EXPECT THE UNEXPECTED

CASE STUDY: HIGH POTENTIAL CONVEYOR INCIDENT

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INTRODUCTION

This paper reviews an unexpected incident that occurred involving the overturning of an LDV (bakkie) by an underground conveyor belt and examines the circumstances leading to this incident.

High Potential Incidents, or HPIs, have the potential of resulting in fatalities and thus full understanding of the event, the aspects that led to the event occurring and the consequences need to be fully examined and documented. A plan of action is required to prevent the likelihood of such an incident occurring again.

This paper highlights the major aspects contributing to the conveyor belt coming into contact with the LDV as well as the methods that could have prevented the incident from occurring.

2. BACKGROUND

2.1 MINING LAYOUT

Presently the mine comprises of five low seam sections. These are sections where the seam height ranges between 1.6 m and 2.2 m and where JOY HM31 AAA type continuous miners are used. Two high seam sections with a seam height ranging between 2.2 m and 4.8 m are in production and utilize JOY HM31 B type continuous miners. It should be noted, however, that it is only in the last two years that mining operations migrated to predominantly low seam sections, as in previous years the mine comprised of five high seam sections and only two low seam sections. This meant that new equipment had to be procured and modifications to infrastructure were required. Risk analysis and change management were implemented to ensure the safety of employees at all times.

2.2 CONVEYOR LAYOUT

The mine where the incident occurred has a total of 27.7 km of physical conveyor belt installations with a total installed power of 10 312 kW.

