Safety in Mines Research Advisory Comittee

Final Project Report

Best Practice: Conveyor Belt Systems

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Executive Summary

The Anglo Technical Division (ATD) was commissioned by SIMRAC to investigate best practices in and around conveyors. After extensive research this report reflects on historic causes of accidents related to conveyors. From the research main causes of accidents were established that would in future enable the industry to identify possible hazards and introduce preventative measures. The objective of the report is to introduce and implement guidelines to industry and improve occupational health and safety, which in turn will improve working conditions, worker morale and well-being as well as productivity at the various mines.

Firstly, several mines and working sites were visited, considering the safety at the particular installation. Meanwhile an extensive literature survey and baseline risk assessment was done, determining historic causes of accidents. From this it became clear that though there are certain guidelines, there are also several grey areas, which needs to be addressed.

An issue-based risk assessment was done in order to preempt possible causes of accidents brought along by new developments and latest technologies. Causes and preventative measures are summarised in accordance with findings. It has become evident that an entire culture change is required in the mining industry and that safety of the workers should become the shared responsibility of individuals and the employers.

This report contains recommendations regarding the specific aspects that will provide a safer working environment. Strategy for the implementation will involve the authorities through providing necessary guidelines, the employers through defining work procedures and educating the employees, the employees themselves through accepting and implementing improvement and lastly the design engineers and manufacturers, through providing safer designs. The success in reducing the number of conveyor accidents in the South African mining industry however depends heavily on the effective implementation of these recommendations at the mines.

Acknowledgements

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Bafokeng Rasimone Mine
Eikenhof Quarries
Goedehoop Colliery
Khutala Colliery
New Vaal Colliery
Premier Mine
Richards Bay Coal Terminal
Target Mine

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Definitions and Acronyms

For the purpose of this report, the following definitions and acronyms apply:

Accident:	Includes fatalities and reportable injuries
COM:	Chamber of Mines (South Africa)
DME:	Department of Mineral and Energy
Fatality:	An accident at the workplace in which a person/s is killed.
MASHA:	Mines and Aggregates Safety and Health Association (Canada)
MHSA:	SA Mine Health and Safety Act, No 29 of 1996
MRAC:	Mine Regulations Advisory Committee
OHSA:	Occupational Health and Safety Act (South Africa)
PPE:	Personal Protective Equipment
Reportable injury:	An injury to a person preventing him or her from performing his/her normal duties for at least 14 days.

1 Introduction

SIMRAC has commissioned the Anglo Technical Division (ATD) to investigate 'Conveyor Best Practices'. As a result, ATD visited several local installations and established possible causes of accidents related to conveyors. International trends were also investigated and a comparison between installations in South Africa and some overseas installations was made. This report contains statistics regarding causes of accidents, how they could have been prevented and how to avoid a recurrence in the future.

The summarised scope of work listing the contractual outputs is listed in Appendix A.

In parallel to the work being undertaken, the Mine Regulations Advisory Committee (MRAC) issued a Guideline for a Code of Practice for the Safer operation of Belt Conveyor Systems (refer MRAC Circular No. 124/99). This resulted from the Chief Inspector of Mines identifying the most appropriate means of legislation to be a guideline for a mandatory code of practice which will allow for mine specific safety measures to be written into a comprehensive mine health and safety strategy.

This document was therefore written as a summary of current and recommended practices to assist mines to document their individual codes of practice.

2 Scope of work

The purpose of this investigation is to improve safety of conveyor belt systems used in the SA mining industry:

- Primarily, by reducing the exposure of mine personnel to unsafe and hazardous conveyor belt systems and thereby reducing the number of belt related fatalities and injuries.
- Secondarily, it will contribute to improved efficiency through improved designs, better availability and motivated mine personnel.

The scope of work included the following:

- Only troughed belt conveyors were considered. Special conveyors such as screw conveyors, chain conveyors etc. were excluded from the study.
- Conveyor feed points and discharge points were included as well.
- Both material conveyors and man-riding conveyors used underground and on surface were considered.

3 Literature search

In 1996, Simpson et al undertook SIMRAC OTH202 and researched the causes of transport and tramming accidents on mines other than coal, gold and platinum (Simpson et al, 1996). Underground and surface material handling systems were included in the study. The study focused on tracked and trackless systems but excluded belt conveyor systems.

3.1 Active vs Latent Failures:

The following categories of human error were identified in OTH 202.:

- Active Failure:
  Errors made by operators and maintenance staff (i.e. those with hands-on control of the system/equipment. They occur immediately prior to the accident and are often seen as the 'immediate cause'. Active failures are those errors, which have been traditionally described as human error; driver error and pilot error being typical examples.

- Latent Failure:

  Factors/circumstances within an organisation, which increase the likelihood of active failures. Typical latent failures would include, for example, inadequate training provision, poor equipment design (particularly ergonomics), poor attitudes to safety (at any or all levels), work organisational problems, poor safety rules and procedures etc.

To focus on the active failure part only leads to a natural tendency to apportion blame, which does not contribute to the prevention of future recurrences. Failure to identify the latent reason may lead to other employees making the same error. Therefore, the removal of an accurately identified latent cause is an extremely powerful and cost-effective accident prevention measure. (Simpson et al, 1996)

3.2 Causes of Latent Failures

Major generic causes of latent failure identified by OTH202 are:

- Attitude to Safety
  - Management attitude to safety
  - Workforce attitude to safety

- Training
  - Limitations in training course material
  - Training instruction
  - Training needs and training effectiveness

- Organisation and Working Methods
  - Poor organisation and planning
  - Failure to provide adequate resources
  - Inconsistencies in roles and responsibilities

- Rules and Procedures
  - Formulation
  - Review and maintenance
  - Content and coverage
  - Communication

- Attitudes to Rules and Procedures
  - Rules, aims and objectives
  - Training: Hazard awareness and risk perception
  - Safety commitment of the workforce
  - Safety commitment of management
  - Supervision: Monitoring and detection
  - Supervision: Style
  - Plant and equipment design

Working conditions
Organisation

- Equipment Design
  Limitations in design of out-sourced equipment
  Limitations in in-house design
  Design modifications
  Furnishings associated with transport and tramming
  Transport system design

- Organising for Safety
  Role and Function of the Safety Departments
  Mine management
  Safety representatives

- Maintenance
  Poor maintenance of plant and equipment
  Poor maintenance of environmental conditions

3.3 OTH202 Recommendations:

The OTH202 researchers identified the following parameters as having the most potential to reduce transport and tramming accidents in the mining industry:

- Equipment Design:
  Equipment designers and manufacturers are to place a stronger emphasis on the ergonomic implications of the equipment designs.

- Training:
  A more systematic approach to safety training needs analysis is to be implemented. In parallel, hazard awareness and risk perception should be developed amongst the workforce. More innovative training methods should be utilised and the actual effectiveness of training needs to be evaluated.

- Codes, Rules & Procedures:
  Supervisors and the workforce should participate in re-writing the current work instructions that are perceived to be impractical, incomplete, too complex, irrelevant, contradictory and too many to remember.

- Safety Management:
  As mine management controls most resources, a change in behaviour and circumstances, which shape the undesirable attitudes to safety, must be driven top-down.

4 Research methodology

The GEN 701 research was approached in the following manner:

- The current state of safety regarding conveyors was established. During this process, findings obtained in available Department of Mineral and Energy (DME) reports were considered. Accident statistics in South African mines since 1988 were taken into account. Existing codes and practices in use at the mines were considered to ensure its suitability and adequacy. Various mines were visited in order to obtain first hand information as to how safety is addressed.

- From the above, main causes of accidents were identified. Baseline risk assessments as well as an issue-based risk assessment were done for both material and man-riding conveyors and risks identified and assessed.
- International accident statistics were obtained and South African accident figures were benchmarked against it. Codes of practices and standards were obtained from overseas countries and South African standards were compared to it.
- From the above, possible actions were identified and a strategy to implement the recommendations was formulated.

Inputs from current users and design authorities were incorporated wherever possible to ensure that the study is based on the experience of all stakeholders. The methodology and results are discussed in detail below.

5 Baseline Risk Assessment

It was found that almost every mine has conventional belt conveyors, be it underground or on surface. Conveyors can vary in length from less than 5m to as much as 15km or even longer. Ninety percent of conveyors are however between 40m and 300m long. The variation in length implies that drive arrangements can vary from a single shaft mounted drive to multiple ground mounted drives. Even though the equipment of which a conveyor is made is mostly standard, there could be a multitude of arrangements, thereby affecting the safety of the system.

5.1 SA Statistics on conveyor accidents

The DME records regarding conveyor accidents in the SA mining industry for the period 1988-1999 can be summarised as shown in figure 1.

