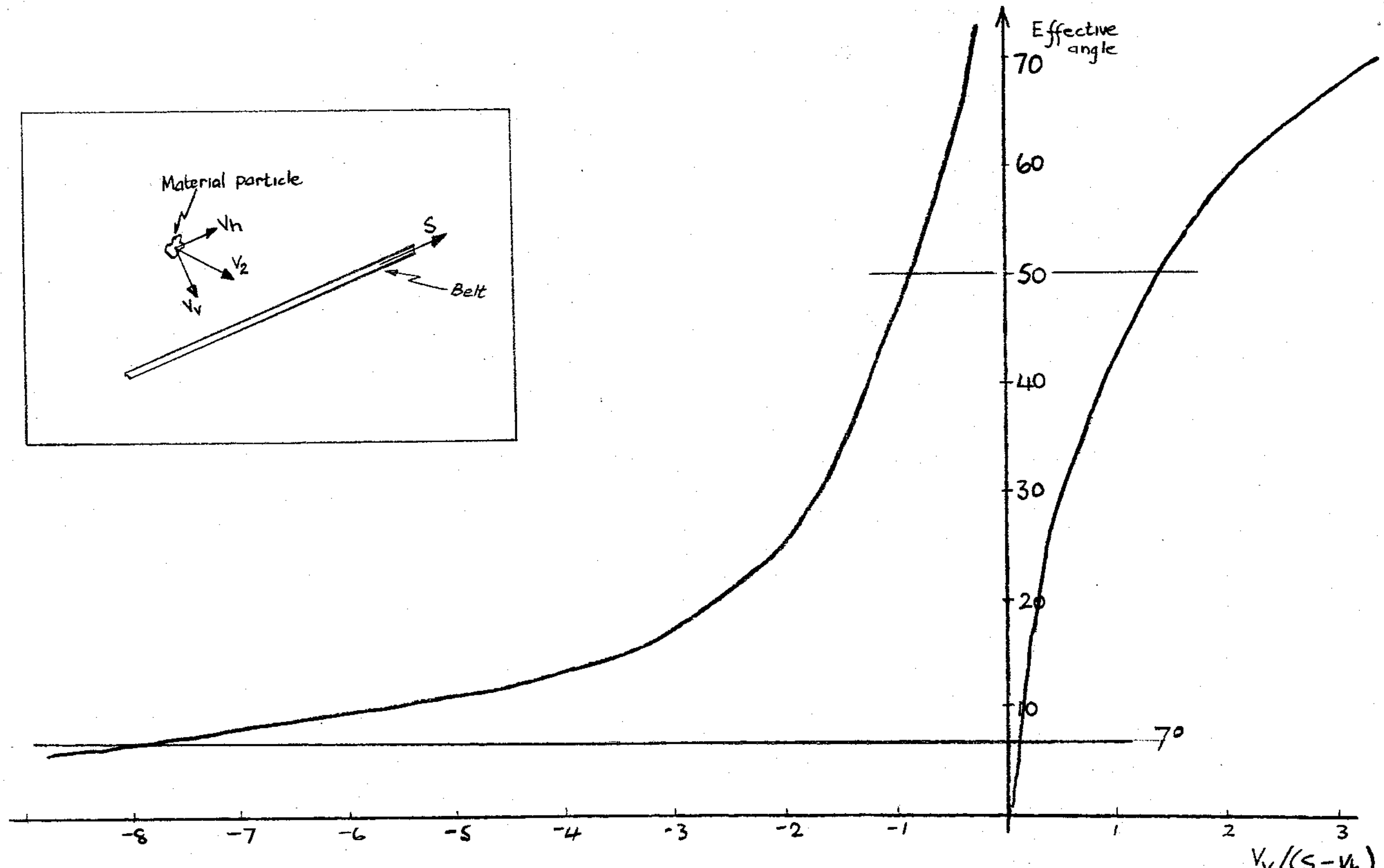

Effective angle
70
60
50
40
30
20
10
7°
-8
-7
-6
-5
-4
-3
-2
-1
1
2
3
Vv/(S-Vh)
Material particle
Vh
V2
Vv
S
Belt

Diagram 3.2.4

material. If V_v is velocity of the material in a vertical direction relative to the belt, V_h the horizontal velocity and S the belt speed, then the effective angle of impingment is:

$$\text{Effective angle} = \arctan\left(V_v/(S-V_h)\right)$$

Plotting the velocity ratio $(V_v/(S-V_h)$ against effective angle results in the graph shown in diagram 3.2.4. To keep the wear rate less than 3 the effective angle must be smaller than 7^o or larger than 50^o. This means that in the case of a positive velocity ratio, i.e., belt speed greater than horizontal material flow rate, the velocity ratio must be less than 0.1 or greater than 1.2. For material flow rate greater than the belt speed the ratio should be less than -8.2 or greater than -0.9.

