Confidential Report

COALTECH

RESEARCH ASSOCIATION

Cleaning Near Moving Conveyors
Final Report

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Mechaneer – Your Mechanical Engineering Solution

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Abstract

Current mine health and safety legislation applicable to conveyance systems was promulgated in 2008 and started being strictly enforced shortly after. Only then did the coal mining industry begin to appreciate the full impact the overly onerous regulations imposed upon them.

If proposed legislation changes come into effect, under specific preconditions, it will be possible to clean near and under some parts of moving conveyor systems again, but many challenges remain.

The purpose of this project is to accurately define the problems faced by industry in terms of cleaning moving conveyor systems and to identify any practical and safe means of cleaning all areas of conveyor systems (including the conveyor itself), with a specific focus on finding ways and means of cleaning high risk areas such as drives, take-ups, snub pulleys, tail end pulleys & transfer points.

The project is split into two phases. Part 1 collects widespread relevant information to fully define the problem and test the availability of readily available solutions. Part 2 will later be focussed on appropriately enacting and implementing Part 1 learning and recommendations.

Results obtained from this study are presented, including a structured data base of potential base platform options available for further pursuit to achieve the objective.

The report concludes with a summary discussion of conclusion made and puts forth a recommendation for further action.

Table of Contents

List of Figures

1 Introduction

Current mine health and safety legislation applicable to conveyance systems was promulgated in 2008 and started being strictly enforced shortly after. Only then did the coal mining industry begin to appreciate the full impact the overly onerous regulations imposed upon them.

SACMA and SACEA have lobbied MRAC for several years to review regulations. Recently, government agreed – all the while many mines started suffering the ill consequences of complying with legislation which prevents cleaning of, near and under conveyor systems while any part of it is moving.

Many mines are battling severe delivery pressures, forcing them to sustain high production running hours. In many instances, 'compliance' to legislation is only achieved by cutting back on complete system shutdown periods required to allow cleaning of, near and under conveyor systems, and, consequently, also on associated maintenance.

***Figure 1**: A poorly maintained idler and conveyor system*

If proposed legislation changes come into effect, under specific preconditions, it will be possible to clean near and under some parts of moving conveyor systems again, but many challenges remain. On many mines significant and urgent intervention is needed to prevent widespread conveyor system degradation beyond economic return.

The purpose of this project is to accurately define the problems faced by industry in terms of cleaning moving conveyor systems and to identify any practical and safe means of cleaning all areas of conveyor systems (including the conveyor itself), with a specific focus on finding ways and means of cleaning high risk areas such as drives, take-ups, snub pulleys, tail end pulleys & transfer points

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This research report documents and discusses the findings made during Part 1.

2 Methodology

The first part of the project is defined and being executed (Part 1, Fig 2). Depending on the learning gained, more parts or phases may be defined upon completion. Part 1 focuses on fully identifying and defining the problem before one is able to implement potential solutions worthy of further pursuit (Part 2, Fig 2).

