

Compendium of Research Project Summaries on Machinery and Transport Systems - 1994 to 2014

MHSC
Mine Health and Safety Council

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CEO's FOREWORD

The Mine Health and Safety Council (MHSC) is a public entity that is mandated, in terms of the Mine Health and Safety Act (MHSA), to advise the Minister of Mineral Resources on research programmes, regulations, standards, policies and procedures focused on minimising the occupational health and safety (OHS) risk at mines. The Council is also tasked with promoting a culture of health and safety in the mining industry.

The MHSC office executes the operational deliverables of the Council, including the provision of secretarial support to the Council and all its committees, managing OHS research programmes, finances, communications and promotions, and liaising with other statutory bodies on matters relating to occupational health and safety at mines. Council provides a platform for stakeholder engagements on OHS matters.

The Commission of Inquiry into Safety and Health in the Mining Industry chaired by the Honourable Mr. Justice RN Leon identified haulage and transport accidents as the second largest category of accidents in mines.

In an initiative to address this challenge, a tripartite sub-committee was established under the auspices of the Mining Regulation Advisory Committee (MRAC). The task group prepared a report which recommended, amongst other items, that a guideline for a mandatory COP for trackless mobile machines be drafted. As a consequence the guideline was issued on 30 November 2000 and came into force on 31 May 2001.

In 2011, the Mine Health and Safety Council (MHSC) noted that accidents involving trackless mobile machines were still at an unacceptably high level. The MHSC requested MRAC to review the legislation with the view of incorporating minimum performance standards. MRAC recommended that, in addition to revising the Trackless Mobile Machinery (TMM) guideline, regulations dealing specifically with trackless mobile machines should also be developed and published. This recommendation was agreed to by the MHSC.

In conclusion, the MHSC office, through the Machinery and Transport thrust area, is doubling its efforts in eliminating and mitigating risks associated with the use of transport systems and machinery.

This publication provides a synopsis of research reports that the MHSC has done to assist the South African Mining Industry to reduce incidents as a result of Transport and Machinery systems such as conveyors, rail bound mobile equipment, trackless mobile equipment, scraper winches, winders, shafts etc. The MHSC is currently developing a collision avoidance system for use by the SAMI to reduce collision between vehicles, persons and machinery.

Thabo Dube
Chief Executive Officer
Mine Health and Safety Council

Dec 2017



1. Develop remote control systems for mining equipment

By Kononov V.A., CSIR Mining Technology, Ref: GEN 109, 1994

SUMMARY:

Telecontrol can be a significant factor in increasing safety and productivity in the mining environment. Various methods of remote control are possible with telecontrol, beginning with simple stand-off control via umbilical connections to remote and automatic control. Suitable communication channels can be physical line systems via electrical cables, machine trailing power cables and fibre optic cables, or wireless systems based on radio or infrared signals. Many systems are in operation worldwide in applications such as longwalling, continuous miners and roadheaders, load-haul-dump machines and drill rigs. Commercial Products which use this technology are available from several companies across the globe.

However, in the South African context, only limited trials have taken place and a strategy is proposed based on this study, to approach the problem, taking into consideration the local needs and conditions and the human factor when introducing new technologies to the SA mining context.

2. The safe use of winding ropes

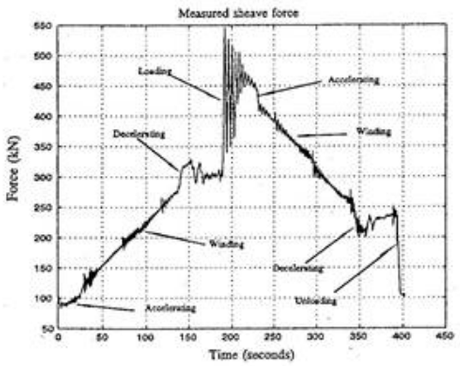
By Hecker G.F.K., CSIR Mining Technology, Ref: GAP 054, 1996

SUMMARY:

A total of 29 reports and a summary report were generated covering the subjects of

- Recommendations for changes in rope safety factors
- Rope terminations
- Code of practice for rope condition assessment
- Training manuals for incumbent rope inspectors

- Code of practice for performance, operation, testing and maintenance of drum winders
- Forces acting in shaft sinking winder ropes



Typical sheave forces measured during a winding cycle

CONCLUSION:

Based on the reports, it is possible to sink shafts with stage and kibbles winders in the conventional way to depths of 4 000 m, provided that appropriate rope regulations for such operations are drafted. Such regulations would probably need to include references to codes of practices for sinking winders and special considerations for rope condition assessment.