If the belt is inclined at the loading point it is difficult to avoid large differences in speed between the material and the belt. Table 3.2.1. shows the ratio between horizontal and vertical velocities for different angles. In the case of an inclined belt the angle of flow of the material is effectively increased by the amount of the incline. Suppose, for example, the chute angle is 50^o to the horizontal and the belt inclined at 15^o then the angle relative to the belt is 65^o. Reading from the table it is seen that the horizontal speed, or the speed in the direction of the belt, is 0,466 times the vertical speed, If the belt was not inclined the ratio is 0.839. This means that inclining the belt has nearly halved the speed of material in the direction of belt travel, which bearing in mind what has already been said, could lead to a very much faster rate of wear.

ANGLE OF FLOW θ	COS θ / SIN θ
30.	1.732
35.	1.428
40.	1.191
45.	1.000
50.	0.839
55.	0.700
60.	0.577
65.	0.466
70.	0.363
75.	0.267
80.	0.176

TABLE 3.2.1

3.3 Skirtboards

Invariably there will be some turbulence in the material as it is loaded onto the belt. Skirtboards are used to confine the load to the belt while it settles. These are an extension of the sides of the loading chute.

The gap between the bottom edge of the skirtboard and the belt surface must be sealed with a rubber strip to ensure that the material cannot become lodged between the solid skirtboard and the belt. The spacing between the skirtboards should increase from a minimum of about one third the belt width at the point of loading to about twice this distance at the other extremity. This will allow material that may become trapped between belt and skirtboard to dislodge itself. Another good practice is to progressively increase the gap between skirtboard and belt, in the direction of belt travel.

The length of the skirtboard is a function of the difference between the material velocity and the belt velocity. Ideally the material should be at rest relative to the belt, before leaving the confines of the skirtboards. In practice, unless the difference in velocities is large, the skirtboards, should be approximately 1m in length with an additional 1m for every 1m/s belt speed.

The height of the skirtboard is related to the material size and the direction of feed onto the belt. In addition the height must be sufficient to contain the material volume which is a funtion of belt width. As a general rule of thumb, for cases where the material feed is in the direction of belt travel the skirtboard height should be not less than the figure shown in table 3.3.1.

20 DEGREE TROUGH ANGLE									
BELT WIDTH	LUMP SIZE 50	100	150	200	250	300	350	400	450
450	125	125	125						
600	135	135	150	165					
750	145	160	175	190	210				
900	170	185	200	215	235	250			
1050	195	210	225	240	260	275	290		
1200	220	235	250	265	285	300	320	335	
1350	245	260	275	290	310	330	345	360	385
1500	270	285	300	320	335	355	370	385	410
1800	320	335	355	370	385	405	420	435	460
2100	370	385	405	420	435	455	470	490	510
2400	420	435	455	470	490	505	520	540	560

35 DEGREE TROUGH ANGLE									
BELT WIDTH	LUMP SIZE 50	100	150	200	250	300	350	400	450
450	175	175	175						
600	190	190	200	215					
750	220	220	240	255	270				
900	245	260	275	290	310	330			
1050	280	295	315	330	350	365	380		
1200	320	335	355	370	385	405	420	435	
1350	370	375	390	405	425	440	455	475	500
1500	395	410	430	445	460	480	495	515	535
1800	470	490	505	520	540	555	570	600	635
2100	550	565	580	595	615	635	650	690	725
2400	625	640	660	675	690	710	725	775	825

TABLE 3.3.1 SKIRTBOARD HEIGHT (MM)

Skirtboard dimensions are illustrated in diagrams 3.3.1 and 3.3.2.