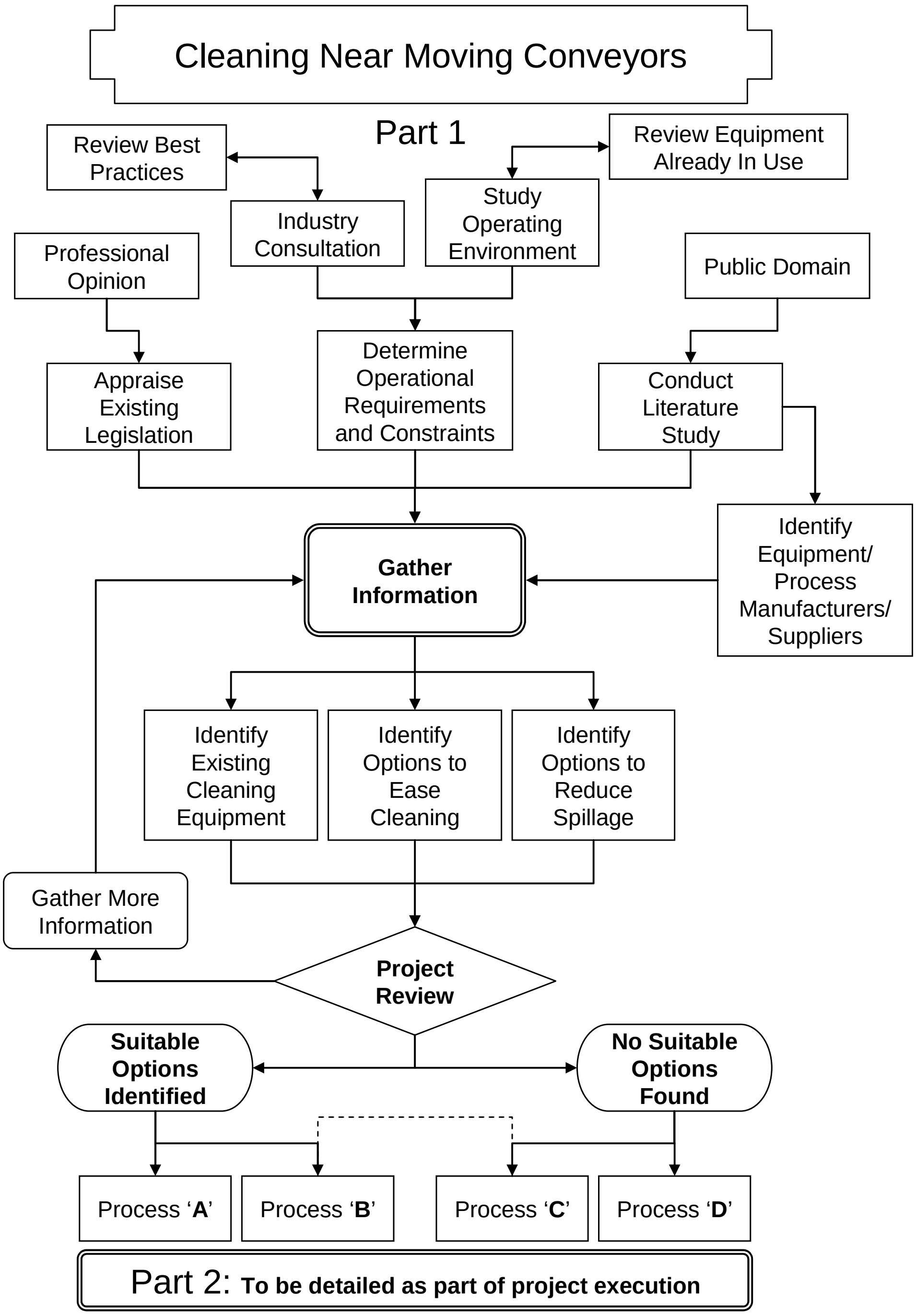

***Figure 2**: Part 1 process diagram*

A four-pronged approach is used to interrogate the various bodies of knowledge available on cleaning technology potentially applicable to conveyor systems, which are the following:

Internet Based Literature Background Search

An extensive and comprehensive internet based literature background search is conducted to assure that the most recent up to date data on methods and equipment is included in the research. An extensive data base of relevant technology and equipment that can potentially be applied is built up from this work.

Legislation Appraisal

The interpretation by government of relevant legislation applicable to conveyor systems resulting in the current state of affairs regarding conveyor reliability is investigated to contextualise the ‘sort of solutions’ that can be considered to be part of this study. The proposed changes to existing legislation only widen the scope of potential solutions that can be considered as part of this project brief.

Industry Consultation

An industry wide consultation process lies at the heart of the project to assure relevance and overall accuracy of findings. This process is only followed once the above two steps are functionally complete and is done by visiting various mines and interviewing their belting experts, sharing and expanding the learning in open debate. A review of industry accepted conveyor cleaning best practices and policies is used to gauge how closely theory and reality meet. Thus, the industry consultation process assures that an accurate assessment of the current state of affairs throughout the coal mining industry is made and that any ‘holes’ in the literature study are identified so that they are followed-up before concluding Part 1.

Operational Review

During the initial project planning phase, it was hoped to find a means whereby the operating environment could be described in such a quantitative way that it could be used to assist interested parties in defining the operating requirements cleaning system embodiment would have to conform to while in operation. This was abandoned as it was immediately evident that it would be a practically impossible task, as the degree of detail needed and the infinite variations would turn this task into an imaginably large task to complete within the ambit of this research project.

It was thus planned that the way forward would be to rely on a qualitative approach highlighting some of the extreme conditions and considerations to be encountered if one was to traverse and access the conveyor system to clean what may be loosely described as the majority of the length of most typical conveyor installations found underground in our coal mines.

The above information gathering process identifies information in three solution categories:

Existing Cleaning Equipment Options

These solutions include any existing cleaning options (i.e. an applied technology used at least at one mine) to collect or remove dirt build-up around conveyor systems after they have accumulated to nuisance levels. This includes, but is not limited to autonomous/remote controlled equipment/systems, mechanised man operated cleaning systems and manual labour.

Options to Ease Cleaning Load

These solutions are any solutions that can be employed to reduce, limit or inhibit the amount of dirt build-up possible in the first place – i.e. options that represent a more proactive approach to cleaning by tackling the root cause of the problem. These systems are defined here as '**Passive Belt Cleaning Systems**': any mechanised cleaning system commonly recommended by conveyor system manufacturers to be fitted as an integral part of the conveyor structure, aimed at cleaning the conveyor belt surface on an ongoing basis while it is in operation. Figure 3 is a typical scraper.

Figure 3*: Secondary scraper*

Options to Reduce Spillage

Spillage is a specific form of dirt build-up in that it is usually due to the mechanical failure of some containment system, component or interface, resulting in a sudden loss of carry material from the working surface of the conveyor system into its immediate environment. It also happens at transfer points where the change in direction of particles falling down the chute imparts enough kinetic energy to cause particles to 'fly' off the second belt (Fig 4). Solution options are specifically focussed on reducing the frequency or severity of spillage events and most (such as skirts, guide plates, covers and monitoring devices) become an integral part of the conveyor structure, much like passive belt cleaning devices do above.

Figure 4*: Spillage at transfer point*

Ultimately, through a review process of the collected data, options suitable for immediate implementation are set apart from options requiring further work or adaptation in a follow-on phase to the project before they may become ready for widespread implementation.