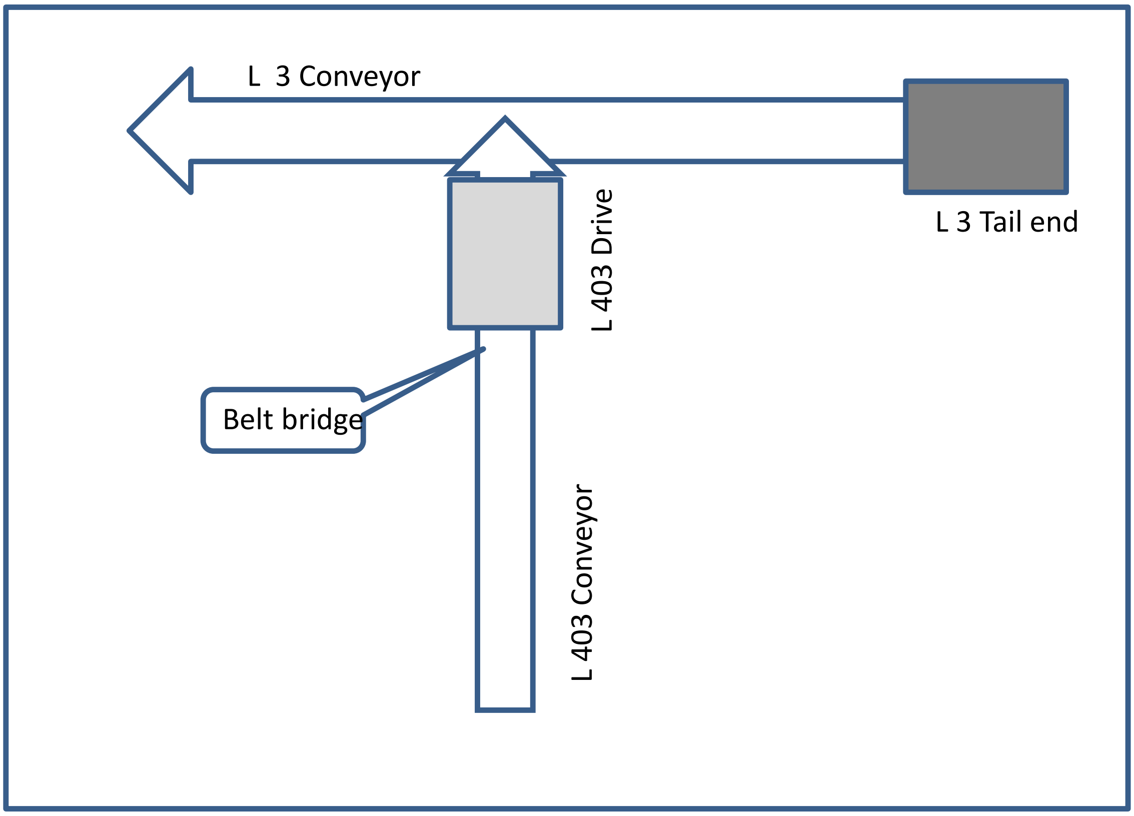

Figure 1. Underground conveyor belt layout at area where HPI occurred

The conveyor referred to in this document, L403, is fed by Section 9. Section 9, at the time, was a high seam section producing on average 40 000 tonnes of coal per month. The coal produced consisted of the following values:

Entity	**Value**
Ash Content	27%
C.V	21.6 MJ/kg
Abrasive Index	452 mgFe
Density	1.59 t/m^3

Table 1. The values of the coal produced

The conveyor drive discussed is based on a 1 200 mm portable drive and has a pulley configuration shown in Figure 2 below.

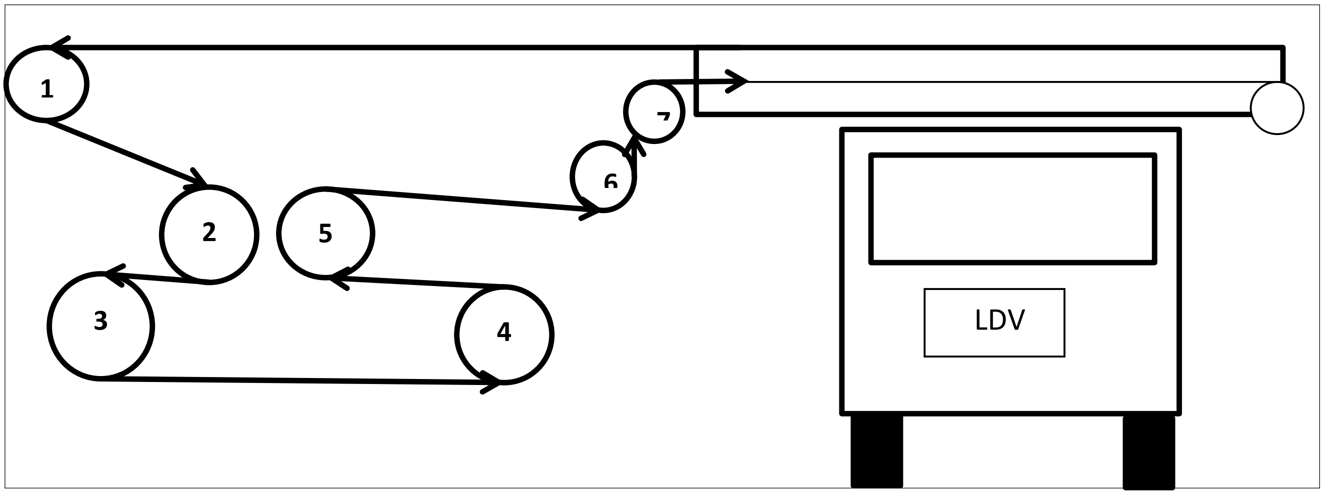

Figure 2. Schematic for the pulley configuration on conveyor L403 Drive with LDV crossing underneath the conveyor

Pulley No.	Pulley Position
1	HEAD PULLEY
2	SNUB PULLEY
3	DRIVE PULLEY
4	TAKE-UP PULLEY
5	TAKE-UP RETURN PULLEY
6	BEND PULLEY 1 (ON BRIDGE PIECE)
7	BEND PULLEY 2 (ON BRIDGE PIECE)

Table 2. Pulley positions as in Figure 2

At the time of the incident the conveyor had the following specifications:

	Conveyor Number/Description		L403 – Installed	L403 – Required
	Information for design calculations			
	Belt width	mm	1350	1200
	Belt speed	m/sec	3.10	3.10
	Peak capacity	tph	2400	2000
	Material density	t/m^3	1.1	1.1
	Angle of idlers	Degrees	35	35
	Troughing idler spacing	m	1.5	1.5
	Drive wrap angle	Degrees	210	210
	Horizontal centre to centre distance	m	292.581	292.581
	Overall lift/drop	m	9.00	9.00
	Drive data			
	Motor power (Primary)	kW	160	55
	Motor power (Secondary)	kW	N/A	N/A
	Motor RPM	RPM	1495	1495
	Gearbox ratio		15:1	15:1
	Idler data			
	Troughing idler pitch	m	1.5	1.5
	Return idler angle	Degrees	0	0
	Return idler pitch	m	3	3
	Take-up data			
	Type		Counter Mass	Counter Mass
	Travel	m	2.00	2.00
	Belt data			
	Class		1250	1250
	Number of plies		-	-
	Belt width	mm	1350	1200
	Top and bottom cover	mm	3.0 x 2.0	1.0 x1.0
	Type of rubber		PVG	PVC

Table 3. Specifications for L403 at the time of the incident as well as the expected design specifications

2.3 INCIDENT

On 29 August 2013, an unfortunate incident occurred. Whilst the LDV was driving under the L403 Bridge above which the conveyor passes over the road, the conveyor belt started up. With the starting of the conveyor, the belt sagged to the extent that it was able to touch the top and side of the LDV canopy. The rubber covered conveyor belt coming into contact with the corner of the canopy enabled the conveyor to grip the LDV and consequently flip the LDV onto its side. Fortunately none of the three occupants inside the LDV were injured. However the incident is classified as an HPI as there was a high possibility that one of the occupants of the vehicle could have been seriously injured or even worse.

Many aspects contributed to the incident. Aspects such as inadequate guarding, the wrong conveyor belt being used, insufficient tension in the belt and finally, the installation of a larger motor than the system was designed for. All contributed to the final outcome where the LDV was turned on its side. Each of these aspects, if corrected, could individually have prevented the incident from occurring and therefore will be discussed in detail to determine their effectiveness in preventing the incident from being repeated.

2.4 SEQUENCE OF EVENTS

The following is the timeline of events leading to the HPI, and gives insights as to how the event happened**:**

1. On 29 August 2013 at approximately 07h30, the belt crew and the beltsman (immediate supervisor) went underground to remove slack from the primary/leading conveyor tail end as planned.
2. Conveyor L3 was locked out.
3. Slack was removed from L3.
4. Work was completed and communicated to the shift overseer.
5. Lockout was removed to start L3.
6. Pull key was reset at tail end of L3.
7. Shift overseer and crew left L3 to do alternative work in other locations.
8. As L403 started up, a section of slack developed on the return side of the belt directly over the roadway. At that moment an LDV travelling in the roadway was crossing the conveyor and came into contact with the sagging conveyor belt that overturned the LDV.
9. Emergency procedure was followed.
10. In-loco investigation took place.

