Western Australia

PO Box 1856
Fremantle WA 6160
Phone: 0419 293 405
Fax: (08) 9336 6639

New South Wales

15 Yanilla Ave.,
Wahroonga NSW 2076
Phone: 0419 293 405
Fax: (02) 9487 1584

Conveyor Belt Transitions

Information Paper

Rev.	Status	Date	Author	Approval	Description of change
1	final	12/02/10	C.Benjamin	P.F.	

Contents

1 Overview

The basic tenet of conveyor system design is to move high material volumes in a very reliable manner. Reliability is directly linked to maintenance; the more maintenance necessary consequently means a less reliable system. In many cases it is very fundamental flaws in the design or installation of a system that leads to a great deal of maintenance and this is the case if the transitions between the points where the belt is troughed to where it has to go over a flat pulley face are not correct. These sections in a conveyor system are usually termed the “Belt Transitions” and in all troughed belt conveyors there is always at least 2 points, one at the head end of the conveyor and one at the tail. It should however be noted that a transition occurs whenever there is a change in the idler trough angle such as a loading point where the angle at the load point is 45 degrees and along the conveyor, 35 degrees.

The consequences of having one or more poorly designed or installed transition areas are very significant. They are;

- Abnormal and rapid pulley lagging wear. It is by far the most common reason why lagging wears out prematurely.
- Idler shell wear on the return side idlers.
- Idler bearing failures especially on the wing section idlers on the troughed side of the belt at the beginning of the transition section.
- Breaking the outer cables of a steel cord conveyor belt or fracturing the belt edges. It is also possible to break centre cables in a steel cord belt.
- The inability to adequately clean a conveyor belt leading to dust, spillage, build up around the return idlers and an acceleration of any wear that is occurring.
- Damage or premature wearing out of the conveyor belt especially if inappropriate remedial action is taken, e.g. using ceramic lagging to extend pulley lagging life.
- The potential for an extreme failure if a major slip occurs during a belt start or a pulley mounting fails due to the unbalanced forces across the pulley face.

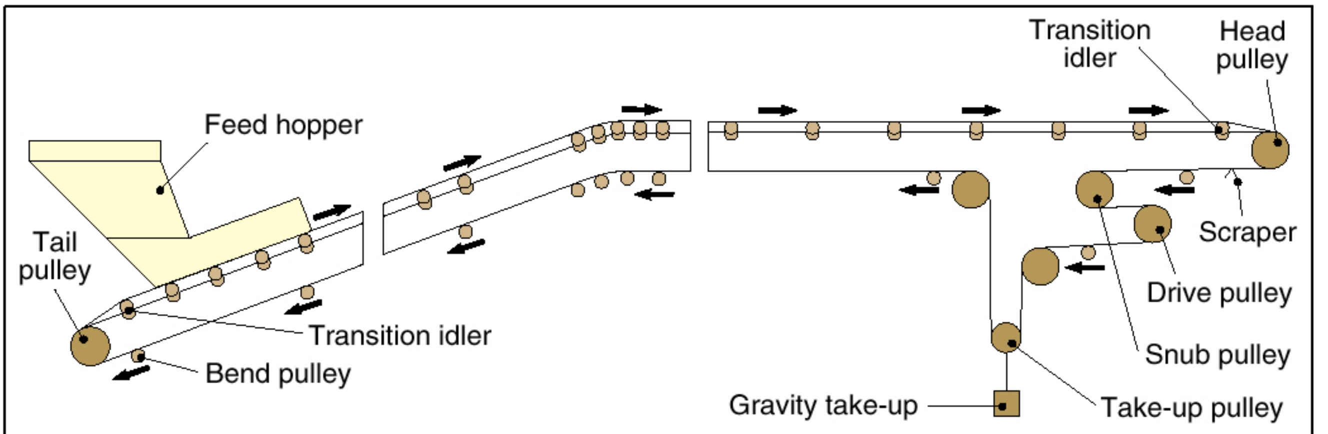
In the following the design and installation of a conveyor transition is covered along with sections on why there are such consequences, how to avoid or fix the problem and if the system is a mature system which has operated for a period of time, how to manage the problem until it is opportune to address the root cause.