3 Results

The literature study revealed that there is a vast array of passive belt cleaning devices commercially available to mines. It also became apparent that even if one implemented these devices right, one would still sit with a fundamental limitation resulting in eventual muck build-up along the entire length of the conveyor system. In other words, by applying passive belt cleaning systems effectively, the best one could hope for is a meaningful reduction in the *rate* of muck build-up, but it will still occur and be significant.

A few more definitions are in order here to assure alignment of reference frames:

Ground/First rule – A properly designed conveyor system & installation

First hurdle – Installing & maintaining ALL recommended passive belt cleaning systems

Second hurdle – Implementing effective maintenance & cleaning processes

There is a lot that can be done to drastically improve things.

3.1 What Mines Are Doing That Works

Among the eight mines visited as part of this study, two mines stood out, reporting that they have ‘no’ problems with their conveyor belts. The discernable difference between these mines and ‘the rest’ was at first very difficult to pin point.

All mines visited do much the same, but the discerning factor seems to come down to ATTITUDE, i.e. attitude towards the importance of passive belt cleaning systems, attitude towards keeping system components in good working order, attitude towards clean-up and maintenance and the attitude of people saddled with the ‘burden’ of looking after the conveyor system (in all its facets), which collectively seemed to drastically improve availability and reliability.

These two mines continue to invest huge ongoing amounts of effort into their conveyor systems, both material and immaterial. Most importantly, these mines did not succumb to the pressure/temptation to cut back on standing time (and maintenance) to meet short term production targets in order to gain regulatory compliance with respect to cleaning near moving conveyor belts.

These mines typically dedicate the first two hours of EVERY shift to specifically cleaning and maintaining their conveyor belts – with no exemptions. They have additional weekly shutdown shifts/weekends specifically dedicated to cleaning and maintaining their conveyors (together with their other equipment). These mines also have very evolved conveyor problem reporting, documenting and follow-up procedures in place, and their infrastructure and resources have been arranged to facilitate and ease the regular replacement of high wearing components such as idlers. Conveyor system errors, problems and breakdowns are immediately addressed (even if production is temporarily halted) – only tasks that hold no risk to the running or embodiment of the conveyor system are deferred to the FIRST available standing hour or shift.

These mines go to great lengths to assure that they employ people that share this passion for keeping the conveyors in pristine condition and reward accordingly.

Both mines are now picking the fruits of these inputs. Both mines expressed a simple attitude – “without the belts in good working order, not much else we’re doing on the mine will matter…”

As a result of the above being in place, it is no surprise that these mines also have all the manufacturer recommended passive belt cleaning equipment components in place, that they are functioning as designed and that they are regularly maintained.

Only three mines had designed their conveyor structures with specifically easing cleaning in mind at the onset. There are many good plausible reasons why, but the other mines all broke the first rule in terms of cleaning – their conveyors were all designed by acknowledged experts in this field, to all relevant standards, but were not expanded to specifically address or ease cleaning around the installations.

A worrying observation made during the execution of this project is that industry wide, very little investment seems to be made by anyone into serious ongoing research and development of new technologies specifically applicable to cleaning conveyor systems, indicative of a stagnated industry outlook/mindset in this field. This opinion was echoed by many specialists consulted, stating in their own words: “there isn’t anything new we can do…” From information contained in this report it is evident that this is simply not true.

3.2 Structured Data Base of Mechanised Options

Since conveyor systems lie at the heart of any big coal mining operation, there is not much value in compiling a data base on conveyor manufacturers – this representing a data mines should be familiar with already. For this reason there is no conveyor manufacturer data base, with one exception: reference has to be made to a 500+ page book worthy of mention, totally dedicated to one topic only – cleaning of conveyor systems! The book is called “Foundations 4”, a **free** PDF download off the Martin Engineering website. It was very surprising to discover that among the 22 highly experienced and skilled conveyor experts interviewed as part of this study, only one had ever heard of this book (and coincidently possessed a hard-copy of Foundations 3, a slightly older, jet valid version). Throughout the study and mine visits it was noted that there was no “passive” cleaning aspect not addressed in the book in significant detail. It was thus no surprise to determine that nearly everyone else (i.e. five of the remaining six mines visited) fell over the first hurdle and consequently also over the second hurdle (i.e. those that did not see the need for all the passive belt cleaning systems, also did not seem to fully appreciate the importance of maintaining the systems they did have – some sighting in desperation reasons starting with “what’s the point…”). The one exception amongst the remaining six mine was a mine that in the past had also miserably fallen over both hurdles, but recently (a year or so ago) consciously decided to rectify this situation and has progressed significantly towards joining the two mines that report ‘no’ conveyor problems.