3. Investigation of the causes of transport and tramming accidents on mines other than coal, gold and platinum

By Simpson G.C., Rushworth A.M., von F.H., International Mining Consultants Limited, Ref: OTH 202, 1996

SUMMARY:

Transport and tramming accidents are some of the largest sources of occupational safety risks, especially on mines other than gold, platinum or coal. Due to the wide variety in the type of mines in the other mining sectors, this project studied a range of transport and tramming operations on four mines, including an underground diamond mine, an underground chrome mine, a surface copper mine and a surface iron mine. The range of operations considered is identified in Table 1, with some of the operations being covered on more than one of the mines.

In order to clearly to identify the causes of transport and tramming accidents, each operation was audited to highlight potential active failures (PAFs) which are likely to represent the immediate causes of accidents. A strong emphasis was placed on the identification of potential for human error, either slips or lapses, mistakes or violations as is appropriate for systems where the dominant causes of accidents tend not to be technical failures. Table 1 identifies the number of PAFs identified during the operation audits for each of the operations studied. For each PAF identified, a preferred route to solution was proposed. Examination of the PAFs also led to the determination of latent failures, which are essentially factors or circumstances within a mine which are likely to lead to active failures. While the details of the PAFs identified and the recommendations on how they could be addressed tend to be relatively site specific the latent failures are more generically relevant across the sector.

Eight areas of latent failure have been identified, being attitudes to safety, training, organization and working methods, rules and procedures, attitude to rules and procedures, design, organizing for safety and maintenance. It became clear that most of the PAFs are influenced by more than one of the areas of latent failure listed above. Each of the latent failure types influences comparable numbers of PAFs with the exception of maintenance, which is of subordinate importance.

Operation	No PAFs
Underground	
Trackbound transfer of ore to tips	31
Trackbound transfer of supplies	11
LHD based transfer of ore to tips	21
General movement of men and supplies	32
Surface	
Loading with shovels, dozers, shovels, haultrucks	22
Haultruck transfer of ore to tips	44
Transport operations involving service vehicles	40
Transfer of ore and supplies to main railway line	8

Table 1: Number of potential active failures per operation studied

Based on the PAFs and the latent failures identified, recommendations for improvements have been categorized under four major headings:

1. **Equipment design:** ergonomics of mobile equipment is identified as a major issue, with many items of the equipment being used considered to have significant built-in accident potential. Recommendations are to impose ergonomics requirements on equipment suppliers and development of industry wide approaches for retrofitting equipment with unsatisfactory ergonomics.

2. **On training:** several needs are identified including a greater emphasis on hazard awareness and risk perception, a more systematic approach to safety training needs analysis, training of supervisory staff and safety representatives, the development of more innovative training methods, systematic evaluation of safety training effectiveness and management safety training. Specific recommendations are that the outcomes of risk assessments should include a training needs analysis and innovations such as industrial theatre to overcome difficulties of language and literacy.

3. **Codes, rules and procedures:** These are inappropriately written such that they are impractical, incomplete, too complex, irrelevant, contradictory and too numerous. It is recommended that the rule sets on mines should be systematically re-examined by a participative team involving managers, supervisors and workers, and driven by the outcome of risk assessment. Training should also incorporate current information on the applicable rule sets.

4. **Safety management:** a need for greater pro-active safety management is identified, with recommendations that managers and supervisors' performance should include safety as a formally measured parameter. In addition, mechanisms are required to enable organizational learning to take place systematically and effectively, with an associated change in emphasis in accident investigation to identification of the fundamental reasons why the accident happened.

CONCLUSION:

Over 200 potential active failures (PAFs) were identified for a range of transport and tramming operations The PAFs include the potential slips and lapses, mistakes and violations and may be attributed to eight areas of latent failure being safety attitudes, training, organization and work methods, rules and procedures, attitudes to rules and procedures, equipment design, organizing for safety and maintenance. Most significant improvements to the safety of transport and tramming operations could be achieved by attention in four areas being equipment design (ergonomics), modified approaches to training, re-examination of codes, rules and instructions to remove complexity and contradictions and new approaches to the safety management system.