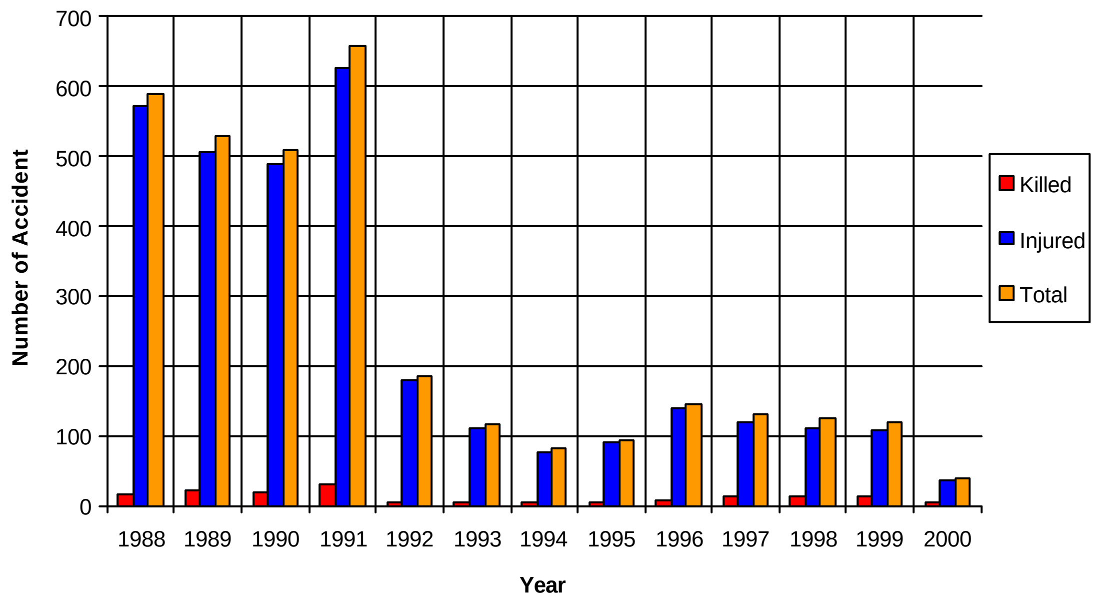

Figure 1: Conveyor accidents recorded in the SA mining industry (1988 – 1999)

(Source: DME accident database)

Note that for the purposes of this discussion, the number of accidents represent the combined sum of fatalities and reportable injuries. The latter refers to work related injuries that prevent a worker from performing his/her duty for at least 14 days. Although statistics are given for the year 2000, it cannot be used in trend analysis as it covers only the five month period of January to May 2000.

Figure 1 reveals conveyor related accident numbers of approximately 500 to 600 per year during the years 1988 to 1991. Since 1992 it has decreased to below 200 accidents per year and reached a low of approximately 80 accidents in 1994. However, during the period 1996 to 1999 it exceeded the 200 accidents per year level again.

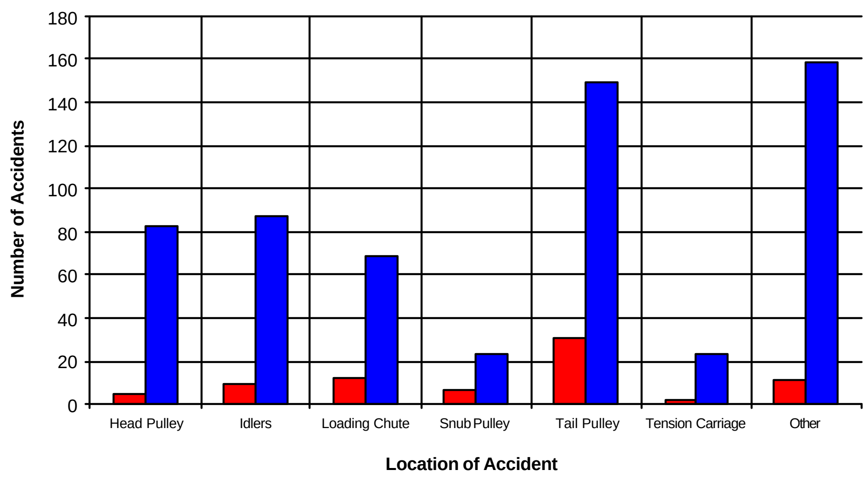

Figure 2: Accidents traceable to specific conveyor sub-systems (1995-1999)
(Source: DME records)

Another source of useful information is an improved description added to the DME database since 1995. It describes the specific conveyor subsystem where the accident occurred as shown in figure 2. It is interesting to note that the tail pulley causes most fatalities while injuries frequently result from people working at the

- tail pulley
- head pulley
- idlers
- loading chute

People working on moving conveyors, inadequate guarding and ineffective locking out stand out as major causes of conveyor accidents.

Table 1: Summary of SA conveyor accidents per standardised cause: (1988 – 1999)
(Source: DME accident database)

Importance Ranking	DME Standardised Cause	Reported Cause of Accident	People Killed		People Injured		Total	
			Number	%	Number	%	Number	%
1	B	Failure to comply with recognized good practice/standard	62	39%	1186	38%	1248	38%
2	H	Lack of caution/alertness	18	11%	1059	34%	1077	32%
3	C	Failure to use safety or protective devices/equipment/systems	10	6%	176	6%	186	6%
4	P	Use of unsuitable (defective) equipment/material/facilities	7	4%	119	4%	126	4%
5	M	Inadequate examination/inspection/test	10	6%	104	3%	114	3%
6	L	Inadequate supervision/discipline	7	4%	77	2%	84	3%
7	F	Lack of (or unsuitable) systems/facilities	6	4%	67	2%	73	2%
8	A	Mental & physical limitations	10	6%	62	2%	72	2%
9	N	Lack of (inadequate) fencing/guarding	17	11%	52	2%	69	2%
10	G	Lack of (or inadequate) standards/procedures	6	4%	55	2%	61	2%
11	K	Lack of adequate (suitable) training/instructions	4	2%	45	1%	49	1%
12	I	Lack of clearance (obstruction)	0	0%	47	1%	47	1%
13	D	Failure to supply safety or protective devices/equipment/systems	2	1%	36	1%	38	1%
14	O	Inadequate preventative maintenance	0	0%	38	1%	38	1%
15	Q	Rendering safety device ineffective	1	1%	16	1%	17	1%
16	E	Failure to supply proper tools/equipment	0	0%	13	1%	13	0%
17	J	Lack of illumination/visibility	1	1%	9	0%	10	0%
TOTAL			**161**		**3161**		**3322**	

To devise a strategy to reduce the number of conveyor accidents in the SA mining industry, the real cause of accidents needs to be identified. Table 1 shows a summary of the DME accident statistics since 1988. A total of 3322 accidents were reported during this period which represents 3161 injuries and 161 fatalities. Note that there are 17 standardised causes used in DME accident reports. These are ranked in order of importance in Table 1 with number 1 being the most frequently identified cause of accidents. The following points are significant:

- 38% of all accidents are reported to be caused by a failure to comply with recognized good practice/standards.
- A lack of caution/alertness contributes 32% to the total number of accidents.
- These two primary causes are followed in importance by:

  6% : Failure to use safety or protective devices/equipment/systems
  4%: Use of unsuitable (defective) equipment/material/ facilities
  3%: Inadequate examination/inspection/test
  3%: Inadequate supervision/discipline

- 11% of fatalities are caused by a lack of guarding.

As per the OTH202 definition of active and latent failures, all the DME standardised causes of accidents can be classified as active failures i.e. errors made by operators or maintenance staff. No or little attention is paid to the contribution of latent failures, in other words failures resulting from factors/circumstances within the organisation, which increases the likelihood of active failures. Simpson et al (1996) also state in the OTH202 report that the most significant safety improvement can result from mines addressing the latent failures and not the active (worker related) failures only.

Typical examples are:

- Failure to comply with good practice: Good practice has until now been poorly defined.
- Lack of caution: This reason is often as ambiguous as the first example and easily confused with other reasons

Table 2: Comparison of conveyor injury and fatality rates with that of SA mining industry (1988 – 1999)
(Source: DME database & COM website)

Year	Number of employees (000)	Conveyor Systems		Mining Industry	
		Injury Rate (/1000 employees)	Fatality Rate (/1000 employees)	Injury Rate (/1000 employees)	Fatality Rate (/1000 employees)
1988	677	0.84	0.03	15.36	1.00
1989	664	0.76	0.03	18.02	1.12
1990	698	0.70	0.03	14.09	0.98
1991	634	0.99	0.05	14.24	0.95
1992	586	0.31	0.01	15.00	0.94
1993	543	0.20	0.01	15.66	1.08
1994	507	0.15	0.01	15.71	0.95
1995	523	0.17	0.01	14.76	1.02
1996	493	0.28	0.02	15.00	0.94
1997	483	0.25	0.02	14.66	0.86
1998	431	0.26	0.03	14.12	0.85
1999	407	0.26	0.03	13.42	0.76

Table 2 puts the conveyor accident statistics in context with that of the total SA mining industry. It compares the respective injury and fatality rates over the period 1988 to 1999. Note that where the injury rate for the total mining industry has decreased from 15,36 injuries/1000 employees to 13,42 in 1999, the corresponding figure for conveyor injuries decreased from 0,84 to 0,26 injuries/1000 employees. What is of concern is that the conveyor injuries reached a low of 0,15 in 1994 and then nearly doubled to reach the value of 0,26 in 1999. This negative trend is also visible in the conveyor fatality rate: The rate improved from 0,03 deaths per 1000 employees in 1988 to 0,01 in 1992-1995 but then trebled again to reach 0,03 in 1999. This worsening of conveyor accident statistics supports the Chief Inspector of Mines' initiative to initiate the draft regulation mechanism on belt conveyors.

Of some concern was the lack of detail in the statistics received from the DME in this country. When compared to other countries' accident information, the following areas were of specific concern:

- Very little information is reported about the accident, only the bare essentials are stated. The employer must be pro-active and this report should therefore include reference to past information if the definition of 'reasonable practicable' of the Mine Health and Safety Act No.29 (as amended) of 1996 (MHSA) is taken into account.

- The cause of accident is almost always reported as a single issue. From this it would appear that underlying causes and contributing factors are not taken into account. The MHSA, in specific section 11(5)(c) requires employers to investigate accidents and incidents to identify the unsafe acts and conditions. This investigation can be held jointly with the inspector from the DME in terms of section 60 of the MHSA. It would be a valuable contribution to the industry if the active as well as latent failures as defined by OTH202 can be identified.