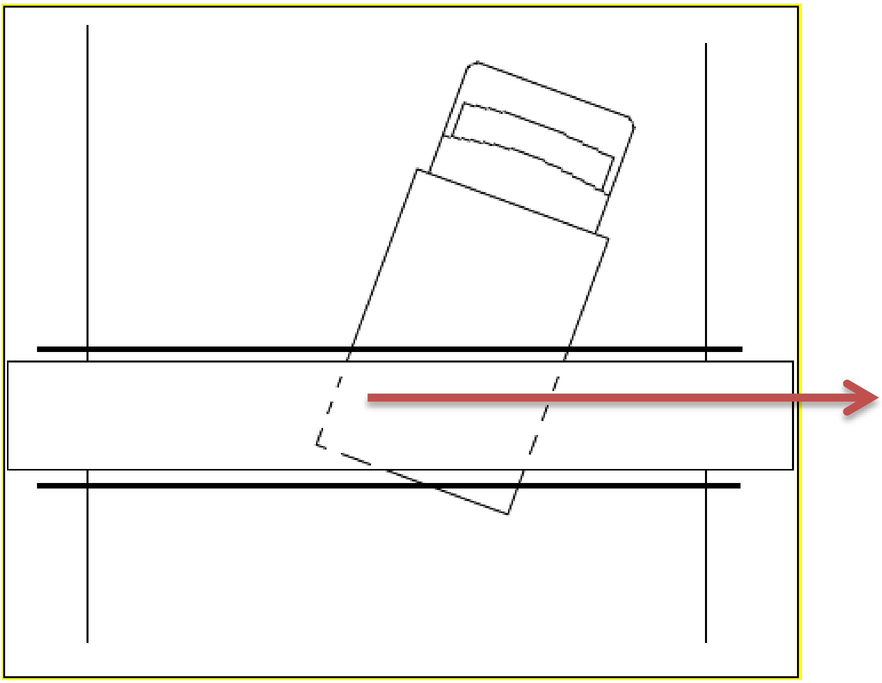

Figure 3. Sketch illustrating the vehicle going under the L403 Bridge

2.5 IN-LOCO INVESTIGATION

As is standard with any form of serious incident that occurs on the mine, it is necessary to immediately investigate (in-loco) the causes for such an incident as well as mitigating any further danger that could still be present. The investigation team consisted of:

- Management
- Safety department
- Area supervisors
- People involved in the incident
- Organized labour
- Full time health and safety representative

3. FAILURE

The following draws attention to, and discusses each of the causes that contributed to the final HPI.

3.1 ROOT CAUSE

3.1.1 Change Management – Incorrect Belt Installed

The design specifications indicated that a PVC belt should have been installed. After the investigation was concluded it was discovered that a PVG belt had been installed. This had a crucial impact on the incident as a PVG type belt has a rubber covering which drastically increases the friction with the drive pulley.

In normal cases when the belt starts up, insufficient tension allows the belt to slip and the slip detector then stops the conveyor. In this case the rubber cover increased the friction with the drive pulley preventing slip from taking place and transferring an excessive amount of tension to the top conveyor, consequently slacking the bottom. The belt thus sagged to the extent that it came into contact with the LDV, resulting in the HPI.

PVG belting is substantially heavier than the PVC belting, as seen below:

- 1350 x class 1250 with 3 mm x 2 mm PVC covers = 16.26 kg/m^2
- 1350 x class 1250 with 3 mm x 2 mm PVG covers = 24.7 kg/m^2

The heavier belt increased the sagging between the idlers, thus contributing to the belt coming into contact with the LDV.

3.1.2 Change Management – Incorrect Motor

The required power for the correct operation of the conveyor belt was a 55 kW power pack. As per the mine standard, a 75 kW power pack would normally be installed. Although this motor is larger than required, it does have some benefits in slightly increasing the power pack size. Some of these advantages include the ability to start the belt while loaded and running the motor at a lower load factor. However, the main reason for over specifying the motor is to reduce the diversity of stock that needs to be held on the mine. By standardizing on fewer power packs that can serve a variety of conveyors, one is able to reduce the required stock, saving capital, and allowing for quicker turnaround times on failures as the probability of having spares in stock at any given time is much higher with fewer standards.

Following an in-depth study into the failure mechanisms affecting this HPI, it was discovered that a 160 kW power pack had been installed as opposed to the recommended, already oversized 75 kW motor.

160 kW Power Pack (Installed)

Assume v = 3.1 m/s

$$P = \Delta T v$$
$$160\ 000 = \Delta T(3.1)$$
$$\Delta T = 51612.9\ N$$

Where *P* = Power in Watt
T = Tension in Newton
v = Velocity in m/s

75 kW Power Pack (Recommended)

Assume v = 3.1 m/s

$$P = \Delta T v$$
$$75000 = \Delta T(3.1)$$
$$\Delta T = 24193.5\ N$$

Take note of the calculations above indicating the difference in tension that would be generated in the belt depending on the size of the power pack. The bigger power pack more than doubled the required tension available. This would contribute to causing more slack behind the drive section enabling more sagging at the belt bridge. In this instance, enough slack was generated for the return belt to come into contact with the LDV resulting in the unfortunate HPI.