4. Deterioration and discard of mine winder ropes

By Hecker G.F.K., CSIR Mining Technology,
Ref: GAP 324, 1997

SUMMARY:

The report assesses the following influences regarding safe working lives of winder ropes and specific scenarios for safe operating conditions:

- The influence of winder design parameters on the safe working life of ropes, using statistical analyses of ropes lives from different winders
- Establishing requirements for a code of practice for shaft sinking winders for shafts up to 4000 m depth by measuring and analysing dynamic forces on stage and kibble winders in operation
- The stability of triangular strand ropes for very deep shafts
- Establishing discard criteria in the code of practice for rope condition assessment by conducting measurements of rope deterioration and dynamic forces on selected winders, including a comparison of actual rope strengths of discarded ropes with inspector reports.

CONCLUSION:

Some useful trends were identified using the statistical model to assess rope life as a function of winder parameters. The results indicate benefits of using low static factors of safety. As the model was based on poor input data, the results must be interpreted with caution. Only when ropes are discarded according to consistent discard criteria can valid conclusions be reached from such analyses.

Regarding requirements for sinking winders for 4 000 m deep shafts, the following was determined:

- a static rope load factor of 3 is recommended due to the low dynamic forces
- a capacity factor of 8 is recommended once the static factor is reduced to below 4,5
- a code of practice should apply only once the rope load factor is less than 4,5
- rope forces after brake control failure would not exceed 60 per cent of the rope breaking strength for the worst scenario
- slack rope can occur at the front end of the rope after brake control failure (this applies to all winders currently in operation and can only be prevented by changing braking specifications).

Regarding the refinement of discard criteria the following was concluded:

- for triangular strand ropes the criteria are generally appropriate, but the criterion of allowable rope diameter changes needs more work
- it was noted with concern that for several discarded ropes total discard factors well above 2 were determined with strength losses up to 30 per cent
- an insufficient number of non-spin ropes were available to draw conclusions
- tests on ropes with cut internal wires suggest that a rope should be discarded when the area of broken wires exceeds 7 per cent of the rope area. It should be noted that the present code of practice only refers to visible wires and this should be revised.

Observed behaviour of triangular stand ropes suggests that they may well be suitable for deep shafts.

5. Investigation into drawpoints, tips, orepasses and chutes

By Stacey T.R. Swart A.H., Steffen, Robertson and Kirsten, Ref: OTH 303, 1997

SUMMARY:

This project's objective was to provide a knowledge base regarding safety issues associated with ore handling in the mining sectors other than gold, platinum and coal. The methodology involved a review of literature on the safety problems associated with drawpoints, tips, orepasses and chutes, study of reportable accidents and visits to mines to acquire a range of information concerning the types of ore handling arrangements and mine personnels' perceptions of the hazards.

There is scant literature dealing with drawpoints, tips and chutes although there is a satisfactory amount relating to orepasses. The information in the literature on the latter relates mainly to design aspects and the identification of problem areas, in particular hang-ups, blockages, collapses, scaling, wear and run-aways.

Records of reportable accidents as maintained on SAMRASS (South African Mines Reportable Accidents Statistics System) revealed that, over a seven and a half year period from January 1988 to June 1995, 651 reportable accidents took place

at the locations of drawpoints, tips, orepasses and chutes. Approximately53 of these accidents resulted in fatalities. It was decided to include accidents on platinum mines since these mines have ore handling systems of similar natures to mines extracting commodities in the “other” mining sector. However, in performing the analysis, accidents were excluded if it was considered that they could not be attributed to the location. A total of 48 accidents were relevant to drawpoints, 288 to tips including both centre gully and shaft tips, 143 to orepasses including boxholes and 50 to chutes.

Fall of ground and falling material or rolling rock are types of accident frequently experienced at all of the location types, with slipping and falling being substantial for tips and orepasses, and vehicle accidents and scraper winches being sizeable categories for tips. The major causes of accidentsidentifiedinSAMRASSare inadequate examination, inspection or test and failure to comply with standards or instructions, with lack of caution or alertness being subsidiary importance. However, the underlying reasons for non-compliance, which is identified as the key issue for improving safety, cannot be obtained from the available data. It is interpreted that the prevalence of these causes is indicative of limitations in the effectiveness of training.