  For example:

  'Failure to use safety devices because of poor ergonomics and work pressure. The employee had been employed at the mine for six years but on this specific job for only two weeks',

  which would be much more useful than,

  'Failure to use safety devices.'

  - The accident report format used by the US Department of Labor (refer Appendix I) is also recommended as it describes the circumstances of the accident, the actual violations and the plan to prevent a recurrence.

5.2 Historic causes of accidents

To complement the identified causes of accidents as listed in Table 1, Dodds & Botes identified the most common causes of fatal and reportable accidents based on their experience as inspectors at the DME (MRAC Circ No 124/99):

Fatals:

No adequate guarding of head and tail pulleys
No proper lockout procedure
Loose clothing
Persons doing all sorts of work whilst conveyors are in motion
Working about control and discharge chutes with and without belts moving
Sleeping on belts
Sufficient stopping devices not installed along the length of the belt

Reportable Injuries:

Working about moving conveyor belts
Cleaning of spillage and removal of material while belts are in motion, including barring of rock
Working about loading chutes while belts are in motion
Belts starting up while people are busy working on belts
Working on/at tensioning devices
Slipping and falling of persons and material

Taking a more holistic view, the following generic contributors to conveyor accidents can be identified:

Active failures:

- No or inadequate guarding
- No or ineffective lockout procedures
- People cleaning or working on moving machinery

Latent failures:

- Abdication with regards to accountability for safety (Employers ↔ employees)
- Limited or ineffective training
- Poorly defined or communicated procedures.

5.3 Benchmark against international statistics

To look at the South African conveyor accident statistics in isolation is of limited use. In paragraph 5.1 the trends during the period 1988 to 1999 was analysed. However, to fully assess the South African performance, it needs to be benchmarked against that of similar industries in other countries.

The identified reference countries and degree of success of obtaining useful data are listed below:

- **Australia:**

  Contact was made with the Department of Mineral and Energy of Western Australia and searches were done using the Internet websites listed in the references.

  Limited information was obtained due to conveyors being included in the category 'Materials Handling'. This part of the search was therefore terminated.

- **Britain:**

  No useful information was obtained

- **Canada**

  Useful accident statistics were obtained from the Mines and Aggregates Safety and Health Association (MASHA) in Ontario, Canada. Mining industry workforce numbers were also made available from Statistics Canada.

- The MASHA Safety focus states that approximately 170 conveyor accidents occurred during the period 1988-1998. This excludes accidents in the Canadian pits and quarries. Also note that MASHA is a voluntary association and mines submit accident reports on a voluntary basis. However, as per the Statistics Canada employee numbers in the Canadian mining industry range from 67500 in 1989 to a minimum of 47800 in 1999 with the average number being 55983.

Assuming that the total of 170 accidents, quoted by the Safety focus, include fatalities and reportable injuries, the Canadian accident rate can then be calculated to be 0,0003 accidents per 1000 employees. Compared to the SA statistics listed in Table 2, this rate appears to be unrealistic and can perhaps be attributed to it being based only on voluntary accident reports.

What is of interest are the stated causes of Canadian conveyor accidents:

- Lockout and tagout procedures not properly used, not known or enforced
- People working on/cleaning moving belts

The similarity of the stated causes with the causes identified earlier in this report is significant.

- **United States of America**

Statistics were obtained from the US Department of Labour Mine Safety and Health Administration Internet site. The summary is that the US mining industry experienced two, three and two conveyor-related fatalities during the years 1998, 1999 and January to May 2000. Employee numbers for surface, underground, milling and preparation plants in the USA were obtained from the references listed and fatality rates calculated. A comparison of conveyor rates for the SA and US mining industries is shown in Table 3.

Table 3: Comparison of conveyor fatality rates for the SA and USA mining industries

Year	SA Mining			USA Mining		
	No of employees (000)	Fatalities	Fatality Rate (/1000 employees)	No of employees (000)	No of fatalities	Fatality Rate (/1000 employees)
1998	431	13	0,03	253	2	0.008
1999	407	12	0,03	245	3	0,012

Although the data sample is small and excludes injury rate, it is clear that the conveyor fatality rate of the SA mining industry is on average three times higher than that of the US mining industry. What is also significant is that Table 2 indicates that during the years 1992-1995 the SA figures decreased to values comparable to the USA figures for 1998-1999.

5.4 Survey of 'Best Practice: Conveyor Belt Systems' in South Africa

A spectrum of local mining operations was visited to determine what practices and procedures are in place and can be recommended to other users. The installations visited included material as well as man-riding conveyor systems used on surface and underground.

Table 4: Conveyor installations visited

Mine	Commodity	Conveyor Duty	Surface/ Underground
Bafokeng Rasimone Mine	Platinum	Material/ Man-riding	Underground/Surface
Eikenhof Quarries	Sand	Material	Surface
Goedehoop Colliery	Coal	Material	Underground/Surface
Khutala Colliery	Coal	Material	Underground/Surface
New Vaal Colliery	Coal/Sand	Material	Surface
Premier Mine	Diamonds	Material	Underground/Surface
Richards Bay Coal Terminal	Coal	Material	Surface
Target Mine	Gold	Material/ Man-riding	Underground

The following are the salient points resulting from the visits:

5.4.1 Richards Bay Coal Terminal

At this installation the key word is speed. Downtime is very expensive in this instance and therefore a strict preventative maintenance plan is in place. Belts operate at high speed and chute design was particularly impressive since there was very little spillage around the installation. Staff is well trained during induction and continuous efforts are made to improve on the existing safety systems. Continuous monitoring of mechanical equipment and maintenance appears to be the secret behind their success. Another contributing factor is the fact that initial cost is not the driving factor when doing maintenance but the focus is on operational availability and reliability.

5.4.2 Eikenhof Quarries

At this installation there are two daily inspections of the mechanical conveyor equipment and if necessary, a shutdown to repair or replace faulty equipment. There is also a planned maintenance system in place ensuring that maintenance is done on a preventative basis rather than correcting problems as they occur. This installation has a fine safety record and has strict rules regarding lockout procedures and training of new personnel.

5.4.3 Khutala Colliery

The first impression one gets when walking onto this mine is that of good housekeeping. There is very little spillage around the conveyors since it is cleaned regularly. It is therefore very safe to walk on walkways next to conveyors without having to climb over mounds of coal. It would also appear that during the design process the chutes were slightly overdesigned. As this may be costly during the initial stage, dividends result during operation of the installation. As is the case with other mines, the installation has strict procedures regarding the lockout of equipment prior to performing any work on them. Where it is possible to pass underneath the conveyor, the return idlers were guarded wherever one can reach the underside of the belt.

5.4.4 Bafokeng Rasimone Mine

This was the first man-riding facility visited and being a conveyor that transports men, the safety systems were of a higher standard than normal. Extensive compulsory induction and training is done prior to using the man-riding belt. It has to be realised by all concerned that a man-riding conveyor is to be used with respect and caution. Adequate training in boarding and alighting these machines is essential. The biggest danger with these machines is that riders may fall asleep on the belt. Safety systems must therefore be in place to ensure that the rider does in fact get off the belt. This installation had a strict code of practice for operating the man-riding facility and also has a control room where an operator constantly monitors the entire belt. The training facility was on an incline, which is a good idea since it is more realistic than a flat training belt. Maintenance is done on a daily basis to ensure that the conveyor remains in prime condition. Whereas SABS 0266 :1995 (Code of Practice for man-riding conveyors) requires walkways to be 600mm wide, they were made 900mm wide at this installation to accommodate a possible fall during alighting, allowing the next person to safely alight.

5.4.5 Target Mine

At this mine there is an entire series of man-riding conveyors. As for Rasimone there are strict procedures in place and training is compulsory before using the man-riding facilities (Refer to Code of Practice attached as Appendix J). Target reported that most casualties result from new employees and visitors using the man-riding belts. This mine also suggested that the existing SABS 0266: 1995 specification for man-riding conveyors requires some attention and updating. Man-riding facilities underline the philosophy of workers sharing the responsibility for their safety. Maintenance is done regularly and since these belts are not of a steelcord construction, belt maintenance is especially well managed. It is also worth noting that Target reported most man-riding accidents to involve new employees and visitors which stresses the importance of training riders adequately before using the facility.

5.4.6 New Vaal Colliery

This installation has a set of regulations that are to be followed and has dedicated beltsmen to look after the conveyors. No fatalities were reported within the last five years and only cuts and bruises resulted from some minor incidents that occurred during maintenance. An effort is made here to contain dust and continuous efforts are being made to improve the dust suppression system to ensure that the dust is not taken into the atmosphere. This installation is also using a pneumatic activated cleaning system to clean chutes, thereby avoiding the need to have people performing this hazardous task.

5.4.7 Premier Mine

At Premier mine, a risk assessment was done on conveyors and potential danger areas addressed accordingly. Conveyors, in general, are seen as dangerous machines and no one area is isolated for special attention. For long conveyors transport is provided for personnel inspecting the conveyors. This is to ensure that equal attention is given to all areas, rather than the inspector having to walk, getting tired and overlooking potential problem areas on the conveyor. Negligence was described as a major contributor to accidents at the mine and addressed through a training program.