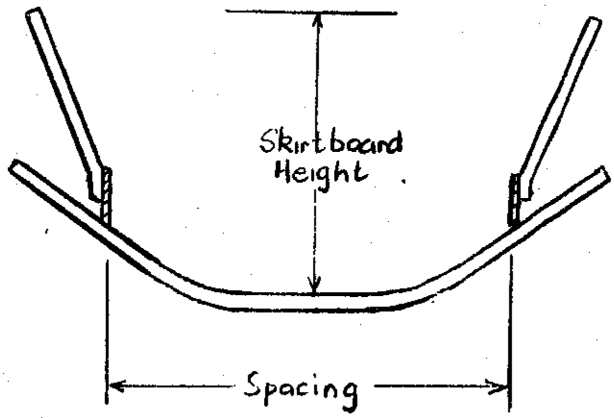


Diagram 3.3.1 Section through A-A

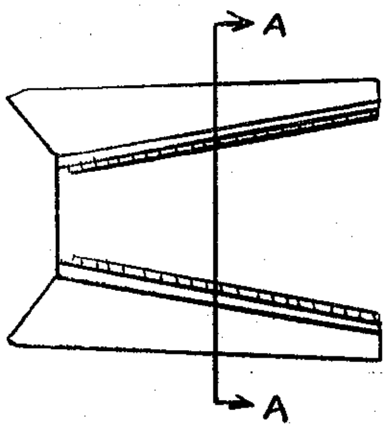


Diagram 3.3.2 Plan of skirtboard

The weight of the load causes a deflection of the belt between the carrying idlers. If fine material is being conveyed it is possible that this could leak between the belt and the skirtboards. The amount of deflection or sag between the idlers is given by the following:

$$Sag = 9{,}81 . M . I^2 / (8.T)$$

WHERE M - Mass of load per unit length (kg/m)

I - Idler spacing (m)

T - Belt tension (N)

The combination of idler spacing and slack side tension together with the arrangement of the rubber sealing strip on the skirtboard must be designed to prevent any leakage.

3.4 Belt Speeds

Advances in troughed belt conveyor technology have made high belt speeds, in the order of 6 to 7 m/s, possible. This has considerably increased the number of combinations of belt speed and width which could be chosen to meet the desired capacity requirement. It appears that the most favoured combination is to keep the conveyor width as narrow as possible and increase belt speed. This alternative seems to be favoured because of the economic advantages of a narrower conveyor and lower belt tensions. However there are disadvantages and sometimes it is worth considering a wider belt at a lower speed. If the cross sectional area increased linearly with increase in belt width there would definitely be little advantage in keeping the belt speed low. However, as seen in diagram 3.4.1 the increase in cross sectional load area is not linearly proportional to belt width. This means that, in some cases, increasing the width by 30 percent can increase the capacity by 100 percent without an increase in speed. Or, said another way, doubling the speed will double the capacity but could substantially increase the wear rate while increasing the width by 30 percent could also double the capacity without increasing the wear rate. There are other advantages to keeping belt speeds low and increasing the width. One that is becoming increasingly important is that owing to the fact that conveying efficiency improves with belt width, a wider belt will consume less energy when moving the same capacity as a narrower belt travelling at an increased speed.