Finally the consequences of having a poor transition are universal but the higher the tensions within the system the more catastrophic and frequent the possible outcomes. Further a poor transition in a high tension zone means the consequences will start becoming evident very rapidly, much more slowly if the transition issue occurs in a low tension zone.

This paper is designed to alert you to the importance of conveyor transitions, how to detect whether you have a potential problem and how to correct the problem.

2 Design and Installation of Conveyor Belt Transitions

In a general belt layout the transitions or transition idlers that are usually looked at are identified in the following diagram.



GENERAL CONVEYOR LAYOUT

The key to designing a conveyor belt system is making sure that all the forces generated under all operating conditions are balanced. When a belt is troughed in order to increase the material volume it can carry, the edges of the conveyor belt have to stretch further than the centre of the belt. In order for this to happen so the forces remain balanced the conveyor belt must be given “time” to stretch and “time” to relax. There are complex equations used that are now contained within most conveyor design programmes that calculate the time it takes for this to happen. The time is mainly dependent on;

- The elastic modulus of the belt carcass. This is a measure of the ability of the belt to stretch, fabric belts have lower moduli and therefore stretch more easily, steel cord reinforced belts much higher. Also the stronger the belt the higher the moduli. The higher the moduli, the longer the transition required as it takes longer for the belt to stretch, i.e. configure to the change.

- Tensions within the system.

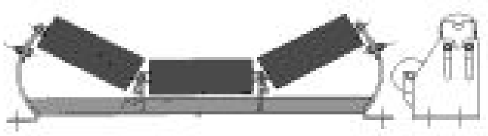
- The angle change (usually the angle of trough), the bigger the change, the longer the time.

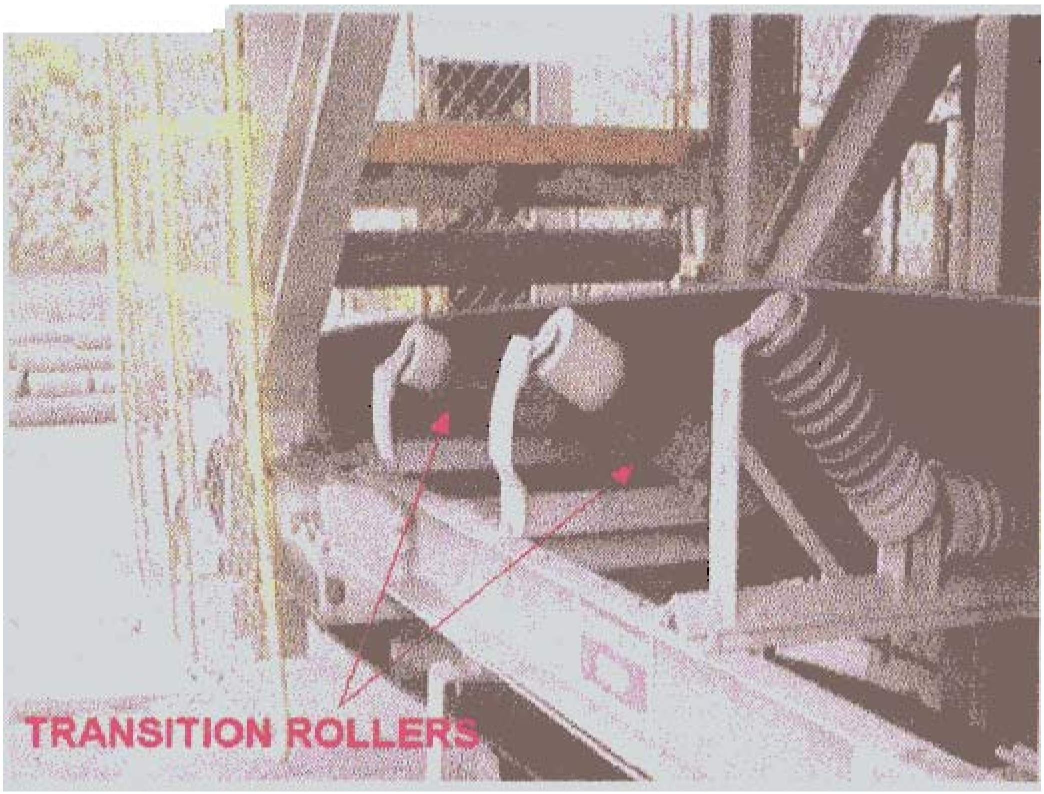
- The positioning of the pulley the belt is coming from or going into relative to the height of the centre roll in the troughed section. The shortest transitions are had by using a point mid way between the height of the wing idler and centre roll as the height of the pulley face relative the idlers. This is because the centre of the belt is being asked to stretch a little and the edges relax (in terms of a head end transition) so there is a dynamic across the whole belt width thus minimising the time the belt takes to equalise its length (or conversely stretch to accommodate the trough). Once again it gets back to balance.