5.4.8 What was learnt from the site visits:

- Preventative maintenance plan contributes to safety and system availability
- Ensure adequate chute design.
- Control spillage.
- Training of personnel is essential.
- Consider cost but not at the expense of compromising the system
- Inspect conveyors regularly.
- Ensure procedures are in place for various activities.
- Guard the belt where personnel have to pass underneath it.
- Proper and adequate staff induction must be compulsory.
- Strict adherence to procedures is essential.
- SABS 0266 : 1995 needs updating
- Change workers' mindset to encourage them to accept co-ownership of their safety and that of their co-workers.
- Dust suppression can be used to good effect to make the environment safer.
- Do a risk assessment on conveyors to determine possible problem areas.
- Treat all equipment with equal respect and do not become complacent.
- Provide inspection personnel with transport to ensure effective inspection of the total conveyor system.

5.5 Existing Standards & Codes of Practice

5.5.1 Standards used in SA conveyor industry

There is no formal national standard relating to safety regarding the use of conveyor belts. There are general guidelines in terms of the MHSA, the Occupational Health and Safety Act (OHSA) and some DME recommendations, but nothing that summarizes best practices for conveyors.

The following list of conveyor related standards traditionally used in the SA mining industry illustrates that the emphasis has been on the technical design and manufacturing of systems. The safe use of conveyor systems and the man-machine interface have not been effectively addressed to date.

5.5.1.1 Design & Manufacturing

- **DIN 22101**
  Continuous mechanical handling equipment; Belt conveyors for bulk materials; basis for calculation and design.

- **ISO 5048:1989**
  Continuous mechanical handling equipment – Belt conveyors with carrying idlers – Calculation of operating power and tensile forces.

- **BS 2890: 1989**
  Specification for troughed belt conveyors
  Design and dimensions of conveyor fitted with rubber or plastic belting with textile reinforcement carrying loose bulk materials and having a maximum belt speed of 5,0 m/s

- **CEMA**: 2000
  Conveyor Equipment Manufacturers Association Guidelines

- **GOODYEAR**:
  Handbook of elevator and conveyor belting. (Metric edition)

- **SABS 971:**1980
  Fire-resistant textile-reinforced conveyor belting (for use in fiery mines)

- **SABS 1173**:1977
  General purpose textile-reinforced conveyor belting

- **SABS 1366:**1982
  Steel-cord-reinforced conveyor belting

- **SABS 1669**:1996
  Conveyor belt pulleys

- **SABS 1313-1**:1999
  Conveyor belt idlers Part 1: Troughed belt conveyor idlers (metallic and non-metallic) for belt speeds up to 5,0 m/s

- **SABS 1313-2**:1999
  Conveyor belt idlers Part 2: Link suspended idlers and fixed-form suspended idlers.

5.5.1.2 Safe Use

SABS 0266:1995

The safe use, operation and inspection of man-riding belt conveyors in mines.

5.5.1.3 Decommisioning

None

From the results of the baseline risk assessment and the above list of standards it is clear that the design and manufacturing of conveyor belt systems have traditionally been adequately addressed. Most accidents can be attributed to a lack of an understanding of the inherent risks of a conveyor system and the safe use of such systems.

However, this shortcoming is not unique to South Africa and this has only been addressed in international specifications during the last 5-10 years. The result of such an exercise is documented in the Australian specification AS1755 - 2000 which was issued late in 2000.

5.5.2 AS1755 – 2000: Conveyors – Safety requirements

AS1755 – 2000: *Conveyors – Safety requirements* replaced the earlier 1986 version, which also focused heavily (like the current list of specifications used in SA industry) on design and construction issues. Note that AS1755 excludes man-riding as man-riding is not allowed in Australia.

The standard applies to the design, construction, installation and guarding of conveyors and related systems, whether of a temporary or permanent nature, for the conveyance of materials. The purpose of such a standard was to establish uniformity in engineering practice across Australia and the requirements have been drafted to provide conveyors and conveyor systems with practical and adequate safety features and to stipulate conditions for safety in operation and maintenance.

As indicated by the scope and objective of this Australian specification, the aim is to minimise the risks and hazards of operating conveyor belt systems. It sets out the minimum safety requirements for the design, installation and guarding of conveyors and conveyor systems. It includes requirements for users and providers of inspection, maintenance, training and implementation of safe work practices for such equipment. Particular emphasis is given to operational safety and the protection afforded to operators, maintenance personnel or other persons who may be exposed to risks to health and safety associated with conveyors or conveyor systems.

AS1755 further states as its objective: … ‘ to enable designers, manufacturers, suppliers, employers and users of conveyors and conveyor systems to minimize the risks to health and safety where conveyors are used.

Additions made to AS1755 – 1986 version:

- Requirements for guarding expanded
- Appendix on ergonomic data to be used in the design and building of guarding added. Note that this provides relevant data to prevent people from encroaching into a danger zone associated with a conveyor. A copy has been attached to this report as Appendix E
- A section on Safework Practices has been added of which a copy has been attached as Appendix F. It outlines minimum requirements regarding best practice, the need to do risk assessment on new or unproven practices and to ensure that procedures are effective and practical. This is to be evaluated by means of regular audits and checks. The main points addressed are:
  - Information to be made available by suppliers and maintained by owner.
    - Synopsis of plant
      (Design capacities, general arrangement drawings, control logic etc)
    - Installation, commissioning and dismantling

(Information regarding the installation, commissioning and dismantling of the conveyor system)

- Operating and maintenance instructions
  (Loading and unloading instructions, maintenance including lubrication, testing and repair, operating instructions and emergency procedures)

- Safework Procedures

  - Access or work in a danger zone
    (Work in a danger zone is not allowed while the conveyor is running. Effective lockout procedures to be used).
  - Work using remote isolating device
    Risk assessment to be used to ensure that isolation method is effective and clear signage to be affixed to the isolation device).
  - Isolation systems
    (To include tagging and locking or a permit system)
  - Installation, commissioning and dismantling procedures
    (To address site establishment including induction and training, materials handling, work methods, minimum standards, emergency plans, documentation, modifications and repairs).
  - Operating procedures
    (Refer to Appendix F)
  - Maintenance procedures
    (Refer to Appendix F)
  - Maintenance management
    (The formulation of a maintenance management program which includes pre-operational servicing, condition based servicing, inspections and recording is required.)
  - Training
    (All personnel involved with the conveyor system or that may be exposed to a hazard from such a conveyor system need to be trained. Training should further cover all procedures relating to installation, commissioning, dismantling, operating and maintenance of the conveyor system.)

It is clear that the intention is not to prescribe to end-users but rather to provide a framework to compile user-specific procedures. The objective of the improved AS1755 closely matches that of this project (GEN701) as the focus is widened from the design and construction of conveyor systems only to reducing the hazards throughout the total life cycle of the conveyor system.

5.5.3 CAN/CSA-Z98-96: Passenger Ropeways – Public Safety

Although AS 1755-2000 will contribute significantly to the safe operation of both material and man-riding conveyors, it does not address the unique man-machine interface requirements of man-riding as it is not allowed in Australia (or Canada or USA).

Man-riding has however been allowed in the United Kingdom, Germany and South Africa. Due to the limited information found on specifications regarding man-riding belt conveyors, the search was broadened to look at comparable applications where continuous carriers are used to transport people.

Canadian standard CAN/CSA-Z98-96: *Passenger ropeways – Public Safety* was identified as a reference to investigate how other industries manage safety risks. This specification covers the design, installation and operation of ropeways used by the public at ski-resorts. Note that it was last revised in 1996 and is structured similarly to the Australian conveyor standard AS1755-2000.

The similarity of ropeways and man-riding belt conveyors lies in:

- Both carriers are continuous and used to transport men and material
- Average speed of carrier up to 3m/s
- People board and alight from moving carrier.
- Users (skiers) are not regular users and may include inexperienced people.
- Importance of effective lockout during maintenance
- Failure of the design or bad operational practice may lead to fatalities/injuries.
- Carrier, drive mechanism, counterweight et cetera is comparable to conveyor installation.

The scope of CAN/CSA-798-96 states that it 'establishes requirements for the design, manufacture, installation, operation, maintenance, testing, and inspection of passenger ropeways'. It is therefore clear that the total lifecycle of the ropeway is covered. It further stresses the importance of competent engineering and operational judgement in the use of ropeways. It can therefore be seen that, similar to man-riding conveyors, misuse of or use by poorly trained riders may result in injuries or fatalities.

Specific examples of areas covered that may contribute to the safe use of man-riding conveyor belt systems are:

- Lockout Procedures:
  All operational and maintenance personnel shall be made aware of lockout procedures. Each maintenance staff person to have own sign reading 'Work in Progress" and a personal padlock. When working on the drive system, the main supply shall be padlocked OFF.

- Safety gate:
  A safety gate shall be provided to stop the ropeway if a passenger fails to unload at the intended unloading point. Distance from the safety gate to the first obstruction shall not be less than 1,5 times the distance required to stop the ropeway at maximum speed.

- Boarding and alighting pictograms:
  Clear pictograms are to be used at boarding and alighting stations (refer to Appendix L for examples of pictograms used on Canadian ropeways)

- Training:
  This is a management responsibility and the personnel responsible for training need to be appointed. What is of significance here is that training should not only cover standard procedures but also equip operational personnel to look out for potentially dangerous situations.

- Operational requirements:
  Only authorised personnel are allowed to operate the ropeway. They are to ensure that the actual design comply with the Standard and that no unauthorised modifications have been implemented.

- Operational Manual:
  An operational manual, which addresses the correct usage and maintenance of the installation, shall be available to the operating personnel.

- Minimum number and Location of Operating Personnel:
  One operator is to be in charge and one attendant to be at each boarding/alighting station.

- Operational Procedures and Rules:
  After any unscheduled stop, the cause of the stop shall be determined. No restart shall be allowed until the cause is known and clearance from all stations have been obtained. Controls that bypass any portion of the operating control circuitry shall be locked when not in use. When a bypass is in operation, the function bypassed shall be under constant and close supervision.