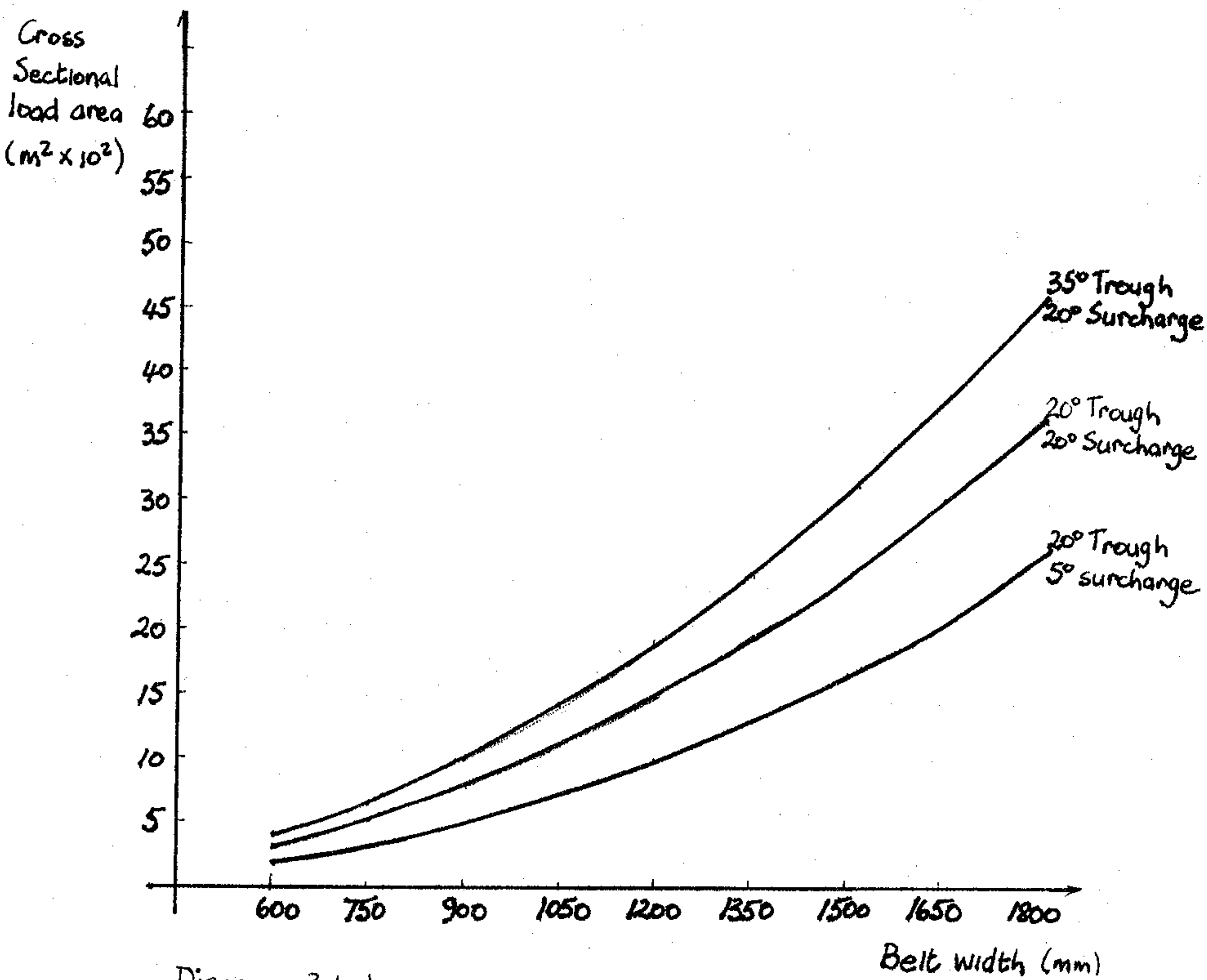


Diagram 3.4.1

3.5 Impact at the loading point

In the preceding discussion belt wear has been taken to mean removal of the cover by abrasion, cutting and gouging. In addition to this type of wear belts are damaged by impact. It could even be argued that impact damage is one of the greatest causes of belt damage and consequently design should concentrate on attempts to limit impact.

Very fine materials, even if heavy, do not cause much impact damage. However, lumpy materials, particularly those of high density, can cause appreciable impact damage and the design of the loading chutes should take this into consideration.

Where the material consists of mixture of fine and lumpy material, the chute can be arranged to first deposit the fines on the belt. The bed of fine material then acts as an impact absorbing layer for the more severe lumpy material. In practice this can be achieved fairly simply by cutting a Vee into the bottom plate of the load chute, as shown in diagram 3.5.1.

A more sophisticated, and not always as effective arrangement is to have a screen arranged inside the chute. (see diagram 3.5.2). One of the problems with this is the difficulty of getting to the screen for removal of the inevitable blockage.

As has already been mentioned the vertical speed of the material relative to the belt is increased when the loading portion of the belt is inclined. Consequently impact problems are accentuated in these circumstances and it is recommended that large heavy material is loaded onto a horizontal belt.

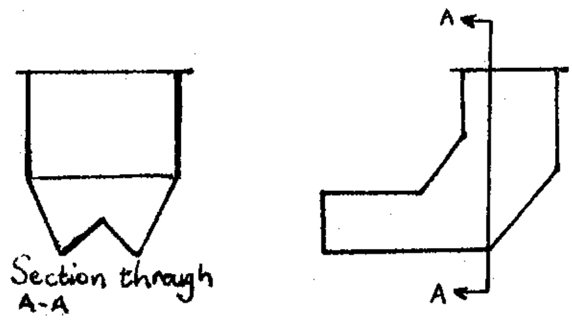


Diagram 3.5.1

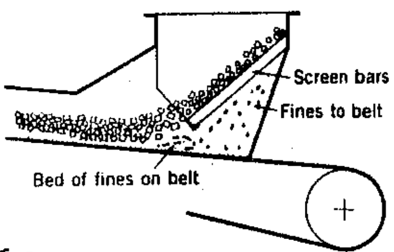


Diagram 3.5.2.

4. DISCHARGE

Materials carried by a belt can be discharged in many different ways to effect certain desired results. A few of the more commonly encountered ways are discussed briefly.