Once the time has been calculated, the belt speed by time gives the transition length required.

Some companies at the project level (e.g. BHPBIO) take a conservative approach of multiplying the belt width by six (6) to establish the transition lengths for new projects. This is conservative if the belts are wide and do not have a tensile rating greater than 3500 KN/M width of belt, it therefore does not guarantee a satisfactory design in all instances.

Once the transition length has been calculated simple geometric lines are drawn from the centre roll and the idler wings to the pulley face. At points where an idler would be installed, what is termed a transition idler is installed. These idlers basically have adjustable trough angles and the trough angle is established by ensuring the wing edge touches the upper line and the top of the centre roll touches the lower line.





Once the design has been done and drawn up, it is up to the installation team to translate the design into a reality. Errors can occur in installation if the installers are unaware of the importance of transitions and these errors can be a result of such factors as;

- Having installation drawings where the dimensions are taken off centre lines and the installers apply these to wing idler alignment as it is too difficult to access the centre of the structure. This usually results in the pulley being installed too high relative to the centre rolls of the transition idlers.
- Not taking enough care especially with packers etc.
- Inclined conveyors when installed may have slightly different R/L's due to minor steel work or foundation variations. This may result in the pulley being anything up to 50mm higher or lower than expected. Failure to adjust the idler alignments for such an eventuality or to adjust the R/L of the pulley back to the drawings distorts the transition.
- If a conveyor has a shuttle, installing the shuttle such that the shuttle belt storage carriage can come too close to the head pulley when the pulley retreats. It could be argued this is a design issue rather than installation.
- Neglecting other transitions such as those from the belt storage carriage of a shuttle to the normally aligned trough section. Once again this could be argued to be a design issue.
- Poor construction and steel work tolerances.

In the following the consequences of such errors are looked at and then how to detect if an error has occurred.

3 Consequences of Operating Conveyor Belts in Systems with Poor Transitions

If a belt does not have the time to recover the tension balance once it goes from trough to flat or vice versa then sections of the belt carcass will be “out of balance” relative to the new circumstances.

1. In the case where the belt is going from trough to flat (i.e. reducing the amount the belt edge must stretch) then the belt edge will be longer than the centre of the belt when it goes over the flat pulley face. This has the effect of;

    - Ensuring the belt is not evenly flat across the pulley face.
    - As this usually happens in the high tension zone, the belt tries to equalise the imbalance by permanently distorting as dictated by the tension imbalance across the pulley face. This is particularly the case with steel cord reinforced conveyors. This basically translates to the belt never being able to lay flat again. In such case the term used is that the belt has a “permanent memory”.
    - Once the belt has acquired the “permanent memory” it will not lay flat against any pulley face, against the scrapers nor against flat return idlers. The problem cannot, as the term permanent implies, be rectified if the installed belt is steel cord reinforced.
    - If the head end transition that is incorrect is so because the pulley is too low relative to idlers it will have the tendency to pulley the belt down physically creating very high edge tensions. This translates to a series of consequences discussed later.
    - If the head end transition that is incorrect is so because the pulley is too high relative to the idlers it has the tendency to lift the belt off the centre rollers meaning the belt lacks correct load support over the last few idlers in the high tension zone. This causes what can be best described as a “W” stretch pattern of the belt. The bottom of the Vee in the “W” corresponds to the idler junction in a 3 roll system. This is the most common head end transition problem and translates to a series of consequences discussed later.
    - If the head pulley comes too close to the shuttle belt storage carriage such that the belt lifts off the centre rolls of the transition sets and possible the adjoining couple of normal trough set idlers. This has the same effect as the issue directly above except the impact is usually more extreme, i.e. the consequences are worse.