- Hazardous Conditions:
  Should a critical component fail, it will be removed and the cause of failure investigated.

- Communication:
  The ropeway shall not be operated without a functioning communication system.

- Design and operation of Boarding and Alighting stations:
  Station shall be marked and shall be closed when boarding is not permitted. A method for marshalling riders for boarding shall exist. Instructions and procedures to be used in case of unusual occurrences to be provided and maintained at attendant stations. Maneuvers shall be devised and practiced to assist passengers who have failed to board/alight at stations.

- Starting and stopping ropeway:
  Only to be started under direction of designated operator.

- Operational inspection:
  A daily inspection shall be conducted. All abnormalities shall be recorded in the log book and appropriate action taken. (Refer to example sheet in Appendix G)

- Tension System:
  Shall be functional before ropeway is started and shall have a minimum of 150mm travel available when at both extremes

- Evacuation:
  An evacuation drill shall exist to evacuate passengers safely and it shall be practiced at intervals not exceeding 12 months.

- Operational log:
  A daily operational log shall be completed recording information such as: date, names of operating personnel, compliance with daily inspection etc.(Refer to Appendix G for example)

- Maintenance safety procedures:

Management shall prepare, and place at attendant stations safety procedures to be used during ropeway maintenance. (Shall include as a minimum: main power lockout, safe rigging and user safety.

- Maintenance procedures & requirements:
  The manufacturer's maintenance procedures shall be followed.

- Acceptance testing and inspection:
  Before a new ropeway or a ropeway which has undergone a major alteration is placed in operation, it shall be inspected and tested to confirm that it meets the requirements of the Standard and the requirements of the manufacturer's and designer' specifications.

- Periodic load testing:
  Test as per manufacturer's procedure and interval not to exceed 5 years. (Refer to example sheet in Appendix G).

- Testing of rope and splicing:
  Nondestructive testing interval not to exceed 12 months (Refer to example sheet in Appendix G).

- First Aid:
  Trained personnel and equipment to be available.

- Fire protection:
  Fire fighting equipment shall be available and inspected for serviceability.

The similarity of ropeways and man-riding belts is clear from the above list of ropeway parameters and procedures. The existence of CAN/CSA-Z98-96 and the topics addressed in it prove that accidents experienced earlier in the ropeway industry necessitated the formalisation of such a code.

What is also of importance regarding this standard is that, similar to AS1755-2000, it does not prescribe to the last letter but rather provides a framework to ensure that users address all stages of the lifecycle i.e. design, installation, commissioning, operation, maintenance and inspection

5.5.4 BS 7801:1995 Code of Practice: Safe working on escalators and passenger conveyors

As the SA conveyor accident statistics (refer paragraph 5.1) indicate that numerous injuries/fatalities result from maintenance activities and the fact that no specifications listed in paragraph 5.5.1 address safeworking on conveyor systems, the need exists to look at what is available from other industries.

BS 7801 : 1995 covers specifically safeworking practices applicable to escalators and passenger conveyors. Note that the design and construction is addressed in BS EN 115: 1995 and the test and examination in BS 5656 : 1997. As discussed above, poor maintenance practices cannot only affect the safety of maintenance personnel but also that of people using the system or being in the vicinity.

An abstract from the British Health and Safety at Work Act 1974 quoted in BS7801 sketches the responsibility of the different role-players effectively:

- Employers have the duty to ensure that, so far as is reasonably practicable, the health and safety of their employees at work. This includes the provision of plant and systems at work that are safe and without risk to health, means to safely use and handle articles and substances, necessary information, instruction, training and supervision, safe means of access and egress and a safe working environment.

- Employers, the self employed and employees have a duty to conduct their undertaking in such a way as to ensure, so far as is reasonably practicable, that all persons who may be affected by the work activity are not exposed to risks to their health and safety.
- Manufacturers, suppliers and erectors of articles for use at work have a duty to ensure, so far as is reasonably practicable, that the articles are so designed and constructed that they will be safe and without risk to health when they are being set, used, cleaned or maintained.

As this is in line with the requirements of the MHSA, it also applies to both material and man-riding conveyors. To significantly reduce the hazards associated with conveyor systems, it is essential that all roleplayers accept their part of the total responsibility and realise the potential benefit of their individual contributions.

All persons working on escalators and passenger conveyors are expected to pay due care and attention to potential hazards, make proper use of safeguards provided and follow defined working procedures if accidents and ill health are to be avoided.

Specific points of relevance from BS7801 are:

- Personnel to be trained in approved practices, potential hazards and foreseeable risks. BS7801 recommends initial training, backed by subsequent experience which can then later be complemented by additional training for particular aspects of the work.
- Only authorized persons to perform work.
- Instructions to be in the form of written procedures.
- Maintenance staff to do site safety assessment beforehand to ensure that required work can be done safely using agreed procedures
- Persons working alone on the system will register their presence with the appropriate personnel and their continued safety will needs to be monitored
- Safety signs and barriers to be used
- Where two or more people are working simultaneously, it is essential that a reliable and effective system of communication exists.
- Work should not be carried out on guarded or unguarded machinery which is in motion.
- Electric lighting of at least of 200 lux at floor level should be available. If not permanently available, emergency lighting needs to be erected.
- Before the conveyor is put back into operation, all persons and tools need to be accounted for. A final test is to be carried out demonstrating the functioning of the emergency stop devices.
- Fire risk to be minimised through high standard of cleanliness and good housekeeping.

5.6 MRAC Draft Regulation Mechanism

The MRAC Guideline (MRAC Circular No 124/99) issued in June 2000 provides a framework of items that can contribute to the improvement of the safe operation of conveyor belt systems. Although the Chief Inspector of Mines has identified belt conveyors in the mining industry as an area that requires regulating, the best mechanism was identified to be a guideline for a mandatory code of practice. A framework for such a code of practice which will require the end users to participate and document a mine specific practice was completed. It presents a list of topics that needs to be included when conveyor safework practices are defined.

Significant risks identified:

- Material belt conveyors:

Starting up of belt conveyors	Lack of emergency stopping devices along long belt conveyors
Belt splicing	Guarding
Lock out	Take-up
Tensioners	Friction and fire
Rollers/Idlers	Cleaning in motion
Excessive spillage	Structural failure
Warning devices (lack of)	Lack of maintenance

- Man-riding belt conveyors:
  Belt safety devices (stop devices, emergency stop devices, safety gates, trip wires, signboard and embarking pictogram)
  Inadequate stopping distance
  Landings
  Overriding
  Persons on belt during breakdowns (fires, power failure, brakes)
  Belt break

6 Issue-based risk assessment

During the investigation, an issue-based risk assessment was done. Mine personnel were invited to take part and possible causes of accidents were identified on material and man-riding conveyors during separate sessions. The assessment sessions were attended by representatives from the following disciplines:

- Design
- Construction and Installation
- Operation
- Mine Safety

Refer to the Acknowledgements page for a list of attendees. Identified hazards were classified into specific risk categories as described in Table 5. Risk can be defined as:.

Risk = Likelihood x Consequence

Where

Likelihood ranges from one event per day (Z) to one event every 100 years (V) and

Consequence ranges from lost time (E) to multiple deaths (A)

Note that Risk Class 1 represents multiple deaths on a daily basis whereas lost time incurred once in 100 years translates into Risk Class 9. This stresses the importance to first focus on the lower risk classes as these will result in more significant safety improvements.

A total of 83 risks were identified; made up of the following risk classes:

Risk Class 4: 7

Risk Class 5: 16

Risk Class 6: 38

Risk Class 7: 11

Risk Class 8: 7

Risk Class 9: 1

Note that three risks of a classification lower than Class 9 were also identified. These are however, not significant.

The most significant causes of accidents i.e. Risk Classes 4 & 5 resulting from this risk assessment are listed in Table 6.

Table 5: Risk classification (1-9) based on likelihood and consequence of an event

Likelihood of event	**Consequence of event**				
	Multiple Deaths (A)	Death (B)	Disablement (C)	Injury (D)	Lost Time (E)
Daily (Z)	1	2	3	4	5
Monthly (Y)	2	3	4	5	6
Annually (X)	3	4	5	6	7
10-yearly (W)	4	5	6	7	8
100-yearly (V)	5	6	7	8	9

Table 6: Most significant conveyor risks identified

Risk Class 4:

Consequence – Likelihood combinations

Multiple deaths 10-yearly or
Single death annually or
Disablement monthly or
Injury daily

Event description

- Person in area caught in machinery [Material/Man-riding]
- People burnt by fire as a result of components overheating [Material/Man-riding]
- Operators breathe harmful particles [Material/Man-riding]
- Maintenance staff caught in machinery [Failure to lock-out] (Material/Man-riding)
- People in area caught in machinery (guards not fitted) [Material/Man-riding]
- People on material belt falling into chute [Material]

Risk Class 5:

Consequence-Likelihood combinations:

Multiple deaths 100-yearly or
Single death 10-yearly or
Disablement annually or
Injury OR
Lost time daily

- Riders on man-riding belt being blinded by airborne particles [Man-riding]
- Hand of person in area caught in machinery [Material/Man-Riding]
- Person injured due to structural collapse (overloading) [Man-riding]
- Person injured when boarding/alighting away from platform [Man-riding]
- People suffocate as a result of burning belt fumes [Material/man-riding]
- People burnt by fire as a result of components overheating [Material]
- Hearing damage [Material/man-riding]
- Failure to alight from belt [Man-riding]
- Rider on belt killed in mudrush [Man-riding]
- Maintenance person irradiated by nucleonic weightometer [Material]
- Death due to overloaded man-riding belt (men+material) [Man-riding]
- Sudden illness of rider leading to him/her being discharged into chute [Man-Riding]
- Maintenance person caught in machinery due to poor access [Material/man-riding]

For details on these identified risks and the risk categories 6-9 refer to Appendix C.