4.1 Discharge over terminal pulleys

This simple discharge is commonly used. The trajectory of the discharged material should be investigated to ascertain where the material will fall. The pile of discharged material must not be allowed to build up to the extent that it fouls with the belt. In particular, when discharging into a chute the design should be such as to minimise the chances of material jamming between the chute and the belt. The prime requirement of the discharge chute is to collect all the material discharged and cleaned from the belt. Having performed this task the chute can be designed for a multitude of other functions such as redirecting the material or lowering it into bins. Where the discharge chute acts as a transfer to another conveyor it is obvious that consideration must also be given to the items discussed in the previous section.

4.2 Plows

Only fine, preferable free flowing, materials should be discharged by means of plows. It is possible to use plows to skim material from the top of a troughed belt but discharge by plows is only really effective if the belt is flat. The discharge plows should be set at an angle less than 35° to the belt centre line. To prevent leakage under the plow it should be fitted with a rubber strip on the underside. If the portion of the belt under the plow is supported by a metal slide plate the discharge efficiency is further increased.

4.3 Trippers

Trippers are used to discharge material upstream of the head pulley in applications where the use of plows is not suitable. A typical tripper arrangement is shown in diagram 4.3.1. The upper pulley acts as a conventional terminal pulley to discharge the material into a chute which directs the material to one or both sides of the belt.

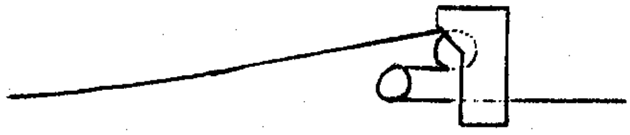


Diagram 4.3.1 Typical tripper arrangement

It is common to find that the radius of the curve to the tripper is totally inadequate. This results in a tendency for the belt to lift off the supporting idlers causing material spillage and in some cases results in the belt wandering off the face of the tripper pulleys. In the case of moving trippers the idlers on the tripper bogey must clear the idlers of the conveyor structure. This normally means an excessive spacing between the last idler on the structure and the first of the tripper bogey. Incorporating a slide which moves along the fixed idlers and which carries the tripper idlers can overcome this problem.

5. BELT CLEANING

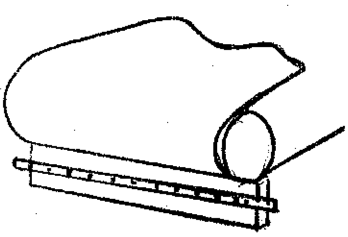
In the past 20 years major advances in conveyor technology have teken place. Despite these technological developments which have allowed higher capacities and speeds, both manufactures and users of belt conveyors are still searching for an effective belt cleaning method.

One of the properties of rubber covered conveyor belts which has led to its wide acceptance is the high coefficient of friction of rubber. While this reduces the tendency for the load to slip on inclines it increases the difficulty of cleaning the belt.

On the return the dirty side of the belt is normally on the underside. Consequently the material clinging to the belt either rubs off onto the idlers or creates a highly abrasive surface which wears the idler rolls premturely. The effect in both cases is to increase maintenance costs. One means of overcoming this problem is to clean the belt. There are a multitude of belt cleaning devices available for this purpose.

5.1 Belt scrapers

The belt scraper is the most common system used for belt cleaning. Belt scraper blades can be made from a variety of materials such as rubber, steel, porcelain and polyurethane.



In theory all that is required to clean the belt is a continuous transverse blade in contact with the dirty side. In practice it is found that certain problems occur with a simple scraper blade, made of relatively thin soft rubber. These are:

1. The flexibility of the blade allows material to pass
2. Vibration and chatter creates excessive blade wear and decreases efficiency
3. Wear of the blade results in a loss of contact and thus loss of cleaning efficiency
4. Uneven wear, in the centre of the blade occurs and prevents adjustment
5. Adjustment of the blade relative to the holder can be difficult after the scraper has been in use.
6. Build up on the blade and blade holder impairs cleaning efficiency.

These problems have paved the way for a variety of designs of continuous blade. A feature of these various types which is common is that they are all aimed at eliminating one or more of the 6 problems stated above.

Virtually all scraper blades now have some means of automatic adjustment ensuring that the blade remains in contact with the belt. The amount of automatic compensation should be limited to prevent the holder making contact when the blade has been completely worn.

Some blades consist of a thick moulded section which is supported on the underside. This design, depicted in diagram 5.1.1 will not bend easily in the direction of belt travel and adjustment of the blade relative to the holder is never needed.