Eleven mines, being a representative cross section of the “other” mining sector, were visited to obtain information on the type of ore and waste handled, the mining method and ore and waste handling arrangements used, the orebody geometry and perceptions of the safety problems experienced and the accident types actually experienced in each environment. Eight of the 11 mines were trackless operations and 10 of the 11 could be considered to be massive orebody operations.

The major problems associated with operation of the various elements of the rock handling system were identified as blockages and hang-ups, especially in orepasses, as is also indicated in the literature review.

These problems are normally cleared either by pinch bar, impact breaker or blasting.

However, none of the reportable accidents recorded on SAMRASS could be directly related to these problems.

Based on the information obtained, the importance of several areas of latent failure were considered encompassing environmental issues, design, procedures, worker involvement in procedures, induction and training, attitudes towards procedures and safety and the relationship between procedures and accidents. While environmental issues were not considered to be significant contributors to safety problems, significant deficiencies were identified in the other areas. The issues were of the rock handling system. These were system design, procedures, training and management.

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Adoption of a more robust design process is proposed incorporating formal internal and external reviews at various stages of the design process. Establishment of a detailed functional specification, covering issues such as the characteristics of the material to be handled and the planned operating and maintenance methods, in advance of the design work itself is also identified as an important element of the design process.

On the issue of procedures, the research has shown that existing procedures on mines tend not to be logically prepared and appear to be reactive. In addition, it was identified that there was only limited worker involvement in preparation of procedures. A proactive basis for preparation of procedures in a standard logical format with emphasis on visual format and minimizing the written content is recommended.

Under the heading of training, most of the training provided was identified to be on-the-job training, with general induction and refresher induction

training also being given. In certain cases, training was provided in specific job functions. This approach is subject to problems as it has no defined syllabus, assumes that supervisors and colleagues are well trained and capable of passing on the required knowledge, relies on the willingness of colleagues to pass on knowledge to new workers and does not provide feedback on training effectiveness. A need for more formal training is therefore identified, encompassing hazard recognition, understanding of procedures and understanding of why compliance with procedures is necessary. The effectiveness of training should also be monitored to ensure that the trainees have acquired the necessary information and understanding.

Under the heading of management, while a strong and genuine commitment to safety from management was observed in spirit, it was identified that this was not carried through into operational practice. For example, it was identified that a relatively low status tended to be assigned to safety departments, there was a lack of processes for maintaining and reviewing procedures and procedures tended to be disregarded by management. Establishment of safety as a high profile corporate portfolio, with management setting an example by complying absolutely with procedures, is considered to be a route to improvement.

It is concluded from the nature of the needs identified that generalized research is not warranted, with specific research into the development of improved approaches to training being the preferred approach.

CONCLUSION:

The major types of accident associated with the rock handling system are fall of ground, rolling rock and material and slipping and falling. The major causes of accidents are failure to comply with standards or instructions and lack of caution or alertness. The main issues leading to accidents in the drawpoints, tips, orepasses and chutes environment are design, procedures, training and management.

It is recommended that the most critical area for change is in the content and approach to training of mineworkers

6. Evaluation and further development of a quiet non-atmospheric polluting blast hole drilling system

By Scanlon T. and Harper G.S., CSIR, Ref: GEN 311, 1998

SUMMARY:

The primary objective of this project is the further development and evaluation of the quiet blast-hole drilling system initially developed under-project GEN 207. The main focus of this work is the resolution of the limitations and deficiencies identified in the prior work.

In the previous work, it was demonstrated that effective noise reduction methods existed for each of the major noise sources within a pneumatic rock drill and that these could be combined to provide a quiet blast hole drilling system provided that the thrust system produced the required thrust along the axis of drilling (ie >in-line= thrust).

As established in the previous work, this was achieved by effectively converting the rock drill to a piston within a sealed cylinder and providing the necessary thrust pneumatically. This arrangement achieved operational noise levels of 87.5 dB during over travel and 92 dB during drilling. Unfortunately, the use of pneumatic thrust introduced several problems relating to the control and maintenance of the required thrust.

These problems generally arose from difficulties in maintaining an acceptable level of sealing in the complex sealing arrangement. The results of the work were sufficient to warrant further development of the system and consequently this project was established. The primary focus of the work was to establish a thrust system which avoided the problems identified in previous work yet retained an >in-line=thrust arrangement, thereby providing the features necessary for the application of the previously established noise reduction methods.