7 Identified Risks vs Available Codes

From the research it has become apparent that although most mines have a code of practice or general information sessions regarding conveyor belts during induction, there is a need for a national standard which will give designers, manufacturers and operators some guidelines regarding safe operation of these machines.

Tables 7 and 8 list the significant hazards identified and summarise the actions to be taken by the designers, training authorities, management and users of material and man-riding belts.

Table 7: Proposed actions to address identified risks: All conveyors

No	Risk Class	Event	Proposed action
7.1	4	Person in area caught in machinery [lack of guarding or guarding not replaced]	1. Care 2. SABS Conveyor Standard: 3. Effective guarding design 4. Safework procedures refer AS 1755 – 2000 & Appendix F 5. Guarding to be replaced after maintenance 6. Training 7. Monitor effective implementation & adjust
7.2	4	Person in area burnt by fire, as a result of components overheating	1. Care 2. Safework Practice: • Manufacturer requirements • Mine maintenance plan • Maintenance procedures • Regular inspection (Appendices F,G & H) • Evacuation plans 3. Training 4. Fire detection systems 5. Fire fighting systems 6. Monitor effective implementation & adjust
	4	Operators breathe harmful particles	1. Care: Use of PPE 2. Mine Code of Practice 3. Training 4. Monitor effective implementation & adjust
7.4	4	Maintenance staff caught in machinery [Failure to lockout]	1. Care 2. SABS Conveyor Standard: 3. Mine Code of Practice. Provision to effective lockout 4. Lockout procedures (Refer paragraph 8) 5. Training in procedures 6. Monitor effective implementation & adjust

No	Risk Class	Event	Proposed action
7.5	4	People on material belt falling into chute	1. Care: Employees to be aware of consequences. 2. Mine Code of Practice. Procedure prohibiting riding on material conveyors. 3. Training. 4. Monitor effective implementation & adjust
7.6	5	Hand of person in area caught in machinery	Refer to 7.1
7.7	5	People suffocate as a result of burning belt fumes	1. Design: SABS Conveyor standard 2. Use SABS 971:1980 flame retardant belting. 3. Mine Code of Practice: 4. Minimise fire hazard 5. Fire detection systems 6. Evacuation procedures 7. Fire fighting system 8. Routine inspection and testing of fire equipment.
7.8	5	Hearing Damage	1. Care: Know hazard and limit exposure 2. SABS Conveyor Standard and SABS 0266 : 1995 to address maximum design noise levels 3. Mine Code of Practice: • Use applicable PPE 4. Training 5. Monitor effective implementation and adjust
7.9	5	Maintenance person irradiated by nucleonic weightometer	1. Care: Be aware of hazard and correct procedures. 2. SABS Conveyor Standard to address 3. Mine Code of Practice: • Maintenance procedures • Weightometer supplier • Use applicable PPE 4. Training 5. Monitor effective implementation and adjust
7.10	5	Maintenance person caught in machinery due to poor access	1. SABS Conveyor Standard to address maintenance access. (Refer to ergonomic standards, AS 1755-2000 and Appendix E) 2. Mine Code of Practice: Maintenance procedures Risk assessment (Refer paragraph 8) 3. Training of maintenance staff 4. Monitor effective implementation and adjust

Table 8: Proposed actions to address identified risks: Man-riding conveyors only

No	Risk Class	Event	Proposed action
8.1	5	Riders on man-riding belt being blinded by airborne particles	1. Care 2. Update SABS 0266 : 1995 3. Mine Code of Practice: Use of PPE 4. Training 5. Monitor effective implementation and adjust
8.2	5	Person injured due to structural collapse (overloading)	1. Care: Know danger of overloading 2. Ensure that SABS 0266 : 1995 adequately addresses structural design 3. Mine Code of Practice: • Procedure on boarding of conveyor • Regular structural inspection 4. Training 5. Monitor effective implementation and adjust
8.3	5	Person injured when boarding alighting away form platform	1. Care: Know danger 2. SABS 0266 : 1995 : • Signage at stations. 3. Mine Code of Practice: • Procedure on boarding/alighting • Training facility 4. Training to instill correct procedure 5. Monitor effective implementation and adjust
8.4	5	Failure to alight from man-riding belt	1. Care: Know risk and consequences 2. SABS 0266 to address design of alighting stations and safety gates (also refer to CAN/CSA-Z98-96) : 3. Mine Code of Practice: • Alighting procedures • Training facility • Emergency procedures (Also refer Appendix J) 4. Training of riders/operators 5. Monitor effective implementation and adjust
8.5	5	Rider on belt killed in mudrush	1. SABS 0266 to require dewatering of material transported/use of transfer belts/design of intermediate loading stations 2. Mine Code of Practice: • Monitoring of dewatering of material • Routine inspection of operation • Emergency procedure 3. Monitor effective implementation and

No	Risk Class	Event	Proposed action
			adjust
8.6	5	Conveyor runs away due to overloading	1. SABS 0266 to address maximum allowable loading 2. Design/installation to be reviewed for compliance 3. Mine Code of Practice: • Boarding/Alighting procedure • Material Loading of belt 4. Stagger end of shifts to reduce peak man loading 5. Training 6. Monitor effective implementation and adjust
8.7	5	Sudden illness of rider resulting in him/her being deposited into chute	1. SABS 0266 to address design of safety gates (Also refer to CAN/CSA-Z98-96) • Possible use of transponder in cap lamps • Trip wire design 2. Mine Code of Practice • Emergency procedures 3. Training of operators 4. Monitor effective implementation and adjust
8.8	5	Riders struck by belt/material when belt/splice fails	1. SABS 0266 to address factors of safety of belts/splices used for man-riding/anti-roll back idlers. (Refer recent UK experience). 2. Design/installation review to ensure compliance. 3. Monitoring effective implementation and adjust 4. Mine Code of Practice • Routine inspection • Load testing • Emergency procedure 5. Monitor effective implementation and adjust
8.9	5	People in vicinity struck by flying material when belt / splice fails	Refer to 8.8

8 Recommended Best Practice

Resulting from the mines visited, operational experience and international standards the following points reflect best practice and can assist users in the mining industry to compile a mine specific code of practice as required by MRAC Circular No 124/99.

Note that a draft code of practice developed by ATD as for Venetia diamond mine has been attached as Appendix K. This can serve as a departure point.

8.1 Applicable to both Material and Man-riding conveyors

8.1.1 Failure to lock-out

This is a common problem and does not apply to conveyors only nor does it apply to South Africa only (refer MASHA Safety focus and accident reports attached in Appendix I). In this instance the word ‘system’ refers to the conveyor being worked on, the feed conveyor and also the receiving conveyor in multiple conveyor systems.

The solution to this potential problem would be to encourage and train personnel to take better care when performing maintenance and to have a procedure for both locking out before and locking in after completion of maintenance. Figure 3 shows a worker performing maintenance to the feed-chute of a conveyor. In this instance the system was locked out and maintenance work could be performed safely.

MASHA of Canada has identified this as the primary cause of conveyor accidents and has recommended the following step-by-step procedure as a simple solution to overcome the hazard of ineffective or no locking out:

- Identify the equipment to be worked on
- Identify the energy source
- Isolate the energy source
- Bleed off the stored energy
- Install a lock and tag with worker identification
- Attempt to start the equipment
- Frequent auditing by supervisors to monitor compliance.

With regards to locking out of long overland conveyors, the importance of discipline and formalised procedures is highlighted by the Canadian specification on passenger ropeways. When maintenance on the remote ropeway supports is done, maintenance personnel in a carrier (basket) travel to the point of work while instructing the operator in the control station. Arriving at the point of work, the system is locked out under instruction of the maintenance crew. When maintenance work is completed, the system is locked-in and they are transported back to the base station. This is similar to shaft inspections in underground mines. If lock-out can be effected safely in both these difficult sets of circumstances, no reason exists why long overland conveyors cannot be locked-out safely. Discipline is the key here.

Figure 3: Man on conveyor belt performing maintenance after locking out

8.1.2 Ineffective guarding or guards not fitted

Guards not fitted or not replaced after maintenance may be the cause of limbs being caught in the conveyor pulleys or idlers. MASHA of Canada has identified this as the second biggest contributor to conveyor accidents due to guards being non-existent, inadequate, improperly positioned or not replaced after repairs (MASHA Safety focus).

To effectively guard moving machinery, MASHA recommends guarding that

- Prevents access to danger zones
- Is light enough to be handled
- Is painted with bright colours to quickly indicate missing guards.

Workers should be trained and encouraged to take greater care. Figure 4 shows an example of effective guarding with the appropriate warning signs. Applicable references are DIN 15220 and AS 1755-2000.

Figure 4: Effective guarding around drive pulley

8.1.3 Fire

Fire was identified as a high-risk event, both on surface and underground installations. Moving burning material on conveyors is as big a hazard. Not only is there the obvious danger of people getting burnt during the fire or while attempting to extinguish it, but also the danger of the inhalation of fumes given off by the burning belting. Again, the solution would be to train personnel to take better care, to ensure that fire detection systems are functioning and maintained and that evacuation plans in case of an emergency are in place. General machine maintenance is also important since overheating equipment may be the initial cause of the fire.

8.1.4 Dust generation

This may be hazardous from the perspective that dust particles may become airborne and be inhaled by workers. This may result in respiratory illnesses. Enforcing the use of protective clothing and breathing apparatus could prevent this. This issue should be included in a general design code for conveyors.