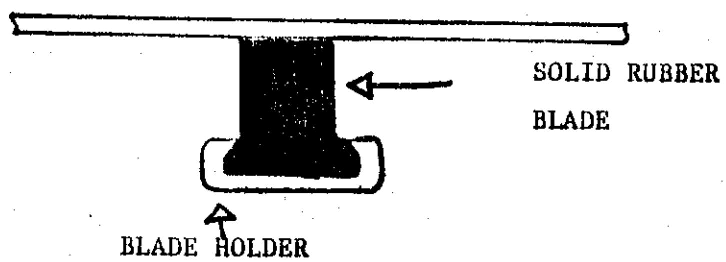


DIAGRAM 5.1.1

A similar design incorporates a square metal tube giving transverse rigidity which eliminates adjustment of the blade relative to the holder. This design (diagram 5.1.2) has 3 scraper sides. When the first blade is worn the scraper is turned through 90° to bring the second into use.

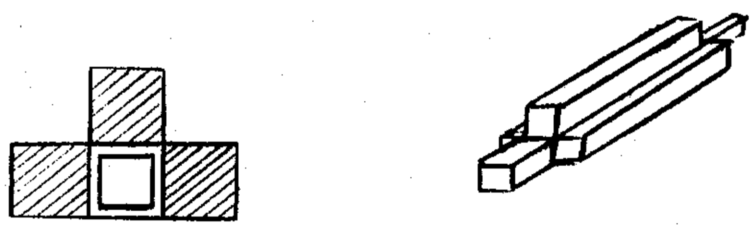


DIAGRAM 5.1.2 - T SCRAPER

A variation of the conventional soft rubber blade is one which comprises three layers of rubber moulded together. The two outer layers are very hard while the inner layer is a soft abrasion resistant compound.

The hard rubber assists in scraping sticky materials without being deflected while the soft inner core improves blade life.

However, no continuous blade will overcome the problem of uneven wearing. Since blades will never wear evenly the efficiency of all continuous blades soon drops off.

There are a variety of sectional scraper blades available which allow for uneven wear to a greater or lesser extent depending on the number of sections.

Some of the types are discussed briefly:

5.1.1. Independent blades numbering from 2 to 6 depending on the belt width, are automatically adjusted by means of independent weighted levers. Longitudinal and transverse pivot axes allow the blades to 'follow' the belt.

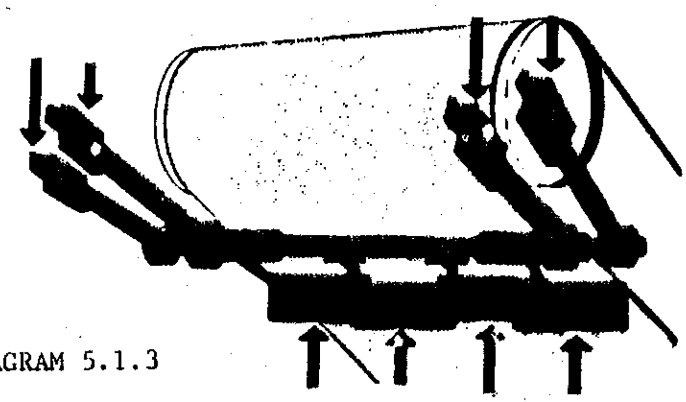


DIAGRAM 5.1.3

The blades which are tilted in the direction of belt travel to prevent chatter, drop onto the holder for easy replacement and are secured by a split pin to prevent them inadvertently falling off. Three blade materials are available.

a) Tungsten carbide tips for exceptional high wear resistance and excellent cleaning efficiency
b) Ceramic tiles for good blade life and excellent cleaning efficiency provided metal fasteners are not used
c) Metal backed rubber for fair cleaning efficiency and blade life.

5.1.2.