To fully appreciate the extent of carry-back problems encountered, a reference scale needs to be defined. Carry-back itself is defined as the material still adhering to the dirty part of the belt after passing the tipping point and passive belt cleaning systems. It is quantified in grams per square meter (g/m^2) of belt. In Foundations 4, p231 to p232 reference is made to R. Todd Swinderman’s performance-based scale, which in summary comes down to the following:

Level 1 cleaning is the least efficient level of cleaning. Passive belt cleaning devices are not well maintained and carry-back levels are typically 250 g/m^2 or more. Carry-back fallout from the belt along its return path (as per Foundations 4 referenced above) is typically around 75 % (i.e. 187.5 g/m^2) and frequent cleanup (daily) of the fallout is required. Using the formulation in Foundations 4, p391, adapted to give the result per hour of belt running time, at an average speed of 3.5 m/s, a typical 1.2 m wide belt, loaded to 1 m of its width, will deposit around 2.4 ton carry-back fallout per running hour of operation along the length of belt return way, or 14.4 tons per 6 hr operating shift. The six mines reporting conveyor problems all seem to clean to this level of cleanliness.

Level 2 cleaning is a lot better at cleaning, having multiple passive belt cleaning devices in place, that are regularly maintained and always kept in good working order. Carry-back levels are typically 100 g/m^2, of which only 50 % falls off. This relates to around 0.6 tons carry-back fallout per running hour of operation and could be cleaned weekly. The other two mines visited seem to fall in this cleaning level.

Level 3 cleaning is probably too costly considering the range of passive belt cleaning systems required. Typically this level of cleaning requires wash bays added to the Level 2 devices. Carry-back levels are around 10 g/m^2, of which only 25 % is lost due to fallout. This equates to around 32 kg of waste per running hour. We do not have any mines cleaning their conveyors to this level of cleanliness.

The above levels of cleanliness are indicative only, since for every belt installation, the material properties of the belt and coal being transported and the moisture content all affect the exact carry-back fallout calculation. However, observations at the mines visited seem to correlate strongly with these rough estimate values above and if one does not clean on a daily basis (as is the case for many mines visited), muck volumes quickly accumulate to such a degree that it becomes more than can be loaded onto a stationary conveyor belt, requiring repetitive cumbersome and time consuming intermediate start-up indexing procedures to clear the ‘loading’ area for more muck to be loaded. This is a particular problem faced when a spillage has occurred. Further, depending on the inclination of the conveyor installation and other factors, the belts can easily be ‘overloaded’, preventing start-up at the end of the clean-up shift, resulting in costly time and labour wastage to manually offload the belt until it will start up, which then has to be cleaned up during the next cleaning cycle.

During the many mine visits it was noted that there was a tendency by belts to ‘dump’ more waste/carry-back at points where the belt underwent a sudden forced change in direction, ostensibly caused by the suddenly highly increased pressure of the roller pressing against the ‘dirty’ side of the belt. This observation could not be scientifically quantified, but was shared with the latter half of the experts interviewed and only two mentioned that they had noticed this too, but had not thought about this further. The rest said something in the line of: “…now that you mention it…” If there is indeed merit to this observation, then the possibility exists to crate a new passive cleaning device, by deliberately ‘super loading’ the belt (within safe limits) at selected points along its return path – with typically a special twin roller-set that deliberately twists the belt through a S-path in the direction of travel, creating what is defined here as ‘designated loading zones’: areas along the length of the belt return way where one knows accelerated drop-off of carry-back will occur and can be selectively placed and can effectively/autonomously be dealt with, thus minimising the deposition of this muck along the rest of the return line further on, where it may be more difficult to clean.

A technique extensively employed along overland conveyors is to throw the return belt over shortly after passing through the tipping point and righting it just before the tail end pulley, effectively keeping the 'dirty side' of the belt off the return idler and drastically minimising carry-back fallout between these points. Note that the righting roller-sets effectively create 'designated loading zones'. This technique was discussed with the experts consulted, who seemed to concur that such throw-over systems are too bulky and expensive. However this opinion may warrant further consideration as it is a means of achieving Level 3 cleaning without the mess of dealing with water pollution issues.

Because of the ease by which access to the book "Foundations 4" can be gained, no further reference to passive belt cleaning systems is made in this report.

3.2.1 Machinery needing adaptation before use in niche mining applications

Though there are some mechanised cleaning machines suitable to specific niche applications (as presented in Section 3.2.2), it is also plainly apparent that there is no functional existing cleaning equipment option anywhere available in the world, suitable for general application along what could be described as the majority of the length of a typical South African coal mine underground conveyor system.

There are over 200 mini earth moving machinery manufacturers worldwide, divided into four subsections – Mini Excavators, Compact Loaders, Mini Dumpers and Mini Backhoes. The most comprehensive internet website where example of such second-hand machinery can be found is http://www.machineryzone.com/

The complete data base is just too big to be included in this printed document, therefore it is available as a separate download from the official Coaltech website as an addendum to this report. However, there are some aspects worthwhile mentioning here.

'Mini' or 'Compact' is defined by manufactures as a tracked or wheeled vehicle with an approximate weight from 0.7 to 7.5 tons. Under 0.7 tons is defined by some as 'micro'. The machinery is typically either centre articulated or skid steered.

A mini excavator (Fig 5) is fitted with an upper structure capable of rotation, which excavates, swings and discharges material by the action of a bucket fitted to the boom and arm, or telescoping boom, without moving the chassis or undercarriage during any part of the working cycle of the machine. Some mini excavators are equipped with a backfill blade and a boom swing.