8.1.5 Maintenance accessibility

Equipment requiring maintenance should be allowed adequate access. This will prevent workers having to squeeze past rotating equipment in order to gain access to maintenance zones. General access may also become a problem as is shown in figure 5. Adequate access should be designed into the system to allow freedom of movement around the conveyor.

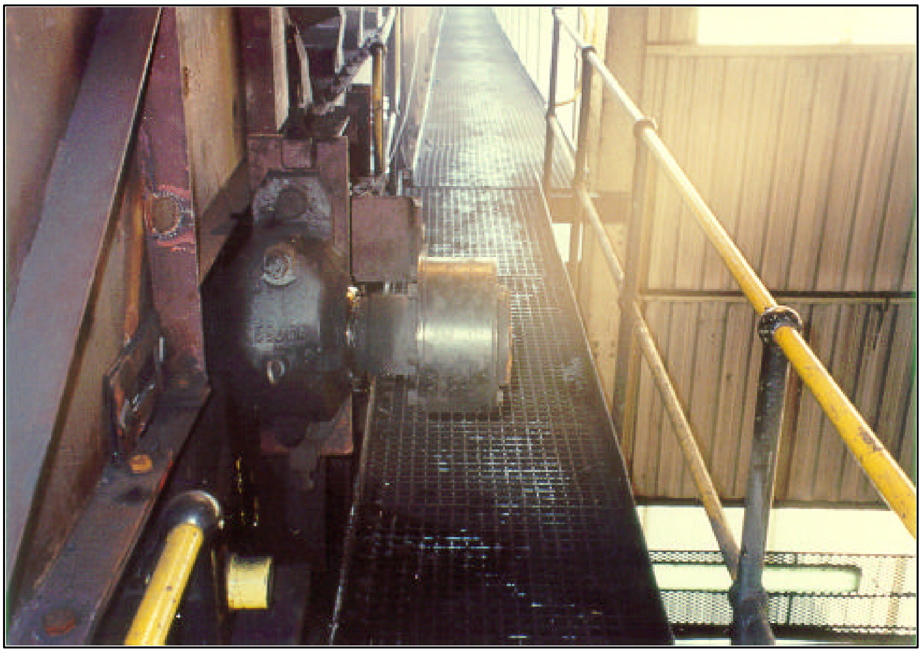

Figure 5: Walkway with restricted access

8.1.6 Noise

Noise is a constant danger around conveyors that may cause permanent hearing impairment. Workers should be encouraged to take care and wear hearing protection, especially around the drive area and loading and discharge points.

8.1.7 Nucleonic weightometers

Radiation during the maintenance of nucleonic weightometers may result in ill health in the long term. Workers should be encouraged to take care and to wear protective clothing. These types of equipment should not be allowed on man-riding conveyors.

8.1.8 Splice failing or belt break

A belt break is most unlikely but a splice failing is a common occurrence. Workers could be struck by material or by the belt, depending on the circumstances under which the system fails. This again highlights the requirement for a conveyor design code and a conveyor belting specification. For incline systems the use of anti-rollback idlers may require further investigation.

Reports from the United Kingdom indicate that splice failures on man-riding belts have been a regular event and have therefore been classified as a significant risk. Investigations have revealed that belt and splice strengths have continuously increased but that the belt to splice joint remains the weak link. Splicing procedures and allowable tensile loads will have to be addressed in SABS 0266.

8.1.9 Structural failure due to belt overload

If the structure should fail as a result of overload, workers may be injured as a result of material or structural members falling on them. Structural design codes are in place but operating codes should be proposed and implemented.

8.1.10 Releasing stored energy on a stalled system

It is important to allow controlled release of stored energy on any stalled conveyor installation. Failing to do so may cause material to be thrown off the belt, causing injury or fatalities. This situation normally occurs on incline systems where a holdback is in operation. Procedures should be in place in accordance with the holdback manufacturer’s specifications to allow for controlled release of stored energy.

8.1.11 Maintenance

Preventative maintenance plans should be in place at every mine. In the modern mines, maintenance is of absolute importance to ensure safety of workers. In line with the safework practices added to AS1755 – 2000, it is recommended to address this in the mine code of practice starting with the supplier maintenance requirements and complement it with a mine maintenance plan (refer Appendix F).

8.1.12 Overriding of safety systems

Overriding of safety systems could be considered to be sabotage. For instance, this would disable devices put in place to ensure safety while doing maintenance and could lead to severe injury or death. However, to be practical the procedures used on passenger ropeways should be considered here. CAN/CSA-298-96 states that any controls that can bypass the control system should be locked at all times. When such a bypass is in operation, the function shall be under close supervision.

8.1.13 Lack of competence during maintenance

Lack of competence is as a result of poor or inadequate training of maintenance personnel. Electrocution for instance may result in death. It is therefore important that personnel are trained to do maintenance properly and that lockout procedures are strictly adhered to. Refer to paragraph 8.1.1. for recommended procedures.

8.2 Applicable to Man-riding conveyors only

8.2.1. Training facility:

Every installation where man-riding belts are installed must have a training facility where visitors and new employees can undergo training by a skilled training officer, before going onto the actual man-riding conveyor. This training facility should preferably be on an incline and must allow for riding both carry and return strand. The training conveyor should also be variable speed, allowing trainees to at first board and alight at a slower speed. Figure 6 shows visitors undergoing training at the training facility before going underground. The more accurately the training facility simulates the actual environment i.e. belt speed, station layout et cetera, the more the benefit to be reaped from it.

Figure 6: Training belt for man-riding

8.2.2 Signage on belts regarding alighting:

A lack of adequate signage could result in a rider passing the last alighting station resulting in injury or worse. Signage should be adequate and clean. SABS 0266 should address this and examples of effective pictograms used at ropeway stations are shown in Appendix L.

8.2.3 Boarding at intermediate boarding platforms:

Workers boarding while others are already on the belt may result in injury to both. From this perspective discipline should be encouraged amongst workers to take care. Training is also important since timing of boarding under such conditions would be critical. Boarding while there is other people on the belt should be discouraged. The key to manage this risk is the awareness of workers of the potential consequences if procedures are not adhered to.

8.2.4 Intermediate loading points:

Control of the system is of importance if injury to workers on the belt is to be avoided. Safeguards should be put in place at the design stage to prevent loading of material onto belts while there may be people riding on the belt. Workers getting struck or riding into chutes may result in injury or death. Again, workers should be educated and trained accordingly and SABS 0266 should address this point.

8.2.5 Riding with material:

The danger involved is that the worker may get injured during boarding or alighting while attempting to ride the conveyor while there is material on the belt. The biggest danger is that workers may stumble over material or may slip on loose material on the belt during alighting. As can be seen from Figure 7, riding with material is accepted practice in the mines, though not recommended by SABS 0266.

The safety risk needs to be evaluated against production requirements. It is believed that due to the four man-riding belts in operation and a fifth being designed, adequate operational experience exists to finalise this requirement.

Figure 7: Man riding with material on conveyor

8.2.6. Sleeping on the belt:

Workers falling asleep on the belt during transportation and failing to alight is a significant danger associated with man-riding conveyors. Workers sleeping on the belt and passing the detection systems may result in the worker being discharged into the chute causing severe injury and probably death. Workers must be educated and trained in the dangers of falling asleep on the belt. Further safeguards such as alarms at alighting stations, rubber strips over the belt and chains should also be installed. A last safeguard should be a passive transponder in the cap lamp that can be detected by a sensor at the station that in turn will stop the belt. The stopping distance of the belt should be such that the worker does not reach the discharge point. It is of interest that this distance on ropeways is a minimum of 150% of the distance required to stop the ropeway at maximum speed. (CAN/CSA-Z98-96).

8.2.7 Splice fails:

The splice failing on a man-riding belt will result in disaster since people will fall in in-between the idlers. Depending on where the people are on the belt at the time and the incline of the belt, they may be whipped back by the belt as the tension in the run-away system decreases. There is no safeguard against this except some splicing procedures and strict belting specifications. In both instances it is recommended that SABS specifications address this issue. Also refer to the recent UK experience discussed in paragraph 8.1.1.8.

8.2.8 Water on the belt:

In a man-riding environment any water on the belt should be avoided. The belt construction is such that the belt will become slippery when wet. Care and training to keep the belt dry should be encouraged amongst the workers. If there is a possibility that the belt may be wet, workers should not be allowed to board since they may slip and fall resulting in severe injury or death.

All of the above were considered to be the most hazardous of events, with the highest frequency, that could occur on conveyor installations. There is the possibility that other types of accidents may also occur, such as a fluid coupling exploding and spraying hot oil and debris around. Those incidents were however considered to be of a lower risk class and do not deserve priority attention.

9 Implementation strategy

The benefit of this investigation will be negligible if the outcome is not implemented operationally. The results of the various activities are therefore summarised as specific strategies with responsible parties identified for the implementation thereof. It must however be emphasized that isolated efforts will not have the same effect as when all role players work towards the common objective of improving conveyor safety.

9.1 Safety culture and Common objective:

Responsibility: Employers, employees, design authorities and suppliers

As mandated by the MHSA, every worker deserves the right to perform his/her duties in a safe environment. Nobody goes to work with the intention to get injured or killed. Accidents do not provide any incentives to individuals or mine management. In fact, the cost of accidents is much higher than the cost of preventative measures.