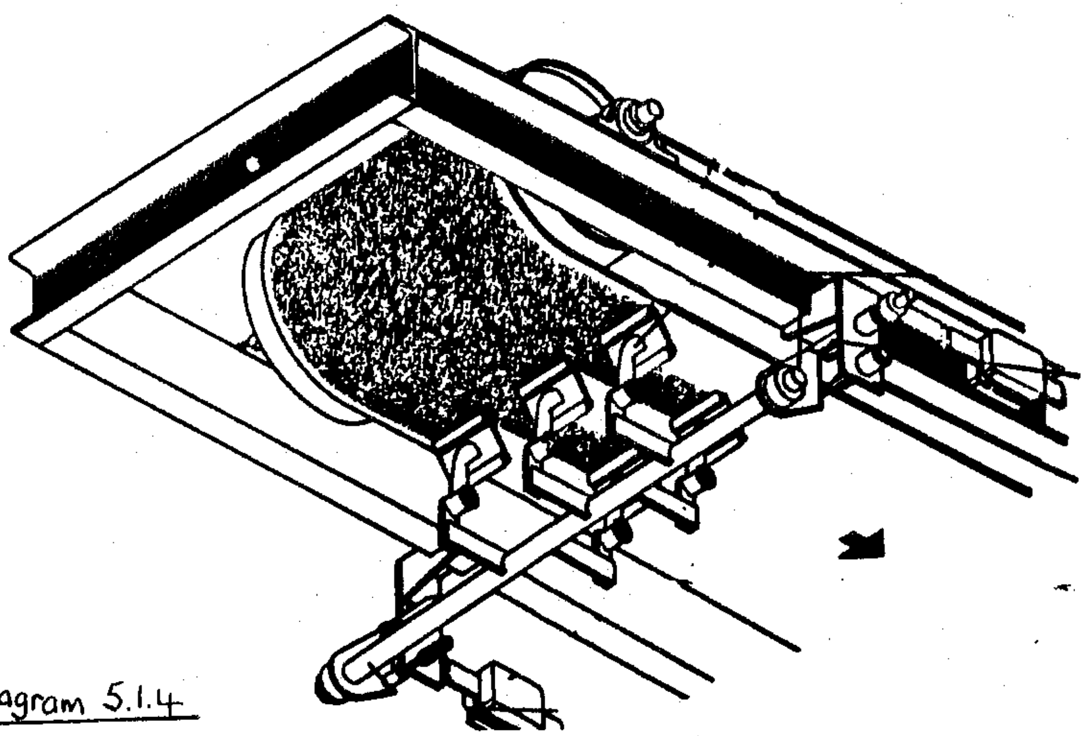


Diagram 5.1.4

In the type depicted in diagram 5.1.4 the blades are tilted in the opposite direction to the previous type. This causes vibration which, it is claimed, will shake embedded particles loose. Each blade, numbering from 4 to 17 depending on belt width, is mounted on a common shaft via a rubber mounting. The rubber mounting damps vibration to prevent loss of cleaning efficiency. The common mounting shaft is connected to a weighted lever to maintain pressure between the scrapers and the belt. Each blade, by virtue of the rubber torsion mounting, is self adjusting to a limited degree. The blades have tungsten carbide tips for long blade life.

5.1.3.