Figure 5*: Mini excavators*

A mini loader (Fig 6) is fitted with a parallel front end boom to which a bucket is attached that lifts and tilts, which is primarily used to "load" material. Typically the whole machine is used to thrust the bucket into a pile of material to be moved.

***Figure 6**: Mini loaders*

A mini dumper (Fig 7) is fitted with a bucket supported by the body of the machine, which is filled with material using another machine or system, and it is emptied by tilting the bucket. Some have an integrated 'self loader' fitted too.

***Figure 7**: Mini dumpers*

A mini backhoe (Fig 8) is a two-in-one combination of an excavator and loader, with the excavator fitted to the 'back' of the machine.

***Figure 8**: Mini backhoes*

3.2.2 Machinery suitable for limited niche mining applications

Though there is a huge selection of ‘mini’ machinery available, very few are remote controlled and none are flameproof. Four remote controlled makes were found, suitable for niche application in mining. These four manufacturers are:

Brokk

Figure 9*: Brokk 50 and typical attachments – electrical tether powered*

Husqvarna

Figure 10*: Husqvarna DXR 140 – electrical tether powered*

Kanga

Figure 11*: Kanga D800R – diesel powered*

Dugless

***Figure 12**: Douglass 900 – diesel powered*

A technology seemingly finding more and more favour in Australia and the United States is the practice of using truck/trailer mounted vacuum systems (Fig 13) to clean plant and overland conveyor structures. Currently, commercial systems may be a bit too large for direct deployment in our underground environment, but should ‘miniaturise’ well and do represent an alternative technology worthy of further pursuit.

***Figure 13**: VecLoader® Titan® 6100HP and Mini VecLoader®*

Another technological aid one can consider is the use of high pressure water jetting systems. These are considered by many to be the bane of the coal mining industry and others consider them an essential asset. The fact however remains that without the development and use of ancillary systems to collect the waste water slurry or manage the polluted water, this technology will continue to find niche application only. The electronic data base contains reference to a steam based system which operates virtually maintenance free, but since steam is generally not used in coal mining, its probable application is unlikely – unless localised steam generation is cost effective – thus retaining the ‘maintenance friendly’ benefit of such systems.

3.2.3 Manual Labour

The final ‘technological’ aid is also the mainstay of the industry…manual labour. The general opinion expressed by conveyor experts is that there is just nothing in existence that is as simple, flexible and adaptable as good old fashioned manual labour to clean around conveyor installations. We are all aware of the safety concerns this practice entails, but it does seem to have a lot going for it at a superficial level. From an operational perspective, manual labour has significant limitations however. As a starting point, current regulations prevent cleaning near moving conveyor belts, but this restraint may soon be lifted.

Over the years leading up to the strict enforcement of regulations pertaining to working near moving conveyor belts, the mines had developed manual utensil technologies to reduce the risk of workers getting caught into the conveyor system – these entail mainly adaptation of the way the utensil is held by the worker.

Spades/shovels (Fig 14 – Left: utensil in the right of picture), which are mainly used to heft a muck-pile onto the belt for removal, have their T-handle either removed and shank lengthened (as done with a typical ‘American Style’ shovel (Fig 14 – Right), or have the diameter of the T-bar increased to such a degree that a firm grip cannot be made onto the handle. Coincidently and unfortunately, both of these countermeasures severely hamper the efficient use of the utensil.

Figure 14*: Typical shovel and hand held scraper, and ‘American Style’ shovel*

To move muck from under the conveyor, a hand scraper (Fig 14 - Left, yellow handled utensil in the left of picture), consisting of an elongated handle affixed to a T-plate at the working end, is used. Though effective to move and collect loosely compacted muck from under the belt into a muck-pile, ready to be shovelled onto the conveyor, they are nearly useless if the muck has compacted and hardened – which is often the case. Vigorous knocking and hitting with the scraper is needed to loosen-up the collected muck, requiring care to ensure the utensil does not damage the bottom of the belt under which it is being used.

Though cleaning these days is supposed to happen only when belts are stationary, the legacy mindset has remained amongst the inspectorate that now insist that these ‘safer’, but ‘more useless’ equipment, be the only utensils approved for mine deployment. So in spite of stopping the belts, one is still forced to use less efficient tooling than could otherwise reasonably have been used in compliance with existing regulations.

Both approaches to improving the safety of utensils cumulate into a fairly unproductive collective effort. The fact that cleaning around conveyors is generally considered to be a thankless, repetitive and tiring task does not help either. There are many more examples that can be sighted that contribute to this same outcome, but the bottom line is that in spite of its flexibility and short-term direct ‘affordability’, manual labour has many hidden cost factors that should collectively drastically overshoot the cost of an effective mechanised cleaning system, especially in the longer term. From the research conducted as part of this study, the catch-22 is that this ‘effective mechanised cleaning system’ still has to be invented!

The quid pro quo is that the apparent flexibility, preference for and direct cost of manual labour precludes the search for this mechanised solution (as demonstrated by the apparent fact that no significant research into this field is being conducted by anyone).