The current culture of transferring responsibility to other roleplayers and apportioning blame should be replaced by a common objective to improve safety. Comparing SA practices to that of countries such as Canada, it is clear that the local culture is to expect employers to provide a ‘safety net’ that makes provision for even the worst malpractice. This should be replaced by a ‘thinking’ culture where workers understand the inherent risks associated with conveyor systems and the potential consequences when deviating from best practice. Any employee including mine management, should therefore continuously assess the impact of his/her actions on his/her own safety and that of colleagues. Safety consciousness should not be on paper but in the hearts and minds of people.

9.2 Standards

It has been demonstrated that standards and codes used in the design and operation of conveyor belt systems focus heavily on design aspects. The commissioning, use and maintenance have been severely neglected. This correlates with conveyor practice used internationally till approximately 1995. Since then, standards such as the Australian AS1755 – 2000 has been updated to address the shortcomings. Regarding SA conveyor standards, the following is recommended:

9.2.1 New SABS Standard on Conveyors

Responsibility: Employers, design authorities and suppliers

The need for a comprehensive SABS standard on conveyors, as initiated by MRAC, is supported. This should address not only the design and manufacturing but also the safe use of conveyor systems. Inclusion of the latter in a national code will assist the mines in compiling their individual codes of practice. To be addressed as a minimum:

Design	Belt types (incl flame retardant belting)
Belt splicing	Examination and inspection of belting

Fire patrolling/prevention	Lockout
Access	Man-machine interface (refer Appendix E)
Noise levels	PVC Idlers
Runback idlers	Runback devices
Excessive spillage and belt structures	Guarding
Corrosion	

Safework Practices (refer Appendix F for details):

- Information to be supplied and maintained, covering
  - Synopsis of plant
  - Installation, commissioning and dismantling
  - Operating and maintenance instructions
- Safework procedures
  - Access or work in a danger zone
  - Work using remote isolating device
  - Isolation systems
  - Installation, commissioning and dismantling procedures
  - Operating procedures
  - Inspection (Refer to Appendix I)
  - Maintenance procedures
  - Maintenance management
- Training

The recently revised AS1755 – 2000 is recommended to serve as a guideline. Standards CAN/CSA –Z98 – 96 and BS5656: 1997 can be used as references in defining safework practices.

9.2.2 SABS 0266:1995 – Man-riding

Responsibility: Employers, design authorities and suppliers

As recommended by MRAC and employers using this Code, a revision will improve the safety of man-riding conveyors during the life cycle. The title of the 1995 Code rightly states that it should address the safe use of man-riding conveyors. However, to date it has strongly focused on design and neglected safe use.

In addition to the generic topics addressed in paragraph 9.2.1, the following needs to be addressed:

Use of PPE (airborne particles)	Structural design
Measures to prevent mudrushes	Overloading
Landings	Guarding
Stopping distances	Pulleys
Belt splicing	Idlers
Design criteria	Belting
Factors of safety	Splicing method
Inspection criteria	Prevention of runback

As the safety of man-riding is not only dependent on technical design but strongly influenced by the actions of the operator, riders and maintenance personnel, examples of best practice from the ropeway industry should be considered. These are:

Lockout procedures	Safety gates
Boarding and alighting pictograms	Training

Operational requirements	Operating manual
Operating personnel	Operational Procedures and Rules
Hazardous conditions	Communication
Operating of stations	Starting and stopping
Operational inspection (Appendix G)	Evacuation
Operational log	Maintenance safety procedures
Acceptance testing	Periodic load testing (Appendix G)
Testing of ‘belt’ and splicing	First aid
Fire protection	

Details can be obtained from CAN/CSA – Z98 –96 and the abstracts attached as appendices.

9.3 Training

Responsibility: Employers, employees and safety representatives

A competent person as defined in the MHSA means a person who:

- Is qualified by virtue of his knowledge, training, skills and experience to organize work and its performance.
- Is familiar with the provisions of the Act and the regulations which apply to the work to be performed; and
- Has been trained to recognize any potential or actual danger to health or safety in the performance of the work; or
- Is in the possession of the appropriate certificate of competency where such certificate is required by regulations.

Training methods should be expanded to train workers to recognise potential hazards and to implement corrective procedures. The effectiveness of training needs to be monitored to ensure that the:

- identified hazards are adequately addressed
- workers understand the training and
- methods are implemented in practice.

To demonstrate acceptance of the shared responsibility, employees and safety representatives should continuously monitor the effectiveness of training and propose improvements where necessary.

9.4 Participation

Responsibility: Employers, employees and DME

Safety improvement relies on the combined contribution of the employer, employee and the DME. It must be a concerted effort towards a common goal. Each roleplayer must realise the consequences of his/her actions on the safety of others. As employees are actively involved in the day-to-day running of conveyor systems, they represent a pool of experience not available from another source. Workers should actively participate in defining operational procedures and hazards. This should be a continuous process and will bear fruit once the workforce sees the benefit of their contribution.

9.5 Mine Specific Code of Practice

Responsibility: Employers, employees and safety representatives

As per MRAC requirement each mine is required to compile a mandatory code of practice relevant to conveyor systems. The format provided in MRAC Circular 124/99 is recommended. Note that apart from the code structure and minimum requirements, the DME is not prescriptive and relies on conveyor users to define their own best practice. The safe use of conveyor systems need to be expanded as per the reference international standards: AS 1755 – 2000, CAN/CSA – Z98 – 96 and BS5656 where applicable. The new and/or revised SABS standards referred to in paragraphs 9.2.1 and 9.2.2 should provide the basis to work from.

9.6 Accident reporting

Responsibility: Employers, DME & safety representatives

The scope of details contained in DME accident reports should be expanded to make it possible to learn from past experience of other mines. The accident reports should include as a minimum:

- Detail description of the accident
- Analysis of events/practices
- Identification of active as well as latent failures
- Preventative measures to be implemented.

Refer to the example attached in Appendix I.

9.7 Conveyor user groups

Responsibility: Employers & safety representatives.

All users should not have to experience the same failure before it is being addressed. Learning from others' experience is a quicker way to achieve the objective of reduced accidents. User groups such as mining houses, resident engineer associations et cetera should be used as an effective means to share experience. However, as can be seen from the US Dept of Labor Fatalgram and Canadian Hazard Alert (Appendix I), the benefit results not only from a clear description of the accident but also the identification of best practice to prevent a recurrence.

9.8 Monitoring and Inspection

Responsibility: Employers, employees and DME

To assist mines in doing effective inspection on conveyor systems a copy of the Canadian MASHA conveyor safety checklist has been attached as Appendix H. As stated initially, safety must be in the hearts and minds of employees. The best way to test this is to monitor the operational implementation of the mine procedures. If not effective, the procedures and/or training needs to be revised.

To complement the action of the employer, Canadian experience has highlighted the importance of DME inspectors focussing their attention on the main causes of conveyor accidents i.e. guarding, lockout procedures, poor adherence to mine procedures in the medium term. This has proven to be the most effective.

10 Conclusion

SIMRAC initiated project GEN701 to quantify the extent of conveyor related accidents experienced in the SA mining industry, identify the main causes of accidents and define the actions to be taken to reduce the identified risks. In summary, the following findings result:

10.1 As per the OTH202 definition of active and latent failures, the main causes of conveyor accidents in the SA mining industry are:

Active failures:

- No or inadequate guarding
- No or ineffective lockout procedures
- People cleaning or working on moving machinery

Latent failures:

- Abdication with regards to accountability for safety (Employers ↔ employees)
- Limited or ineffective training
- Poorly defined or communicated procedures.

10.2 The conveyor related fatality rate for SA mines decreased from 0,03 fatalities per 1000 employees in 1988 to 0,01 during the period 1992-1995. What is of concern is that the rate worsened again during the period 1996-1999 to reach the original value of 0,03. This must be seen against the overall fatality rate for the SA mining industry, which improved from 1 fatality per 1000 employees in 1988 to 0,76 in 1999. This highlights conveyor systems as a key potential area for improvement

10.3 A comparison with available international statistics has indicated that the lowest SA conveyor fatality rate of 0,01 fatalities per 1000 employees achieved during the period 1992-1995 is comparable with the conveyor fatality rate of the US mining industry for the period 1998-1999. Due to the limited data available, this comparison should serve as an indication only. What is of further significance is the fact that causes of conveyor accidents reported internationally closely correlate with the causes listed above.

10.4 Regarding standards and specifications, it is clear that, to date, the South African conveyor and mining industry has focused heavily on design and manufacturing. Very little has been done to address the man-machine interface and safework practices. However, it must also be stated that these aspects have only been included in international standards during the last five years.

10.5 To address the identified hazards associated with conveyor systems, an implementation strategy covering the following nine points has been defined:

- Safety culture and common objective
- New SABS standard on conveyors
- Revision of SABS 0266 on man-riding conveyors
- Training
- Participation
- Mine specific conveyor code of practice (MRAC)
- Accident reporting
- Conveyor user groups
- Monitoring and inspection

The responsible stakeholders have also been identified per action point.

To effectively improve the safety of conveyor systems, a total conveyor life cycle approach is required where each individual not only realises the inherent hazards but also sees the specific contribution that he/she can make.

11 References

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BS EN 1554:1999 Conveyor belts – Drum friction testing

BS 2890: 1989: Troughed belt conveyors

BS 5656:1997: Safety Rules for the construction and installation of escalators and passenger conveyors

BS 7801:1995 Code of Practice for Safe working on escalators and passenger conveyors in use

BS EN 20340:1993 Conveyor belts – Flame retardation – Specifications and test method

Canadian:

CAN/CSA-Z98-96: Passenger Ropeways – Public Safety

German:

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DIN 22101: Belt conveyors for bulk materials – bases for calculation and design

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ISO/DIS 5285: Conveyor belts – Guidelines to storage and handling

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