2. In the case where the belt is going from flat to trough (i.e. increasing the amount the belt edge must stretch) then the belt edge will want to pull flat as it will not be long enough. This has the effect of;

- Creating high edge loadings on the belt that has consequences discussed later.

- Can create a situation where the excess edge tension creates "negative" tension in the centre of the belt. In the case of a steel cord belt in particular this negative tension can result in the wire filaments or strands that are woven together to create the steel cable working against each other and eventually fatigue failing causing cable breaks.

Stated earlier, conveyor system design relies on a balance of forces. If the forces are not balanced because of a poor transition and one or many of the effects above are created then there will be serious consequences for maintenance and overall system reliability. These consequences are;

1. **Pulley Wear:**

A conveyor system relies on friction for things to happen. The greater the contact surface and the higher the contact pressure between the two surfaces the more efficient the interaction is between the two surfaces. This is why high performance cars have larger wider tyres. If a belt is not lying evenly flat against a pulley surface due to tension related distortion of the belt surface then two things happen.

Firstly the section of belt that has contact pressure overall will dictate the pulley speed. This will usually mean the section of belt that has the shortest cables in the case of a steel cord belt. Secondly the remainder of the belt where the cables are a bit longer will move at a slightly different speed and this differential speed can lead to very rapid wearing of the pulley surface lagging. Examples of such pulley lagging wear follow.

In the case where the pulley is too low relative to the transition idlers it is generally found that belt edges have been stretched excessively so lagging wear is along the pulley sides. Where it is too high the belt has stretched along areas corresponding to centre of the idler faces and because this represents the greatest surface area of belt this dictates the belt speed so it at the idler junctions and towards the belt edge the pulley lagging wears.

The wear patterns may be different on the face of pulleys that are drive pulleys as a more complex interaction occurs as it will be a combination of face pressure and contact area that will determine how the power is transmitted.

If the belt has a permanent memory then this wear affect will repeat itself on all pulley surfaces. It will show up quickest where the tensions are highest and the angle of contact greatest.

2. Idler Shell Wear:

Basically what happens to the pulleys will also happen to the flat return idlers.

3. Idler Bearing Failures:

High point loadings on idlers leading into a head transition or coming out of a tail end transition are common causes of repeated bearing failures. Also idlers at the end of a belt storage carriage of a shuttle and other similar areas where there are sections of belt that are not correctly supported in high tension zones. Idlers are not designed to take the high localised loads that can be generated.

4. Ceramic Lagging Failures:

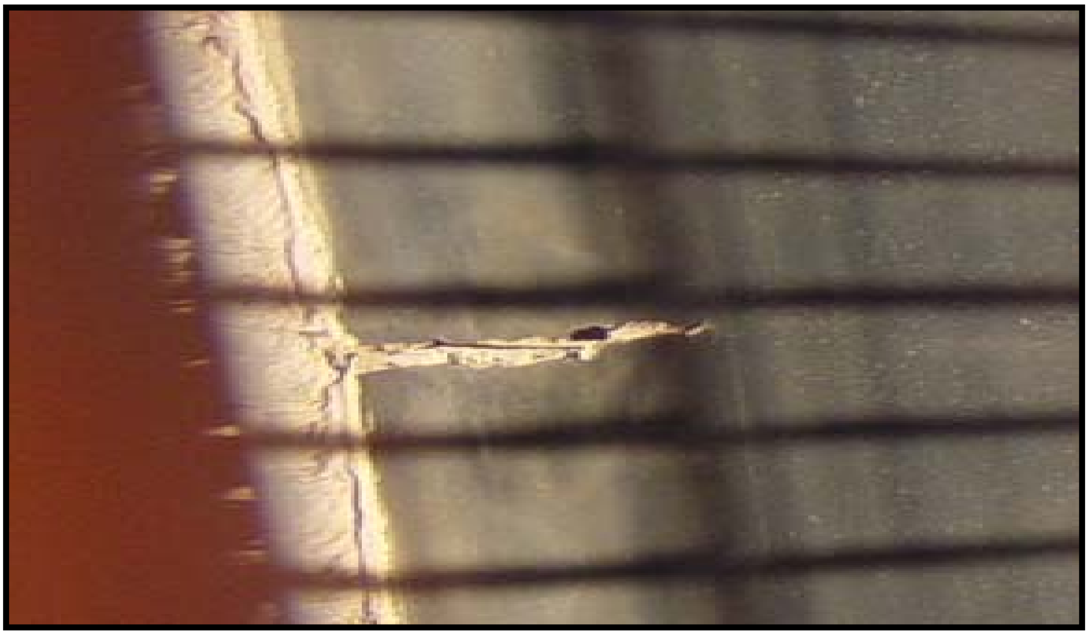
A common "solution" to fixing pulley lagging wear is to replace the rubber lagging with ceramics. This does not solve the problem, only masks it as it usually means the wear that was lagging wear is now belt bottom cover wear. In extreme tension cases, particularly when using relatively high tension steel cord belt, the tensions can be so great as to destroy the ceramic lagging. When this happens not only has the lagging been destroyed but there must be belt edge damage that in some cases will mean the belt being changing out.