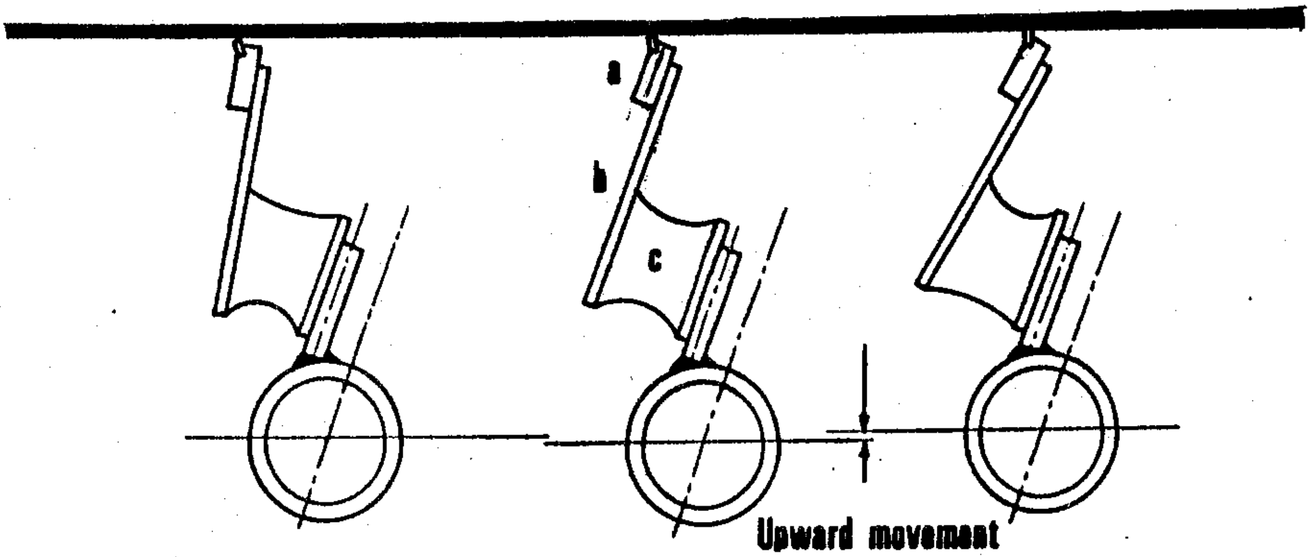


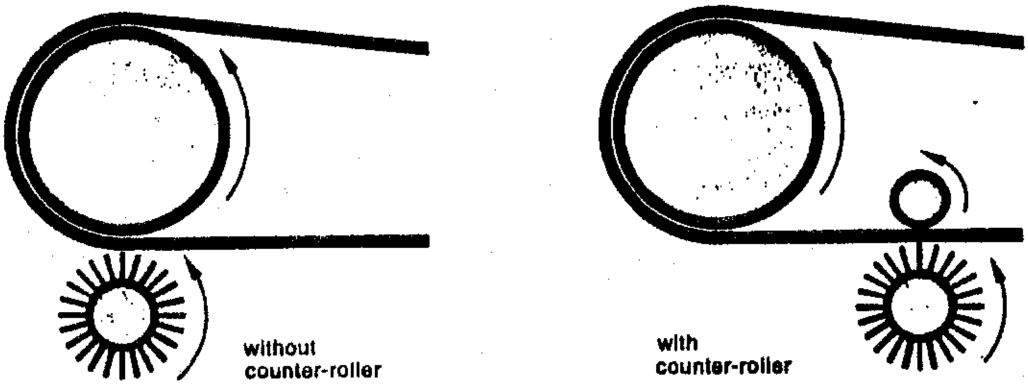
Diagram 5.1.5

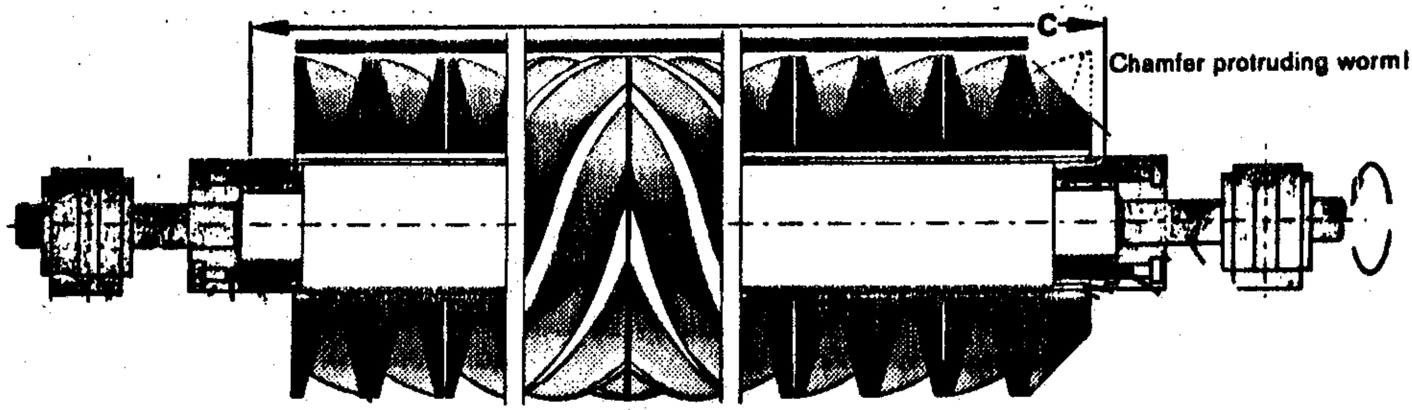
A similar type to that described in section 5.1.2 is shown in diagram 5.1.5. However, there is no lever action on the common mounting shaft. Instead the shaft is twisted to allow pressure between the belt and blade. The number of blades varies between 4 and 14 depending on belt width. The blades have tungsten carbide tips for long life.

5.2 Rotating belt cleaners

These consist of power driven shafts or tubes to which brushes rubber fingers or rubber profiles are attatched. Rotation is in a direction opposite to the belt travel to get maximum cleaning action. Rotary belt cleaners can be driven by chain from the adjacent head pulley shaft, or by a seperate drive.

Mounting position of the brush





5.3 Water spray and wipers

High pressure water sprays can be effective in certain difficult applications. The spray is directed against the dirty surface of the conveyor belt by means of nozzles. A rubber scraper blade is positioned behind the water spray to remove excess water after the belt has been washed.

All the above cleaning devices have been designed to be added to a conveyor as ancillary equipment which suggests that belt cleaning is not given sufficient attention at the design stages. A notable exception to this is the new Selby drift conveyor belt, in the U.K. This conveyor which when installed will be the most powerful in the world will incorporate a belt washing and drying system between the head pulley and the drive. A combination of high pressure water sprays and scraper blades will remove adhering particles after which blades and air will dry the belt.