3.3 Qualified Legislative Compliance

Everyone appointed to a senior position within the coal mining fraternity is intimately familiar with the current wording and meaning of Regulation 8.9 under the Mine Health and Safety Act No.29 (as amended) of 1996. These regulations are acknowledged by MRAC and Industry to be particularly onerous regarding the stopping of conveyors while the structure and area around the moving part of the conveyor are being cleaned. The onerous burden has been drastically expanded since the DMR inspectorate lately expanded the interpretation of legislation to include any mechanized means operating near the belts by literally interpreting the wording “…is not cleaned…” to imply *cleaned* by whatever means.

A protracted consultation process between officials of the DMR, SACMA/SACEA and MRAC has been ongoing since 2008 and seems to eventually be heading towards meaningful change. In essence three sought changes will impact upon cleaning of moving conveyor systems – if accepted and approved by MRAC:

- High risk/designated areas are defined:
    - High risk/designated areas are drive sections, take-up tension sections, snub pulley sections, tail pulley sections & transfer point sections. Non-high risk areas are thus the rest of the conveyor installation;
    - No effective change in regulation pertaining to cleaning in these high risk areas is sought, other than seeking a minor concession allowing the use of high pressure water to clear debris away from under these areas;
    - No concessions are sought in terms of allowing mechanised cleaning systems or remote controlled technology/equipment to be used in these areas to clean them while conveyors are running –an omission industry may regret in future since under current regulation interpretation, these systems are already ‘banned’.

- Non-high risk areas are to be treated differently to the designated areas:
  - May conduct routine cleaning of the run of the conveyor section of the belt, subject to an appropriate procedure being prepared and implemented for this purpose.
- Conveyor alignment and training is to be treated differently in future:
  - May be carried out whilst the belt is in motion, subject to an appropriate procedure being prepared and implemented for this purpose.

More regulatory changes are sought, but do not directly impact upon the cleaning of moving conveyor belts and are not mentioned here.

Though the consultation process is far advanced, the need for finding a more advanced and effective means of cleaning in, under and around conveyor belts shall remain whether all sought changes are granted or not. The conveyor experts consulted believe that manual labour shall continue to be extensively used (with all its faults) and remain inefficient due to its inherent shortfalls.

Clarity on concessions in terms of mechanised cleaning in designated areas while the conveyor is still running needs to be sought and obtained. R&D programs then need to be established to find and develop safe and appropriate mechanised cleaning systems in line with this clarity obtained.

3.4 Operational Requirements

Among the eight mines visited, the full array of extremes was witnessed. In short, as bad as one could imagine a condition to be, somewhere in one of our mines this would be true. This insight alone is thus fairly worthless.

This report covers three types of conveyor installations: underground, overland and plant conveyor systems. As will be presented next in this section, there are many factors to consider. However, to greatly summarise, the overshadowing operating considerations for each type of installation are:

- U/G: Confinement, isolation & undulation of the floor & side walls
- Overland: Occasional spillage & relative ease of general access
- Plant: Working at heights, confinement & narrow walkways

Overland conveyors reportedly are not much of a problem in terms of cleaning for everyone interviewed. Though spillages and belt breaks do occur, they are infrequent and handled fairly easily due to the ease of general access.

Plant conveyors do differ somewhat from overland and underground conveyors, but since they normally form an integral part of the design of the general plant layout, they are fairly well defined and controlled. If one keeps the overshadowing factors above in mind, then appropriate factors applicable to underground conveyors, counts for plant conveyors too.

The conveyor experts consulted concur that cleaning of underground conveyors presents the biggest hurdle to overcome, and thus the rest of this chapter is dedicated to underground conveyors specifically. Obviously, common traits between underground conveyors and the other two types remain valid. To contain the size of this section, the key is thus to somehow describe what could generally be considered to apply to the most of the underground conveyor system and leave it to the reader to extrapolate these findings to the other types of conveyor installations.

It was evident that in spite of belt installations being inspected on a daily basis by most mines, not all installation areas are kept in good condition – many are littered with rubble and fallout from the roof and sidewalls (Fig 15), too big to be loaded onto the conveyor to be removed during routine cleaning. To further exacerbate matters, a lot of confusion reigns in industry regarding what constitutes being 'next to' or 'too near' a moving conveyor belt while in operation, with inspectorate applying seemingly arbitrary rules such as 1.8 m on one mine, and 3 m on another. This then limits inspection of conveyor systems to consecutive splits tying into the belt road and makes identifying conveyor problems and failing idlers (which are only easily identified while running) very difficult to schedule preventative reparatory action. This all collectively culminates in certain areas becoming impassable, even by foot.

Figure 15*: Accumulated rubble*

Belt roads are often long-term installations (except near the working sections, where belts are often relocated). In many cases, support and ground conditions are inherited from the past. A crucial inheritance is that these belt roads are often not straight, snaking to varying degrees along their length. In order to achieve good tracking of the belt, conveyor structure can only tolerate very small and very long wave form deviations off their ideal centrelines. This means that the conveyor often alternates running down to within half a meter off the side wall and then alternate to the other side along its length of travel. In order to move along the entire length of the belt, one will have to cross the beltway numerous times. Some belt installations are hanging off the roof or are lifted high enough off the floor in places so that they can easily be crossed underneath, but in most instances this is not the case.