5. Poor Cleaning of Belt Surfaces by the Scrapers:

If a belt can no longer lay flat then cleaning it is very much more difficult or impossible. Belt cleaners are designed for “normal” belt wear, not “W” shaped patterns. Note the belt bellows seems to have a “W” pattern and this is not only seen by the idler contact but carry back is a consequence.

6. Cable and Belt Edge Damage:

The following picture clearly shows the sort of fractures that can occur in a belt due to high edge tensions.



7. Idler Frame and Pulley Mount Failures:

This is usually associated with convex curves or mis-aligned belts but if the problem occurs near a transition point or there is lagging wear indicative of a poor transition, then the tension imbalances could have caused or contributed to the mechanical failure. This is especially common occurrence in systems containing shuttles.

8. Conveyor Start Failures:

When a conveyor is started the surface area and the face pressure between the belt and the pulley is relied on to transfer the motor power to the belt such that the belt accelerates smoothly away. If the belt surface is distorted and continues to be distorted due to a poor transition then in extreme cases the effective surface area may be reduced to the point the belt may slip on start (usually on full load starts) causing catastrophic failure of the lagging on the drive and severe damage to the belt. If a tension wave is created the belt could be catastrophically broken in two. In rare cases this can also occur when the belt is running.

The following picture is just such a case. The belt was replaced due to damage to get quickly back into production; they have yet to address the pulley damage.

9. Excessive Bottom Cover wear on the Belt:

If pulley lagging and steel rollers are wearing away then so must the bottom cover of the belt. This wear will be accelerated if ceramic lagging is used to “control” the lagging wear and will be further accelerated by any failure to properly clean the belt because it no longer lays flat. It is not unusual unfortunately for bottom cover wear to be the cause of a belt being changed out and this wear is invariably related to transitions.

The above belt has exposed cables in the centre of the bottom cover, top cover fine

4 How to Detect a Poor Transition

It is in the very best interest of Operations and Maintenance Management of a site to have all transitions in a new system visually inspected by their people as part of the handover of a new plant. Why? Because any delay in identifying the transition problem if it exists increases the chance the belt may have acquired a “permanent memory” and once this has happened it is inevitable that some maintenance problems will occur regardless of what precautions are taken.

How it is it checked? Once the belt has been tensioned and run for a period unloaded go to the transition points and check to see whether the belt evenly contacts the faces of the three idlers prior to the transition starting and all the transition idlers when there is no load on the belt at any location. That is the lay of the belt over the seven or eight idlers.

- If the transition is too short there will be an air gap between the belt and the centre roll mainly in the transition area;
- If the pulley is too low relative to idler alignment then there will significant edge contact on the wing idlers and the belt will seem to be lifting off the inner edge of the wing idler i.e. the contact with the wing idler will be unbalanced. In the transition area the belt may not contact the centre roll in some cases.
- If the pulley is too high relative to the idler alignment there will be an air gap between the centre roll and the belt mainly in the transition area.

If any of these things are evidenced then the transition must be adjusted.