3.1.3 Insufficient Tension

In a typical surface type conveyor belt installation, the common method to remove slack from a conveyor is through a gravity take-up. This is useful in that it is an automatic system and requires no human intervention after the initial set-up. Underground, however, one does not have the height available to use a gravity take-up and therefore another method is used, namely the winch take-up. Figure 4 shows a typical winch-style take-up. When tension needs to be applied to the belt, the winch is wound, increasing the distance between pulleys and in that way taking up the slack. In some drive designs this is done manually by physically winding the winch by hand. However, it was recently discovered that the belts were not being tensioned to the correct tension as required. This could be attributed to many factors, such as longer belts (increase in mass); material build up on the slide rails causing excessive friction; thicker, wider belts (increase in mass) and human factors (poor operator practices). This led to the introduction of electrical winches where the manual operation is replaced with an electric motor and a load cell to prevent over tensioning of the belt. This reduced the likelihood of a belt being started when not at the correct tension and therefore reducing incidents where slack in the belt could cause serious injury or worse.

In the case of the L403 belt, the electric winch had not yet been installed. This resulted in the belt starting up without the correct tension and subsequently causing belt slack at the bridge resulting in the HPI.

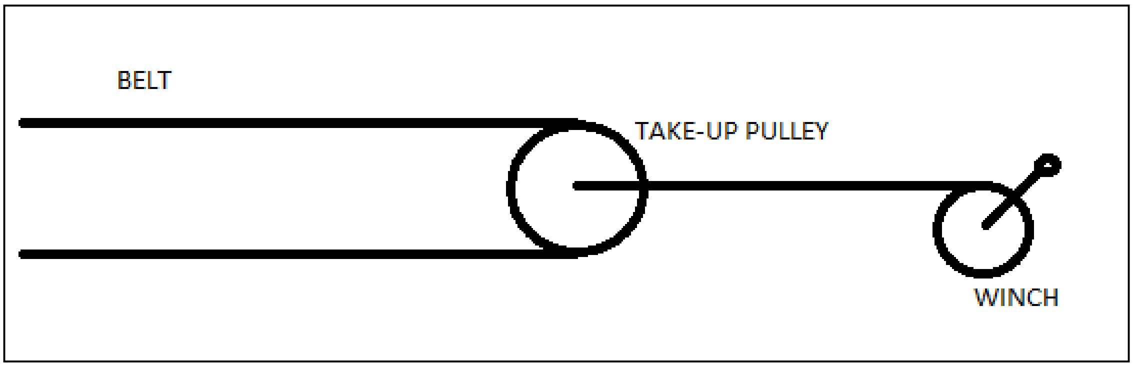

Figure 4. Typical set up of a winch style take-up

3.1.4 Risk Assessment

As stated in Section 2, the mine underwent a great number of changes in recent years. In the past, the mine consisted predominantly of high seam sections, with mining heights up to 4.8 metres. This created a great deal of space to work with in terms of placing conveyor belts against the roof of the mine, and therefore the 3.5 metre reaching clearance was always easily adhered to in terms of the mine's Standard Operating Procedure (SOP), and hence it was unnecessary for the return belts to be guarded below. Due to no threat ever being envisioned, no risk assessments were done in terms of possible belt slacks or the possible consequences of that. When the mine began to move into lower seam sections, the mining height restricted the conveyor height to below 3.5 metres and a risk assessment should have been done.

Failing to do a risk assessment was one of the major contributing factors. If a proper risk assessment had been carried out, the possibilities in terms of accidents that could arise if the belt was too slack or snap with there being insufficient clearance would have been noticed. Adequate guarding would then have been instituted, as well as procedures to ensure safe passage of personnel and vehicles when crossing conveyor belts.

3.2 CONTRIBUTING FACTORS

3.2.1 Skewed Idler Roller

An idler is a necessary part of any conveyor installation, assisting in the alignment of the belt as well as supporting the belt in the transfer of heavy material. To operate optimally, the idlers need to be aligned correctly, running exactly perpendicular to the belt. This is to ensure that no unnecessary friction is added to the system and also to extend the life of the idler.

After the inspection of the bridge where the HPI took place, it was noted that the return idler was not running perpendicular to the belt but was slightly skewed. This resulted in an increase in the frictional forces that were imparted to the belt and the belt could not run over the idler with as little effort as it should have, thus forcing the belt to sag at the bridge area.