Geographic undulation is another critical consideration. In order to track a belt effectively, the belt should ideally be in contact with all idler troughs. However, vertical undulation is common to most mines. If the undulation wave length (defined as the distance between two consecutive crowns – i.e. high spots) is fairly long, the belt under its own weight sags far enough to remain in contact with idler troughs mounted a set distance off the floor. However, in areas where the wave length becomes too short to allow this sagging to happen (typically under 100 m, but this length is very site specific dependant and needs to be confirmed/determined from detailed calculations), then the riding height of the troughing frames has to be varied to compensate, resulting in areas where the belt is just skimming above the floor near crowns and highly suspended near the roof in troughs (i.e. geographic low-spots). In many cases the undulation is so severe that the belt only runs on the troughing idlers when fully loaded, resulting in unpredictable tracking behaviour when running laden and unladen – the most common cause of spillage in some mines. The net result is that in some areas, access below the belt is as low as 10 cm or even less. However, most of the conveyor installation should provide 15 to 20 cm or more of height (Fig 16).

Figure 16: *Restricted access below belt*

Mine water services (Fig 17) are most often installed in the belt road on the floor, next to the conveyor structure. These pipes effectively limit access to under the belt to one side only. Combined with the offline tendency mentioned above causing the beltway to alternate proximity near the side walls, means that in some areas access to below the belt is simply impossible, even for routine cleaning – requiring the belt to be lifted while stationary to gain access below the belt over the services piping.

Figure 17: *Mine service pipes*

Water accumulation on mines as an operational consideration is fairly significant. Many mines have no means of cleaning their water to levels suitable for discard into natural river systems. As an interim measure (until an affordable water treatment solution is found), the water is systematically being stored in big underground holding dams, constructed by walling in old working areas. Many mines are thus averse to using water based technologies to clean in, under and around conveyor systems. Also, in some mines, water logged flooring is common place along long stretches of their conveyor belt installations. Any technology deployed to clean around conveyor systems will have to be able to traverse such ‘muddy’ ground and will also have to be able to remove/clean this same mud/slurry from around the belt structures.

Most mining conveyor installations run along quite uneven floor conditions, but they are not so severe in most places that appropriately wheeled equipment cannot traverse these areas. Areas where sideway slope angle (relative to the direction of travel) along conveyor belts reaches up to about 15 º to 20º (i.e. a 33% to 44% inclination) are common, probably requiring to consideration keeping the centre of gravity low, or to compensate for this by some or other means such as self levelling to prevent sideway rollover. Much steeper slopes do occur on some mines.

Except for temporary transfer points, nearly all mines cast flat cement floors under their high risk/designated areas. This result in an area that is easier to clean than most other areas along the belt – once all guards etc. have been removed. The inspectorate seems to apply ambiguous standards when it comes to the means of fastening protective guards to these high-risk area structures. Some inspectors allow ‘hook-on’/hinged guards that are secured using two bolts in such a manner that the guards cannot vibrate loos or be pried off, while others insist on at least eight bolts being used, one in each corner and one in the middle of each side, of each guard panel – making them extremely cumbersome and time consuming to remove for routine cleaning. Three mines visited have raised the overall height of the high-risk area structures above the cast flooring such that easy access is obtained below the raised guard panels for routine cleaning without the need to remove them. The raised structures, combined with the cast floors collectively make these sort of installations prime candidates for autonomous cleaning systems such as ‘moving floors’ and remote control cleaners, so that the installations do not need to be shut down while being cleaned safely. This would be contrary to the interpretation of current legislation and will also not be allowed if currently sought changes are not expanded to specifically seek exception for mechanised cleaning.

There is a practice common amongst some mining groups where the conveyor is suspended off the roof, leaving the floor under these systems open and accessible for eased cleaning. Interpretation of current regulations by the DMR precludes that one is even not allowed to clean under these raised structures. Amongst the conveyor experts consulted, there was strong opinion both for and against suspending conveyor structures off the roof. From the conflicting issues raised regarding pros and cons of this practice, it is deduced that the choice to suspend the conveyor system is more preferential than fact driven. However, from a purely technical perspective, cleaning does seem easier if the conveyor structure is suspend from the roof, allowing more unhindered access below it.

There is no standardised conveyor structure beam layout or construction, with nearly as many variants out there as there are mines. All designs in principle however share common structural elements such as leg structures to locate the beltway, interconnected brace structures to counteract the tension of the belt and maintain tracking alignment and troughing sets evenly spread out along the braces to carry the weight of the loaded belt. Some mine designs have interconnected the braces to form a long uninterrupted tube, through which electrical/signal cables etc are neatly hidden from sight and harm. Extrapolating this concept further, it should be possible to establish a continuous 'rail' from which to suspend/mount an automated cleaning system, capable of traversing the entire length of conveyor belts to conduct autonomous or remote controlled tasks such as cleaning or bring in repair parts during maintenance shutdowns etc. The standardisation of conveyor structures holds the promise of economy of scale reducing the cost of such installations. Similarly, if the services piping is better placed and structured, it too could form the base 'rail' of an automated/remote controlled technology to access the length of the conveyor.