Once the belt has been operating for a short time physical evidence will be quickly available to alert the maintenance people that all is not well. The two areas to look (other than at the transition itself when the belt is unloaded) that are the best early indicators are;

1) In the take up area if there is along section of belt basically hanging down. The belt quickly starts showing marks that indicate it is not evenly contacting the pulley faces as the following picture shows.

2) If there are flat returns in the high tension zone there will be marks on the idler face that indicate the belt is not lying flat. The following picture is a clear indicator.

If action is taken at this early stage then the potential for problems can most probably be avoided. If you wait for uneven wear patterns to appear on pulley faces or complaints that the belt cannot be cleaned then usually the belt has already acquired a "permanent memory" if it is a steel cord belt so while remedial action may slow down problems occurring, the problem will not be addressed until the belt is changed out. It is sometimes possible to reverse the situation with fabric belts at much later stages as they have a much lower elastic modulus.

Note well, transitions also occur elsewhere in the system, e.g. from a shuttle car to the normal idlers. Wherever such other transitions occur there is the potential for maintenance problems to occur. The checks that apply above apply to these areas as well.

5 How to Correct a Poor Transition

A design guidance such as that used by BHPBIO Project team of six (6) times belt width can be applied to all belts that are 1000mm or wider and less than 3500 KN/M in strength. This is a conservative approach and maintains consistency over all sites. If the belt is narrower than 1000mm, use 1000mm as the default width. This means that a 1500mm wide belt will have a transition length of 9 metres and based on the standard idler spacing of 1.5 metres, 5 transition idlers. If this is not the case and there is evidence that the transition is too short then add transition idlers to meet these guidelines.

It is usually a difficult task to change the height of a pulley sufficiently to correct the transition alignment so the immediate remedial solution is to;

- Firstly ensure that the number of transition idlers is consistent with the guidelines above. This will ensure that the approach is a conservative one and in instances where there is already evidence that there is a problem this is a very good starting point. This is a relatively simple task as transition idler frames are inter-changeable with normal idler frames.

- If the transition is at the tail end of the conveyor and there is not the room to add transition idler frames due to the set up of the loading point then all that can be done is what follows. It will then be necessary to monitor this conveyor for signs there are issues and the most likely early indicator will be either distortion of the frames or bearing failures on the wing idlers on the first set of fully troughed idlers leading into the loading area. If this occurs then the necessary structural changes to accommodate additional transition idlers will need to be done.

- Use the unloaded conveyor belt as the “stringline”. The belt needs to contact about 2/3 rds of each idler face in an even manner. Start with centre roll and adjust the packing to achieve this level of contact.

- Once this has been done adjust the wing idlers to achieve the same result.

- Once this has been done check the contact levels on the fully troughed idlers before (or in the case of a tail end transition, after) and ensure that the contact on the centre rolls and wings are even. If there are air gaps, add packers.

- If packers had to be added to the fully troughed idlers, re-check the transitions and do further adjustments if necessary. If the adjustments have all been done correctly it should be very difficult to push a feeler gauge or similar thin metal strip between the belt and centre of the middle roller.

The transition should now be correct. Monitor the belt to ensure that there re no signs that there are still issues if the belt is a new installation. If there are and this procedure has been followed seek additional professional help.

If the poor transition is a result of a poorly positioned shuttle then the only logical solution is to raise the height of the head pulley. Care must be taken that once this is done and the idler frames re-packed as outlined above, that the trough set idlers do not interact with bottom of the belt storage of the shuttle. What this may mean is that the outcome is not perfect unless the storage loop can be modified.

If the system has been operating for a period or is a mature system then fixing the transition as above is still necessary however there will no improvement until;

- In the case where the installed belt has a fabric carcass, possibly 6 weeks. This is the approximate time the belt will take to normalise its length.
- In the case where the installed belt has a steel cable carcass the belt will have a “permanent memory” and will never lay flat again. This means that it will continue to damage lagging, idlers and be hard to clean. If the belt is near the end of its service life it is best changed out.
- If there are pulleys with badly damaged lagging, particularly in high tension zones then they must be changed out with any belt change as they will damage a new belt. In fact they can re-create the previous belts “permanent memory” if not changed out.
- Once there is a new belt installed and pulleys with lagging damage replaced the system will perform very well. Adjusting scrapers and correcting other issues created by the poor transition can then be addressed knowing they will not be problems going forward.