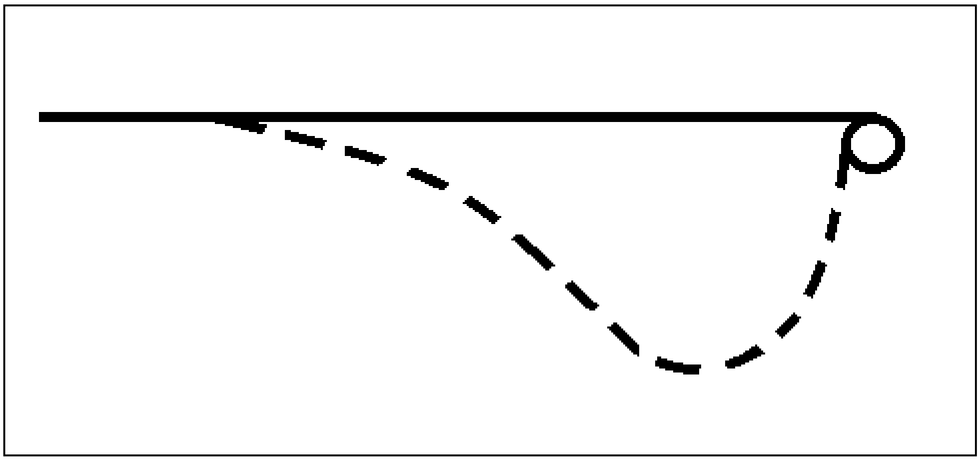

Figure 5. Schematic illustration of how the return belt sagged as it rolled over the skewed idler causing contact with the LDV

This sag or slack in the belt was sufficient to enable contact with the canopy of the LDV, consequently turning the LDV on its side.

3.2.2 Removed Idler

After the inspection on the structure was completed, it was noticed that an idler was missing in the middle of the bridge. This idler had been removed because LHDs were coming into contact with the idler. The easiest solution was to remove the idler.

This contributed to the incident as the distance spanning the bridge had now been increased drastically. It allowed for the belt to hang lower than usual when it slacked and made it possible for the belt to come into contact with the LDV and overturn it.

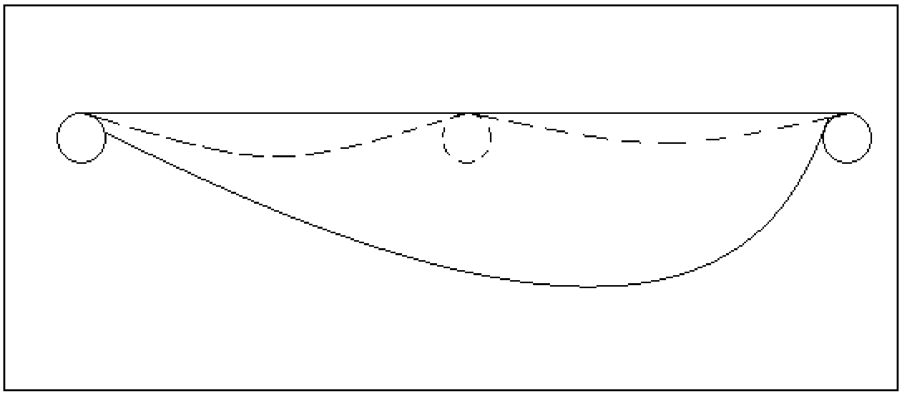

Figure 6. Illustration showing the difference between having the idler in position and having it removed

3.2.3 Guarding

Guarding is a vital portion of any conveyor installation, often being the only safety measure standing between an employee and the conveyor itself.

According to the mine's Standard Operating Procedure – Guarding of Conveyors, there are five aspects of reaching that need to be guarded against namely: upwards, over, into, around and through. In terms of the study conducted into the HPI, the 'upwards' aspect of reaching is discussed.

The Standard Operating Procedure states the following:

> *Any pulley or idler that is 3.5 m high or beyond on upward reach may be regarded as provisionally safe and need not be guarded. Possible reduction of this safe clearance by a buildup of spillage or discharge of material must be considered.*

Looking at the images of the bridge below, the height, due to this being a low seam section, is well below 3.5 metres. In this case the underside of the bridge should be guarded to prevent contact with the belt by either personnel or equipment. This guarding was not installed.