Though many experts consulted expressed that their companies are now trying to re-establish their own inhouse competencies to run conveyor systems, they also expressed that they are having more and more difficulty obtaining services from established conveyor contractors, who are themselves apparently starting to have difficulty obtaining and maintaining skilled labour levels sufficient to service market needs. This directly impacts upon the viability of mechanised cleaning systems as they will require at least semi-trained labour to operate and skilled labour to maintain.

4 Discussion & Conclusions

The only viable means of cleaning near moving conveyor belts currently utilised in SA is manual labour, with mechanised support in niche circumstances doing the bulk handling. This method is currently legally prohibited from being utilised while any part of a conveyor installation is in motion, resulting in significant downtime and overly onerous procedure to be brought into place to operate the mine.

Though some mines are managing to cope under the current load placed upon them by existing legislation, not all mine are in this same position to afford the energy and funds needed to achieve such efficiencies.

No-one seems to be conducting any serious research into developing any alternative cleaning process to *replace* manual labour.

The only technical cleaning developments that have happened over the years have been in refining the operation and effectiveness of passive belt cleaning systems, which even if operated at optimal levels, leave significant amounts of carry-back to be deposited along the length of the return way of the belt. These deposited volumes are concerning, requiring regular, routine cleaning on an ongoing basis to control. It should also be noted that the cost and complexity of passive belt cleaning devices needed to get reduce carry-back fallout rises exponentially with increased cleaning efficiency desired.

The standard recommended minimum passive belt cleaning system set consists of one primary/lead scraper and two secondary/follow-on scrapers at every tipping point, results in a cleaning efficiency of around 100 g/m^2 carry-back. Only a few mines have got this minimum recommended passive belt cleaning equipment in place. Every one of the mines not cleaning to Level 2 requirements is having problems with the reliability of their conveyor systems. Another way of putting this is that conveyor systems are one of the single biggest inventory items on a mines start-up bill, yet it seems to receive way disproportionately small attention after initial installation.

Sought changes to the existing regulations governing the use of conveyor systems on mines seeks to re-establish the right to use manual labour to clean the majority of the conveyor system outside the high-risk/designated areas, but in doing so, fails to redress the need to find an alternative mechanised process whereby the same task can be completed without the need for manual cleaning. If this is deliberate, then political considerations are far outweighing technical merit.

There is no mechanised cleaning system in existence that can effectively clean the majority of the underground conveyor areas we typically have in our mines. Four miniaturised machinery equipment suppliers offering remote controlled products that can possibly be directly deployed in niche applications on our mines have been found. Two operate off an electrical tether and the other two are non-flameproof diesel powered. Locally, a few mines are experimenting with flame proof modified skid-steer machinery in niche applications (such as bulk material removal) in support of manual collection and clearing. They aid, but do not replace manual labour in this regard.

Over two hundred other miniaturised earth moving machinery manufacturers have also been identified, of which their equipment is all of a hand operated or ride-on variety. Amongst these, one is sure to find something that can be developed further into a mechanised cleaning system.

4.1 Structured Approach to Reclaim Control

Though no quick-fix could be found to miraculously turn the clock back, insight gained through the execution of this project indicated that mine with an acute conveyor cleaning related challenge can follow a structured approach to urgently remedy the situation. In principle, it is fairly simple to deploy. The following fundamentals should be put in place:

Step 1: Review current installed passive belt cleaning systems and upgrade to the best recommended set affordable that will fit

Step 2: Review and integrate maintenance schedules, policies and procedures into the cleaning and upkeep of conveyor systems, especially focussing on maintaining passive belt cleaning equipment in good working order

Step 3: Review current belt cleaning schedules, policies and procedures and adopt the mindset that conveyor cleaning matters are equally important to production matters – then man and remunerate accordingly

Step 4: Establish appropriate cleaning periods and shifts to remove the significant levels of carry-back fallout that will still occur

Step 5: Establish/invest into R&D to develop a mechanised means of cleaning near conveyor systems to replace manual labour.

It is important to note that no reference was made to the outcome of negotiations on conveyor regulation changes coming into effect. Legislation should only affect when you're doing what or what you're doing when. Put more explicitly, the fundamentals need to be in place irrespective of the regulatory review outcome. With the benefit of hindsight from the conclusions reached in this report, falling over the first two hurdles may not have had so much to do with the actual wording of current legislation after all…

5 Recommended Follow-on Work

Firstly, mines suffering severe problems with their conveyor systems need to assure that they have the fundamentals in place, that they have all the possible passive belt cleaning systems recommended by manufacturers installed that will fit, that they are properly maintained and that appropriate processes are in place to deal with the fallout that will still occur along the length of their conveyor systems.

Industry wide urgent intervention is needed in terms of establishing a network of ongoing R&D into developing effective mechanised cleaning systems to first augment and later replace manual labour. Without this intervention, nothing will really change.

As a starting concept – a combination of…

- a horizontally mounted excavator arm offering extreme dexterity in reaching under and around low slung structures;
- mated to mini cyclone filtration and vacuum systems;
- mounted on various miniaturised machinery support vehicles (performing breakout, cleaning, collection and dumping functions);
- all possibly operating remotely or even autonomously controlled

... should yield promise.

The bottom line is that in terms of mechanised cleaning system R&D, there is a lot of potential out there to pursue further!