Figure 7. Image showing the bridge where the HPI took place

Figure 8. Image showing the lack of guarding at the belt bridge.

Although having this guarding in place would have prevented the incident from occurring as the belt would not have been able to come into contact with the vehicle, it would not have prevented the belt from producing slack. However, this cannot be seen as an ultimate resolution to the issue at hand. The belt would still be able to slack and could potentially injure someone at another point downstream of the belt or result in damage to the bridge and/or the belt structure.

3.3 SUMMARY

Entity	What happened	How this affected the outcome
Change Management - Incorrect belt installed	PVG belt installed instead of the required PVC belt.	The PVG belting increased the frictional coefficient between the drive pulley and the belt. This allowed the drive to impart an excessive amount of power into the belt. If a PVC type belt had been installed, slip would have taken place due to the low tension levels and the drive would have shut down.
Change Management - Overpowered Motor	Larger than required motor installed.	The larger power pack imparted a force more than double than required for the correct operation of the belt. This initiated a larger than normal stretch on the

		pull/entrance side of the drive and a greater slack on the push/exit side of the drive causing the slack at the bridge. If a smaller power pack had been installed, the conveyor might have been unable to overturn the vehicle.
Insufficient Tension	Belt was not tensioned to the required specifications.	If the belt had been tensioned correctly, this would have taken up any slack in the belt and prevented the belt from sagging and therefore preventing the incident.
Risk Assessment	No risk assessment had been done since going into the low seam sections.	If a risk assessment had been done when the low seam section had initially been commissioned, the area crossing under bridges would have been identified as a hazardous area, and would have been addressed.
Skewed Idler	Idler was not installed correctly.	Because the idler was installed incorrectly, this imparted too much friction into the system. Therefore when slack was created behind the drive, the first place where the conveyor was able to throw this slack was at the first 'high friction' point, in this case the idler. Hence the reason why the dip occurred at the bridge.
Removed Idler	Idler had been removed.	With the idler in the centre of the bridge being removed, it allowed a great span for the conveyor to traverse unsupported. This caused the belt to sag much further than if there were a supporting idler in between. When the belt slacked, the increase in unsupported weight assisted in pulling the conveyor belt downwards until it came into

		contact with the LDV.
Guarding	The bridge was insufficiently guarded.	Adequate guarding would have prevented the belt from coming into contact with the LDV, but it would not have prevented the slack in the belt.

Table 4. Table showing a summary of the events leading to the occurrence of the HPI

4. CONCLUSION AND LESSONS LEARNED

From the afore mentioned points it can clearly be seen that it was not just one aspect that led to the HPI that involved the overturning of a LDV by the conveyor belt in question. Many aspects that were overlooked, if they had been in place, would have prevented this HPI resulting in improved safety of the employees involved in the incident as well as those employed by the mine. Changed belt specifications also contributed to the accident.

This HPI further highlights the importance of ensuring that decisions that are made in terms of specifications and recommendations by both management and reputable OEM authorities are followed. 'Quick fixes' should not be allowed if they have an inherent safety hazard associated with them and should be rectified as soon as possible to prevent similar HPIs reoccurring in the future. If such alterations are made, communication of said changes, through the change management process, should be communicated to all parties involved ensuring the safety of personnel on the mine.

Other lessons that should be noted are as follows:

- When it comes to the guarding of the belt, traditionally only guarding of belting to protect personnel has been considered. The Conveyor Codes of Practice should be revisited to include the guarding of a belt bridge to prevent contact between mobile equipment and the moving conveyor.
- Change management is an important part of any mine, and measurements should be taken to ensure that employees follow the correct procedures when changing equipment as it could have drastic effects on the production of the mine and safety of its employees.
- When doing belt inspections, care should be taken to observe any changes that have occurred and report these to the relevant parties.
- Risk assessments should be completed by trained, experience personnel.
- Risk assessments should include risks associated with various seam heights.

ABOUT THE AUTHOR

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Stuart Marais obtained a BSc Engineering (Mechanical) from the University of Pretoria, South Africa. He is currently employed by Exxaro as a Professional-in-Training (PIT) Mechanical Engineer where he is working as a junior engineer.

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