The thrust method developed was that of a reciprocating mechanism based on a standard beam crawler. Four prototypes were developed and manufactured and tested in surface drilling into Norite. The machines retained the noise reduction levels of the previous prototypes and provided drilling performance more than equal to a standard drill and leg arrangement. However, the thrust mechanisms proved to be limited in available thrust and endurance with several failures of small plastic elements within the pneumatic circuit at lives as low as 40 metres of drilling.

The problems identified during surface drilling are readily amenable to resolution with existing technology and expertise and could be effectively introduced during commercialisation of the product. It is concluded that the concept as presented can provide for a quiet blast hole drilling system..

CONCLUSION:
In conclusion, while the project achieved its objective in proving that the concept of a quiet rock drill is possible, further work is required to take the concept to full commercialisation.

7. Risk analysis and assessment of vertical and incline small winder systems and peripheral activities

By Moss P.S., Talbot C.F., PJ Foster, IMC Knight Piésold Mining (Pty) Ltd, Ref: GAP 636, 2000

SUMMARY:
Small winders (those having a driving motor of not more than 250 kW) are used in many applications in the mining industry, conveying men, rock and material in vertical and incline shafts. They are often installed in distant areas of mines and work under hot and humid conditions. There is concern within the mining industry regarding the safety record of these installations, more especially those unlicenced units used for material hoisting in incline shafts.

This project used a participative risk assessment approach with an engineer and a risk assessment/ behavioural safety specialist together with involved mine personnel to identify hazards, assess risks and suggest possible solutions. The work covered all activities connected with shaft operations, including operation and maintenance of the winder, the shaft itself and the stations. Units assessed included both surface and underground installations on large and small mines, and covered 3 material winders in incline shafts

- licensed kibble and stage winder
- licensed man/material winder in incline shaft
- rock winder in incline shaft
- man, rock and material winder in vertical shaft

The opportunity was also taken to observe shaft activities and apply behavioural safety techniques in order to identify potential human failures that contribute to mine accidents.

Manufacturers of winding equipment were also consulted as to their views on the likely causes of accidents, and this perspective, together with the results of the risk assessments, were presented to and discussed with officials from mines and the Inspectorate. This provided useful input to the report.

Principle Findings:
It is apparent that a significant variation exists in the design, maintenance and operational standards applied to small winders across mines. Those small winders licensed for man winding tended to be well operated and maintained; however the same cannot be said for many small unlicensed material winders.

The significant generic hazards related to the operation and maintenance of small winder installations and peripheral activities are:

- struck by runaway conveyances;
- struck by unexpected or uncontrolled movement of conveyances;
- derailments;
- contact with moving machinery; and
- slipping and falling from heights.

The risk assessments carried out on the mines identified a considerable range of limitations in control effectiveness and reliability. Areas of shortcoming included:

- development and use of operating procedures;
- maintenance, inspection and testing of winder components;
- installation and use of lock bell systems; and
- design of shaft station layouts.



A small winder installation typical of those assessed during the course of the project. Note the modern brake and control system; many of the older units are now being upgraded in this manner. Typical safety features shown include the dial type depth indicator and fail-safe braking. A well-lit and clean environment contributes to the elimination of hazards during operation and maintenance.

CONCLUSION:

Risk assessment has the potential to identify all the significant hazards and control limitations associated with small winder systems, and its application results in significant reduction of the associated risks.

The following recommendations should be considered:

- the Regulations regarding small winding plants should be reviewed urgently;
- a Safety Standard for the design, installation, operation, maintenance, inspection and testing of small winder systems and their peripheral activities should be drawn up. This should also provide technical guidance for users and act as a guide to current best practice;
- in addition to producing generic Codes of Practice for small winder systems, mines should also prepare detailed risk assessments as a matter of priority. A checklist has been produced to assist with this;
- risk assessments should be used as a an integral part of the training process to assist in the definition of training needs and to ensure that employees are informed of the risks andthey face;
- the relevant sections of SABS 0293 should be used as a basis for certification of persons responsible for undertaking rope examinations.

8. The identification, investigation and analysis of end-of-wind devices for vertical and incline shafts

By Ottermann R.W., von Wielligh A.J.,Burger N.D.L., de Wet P.R., Blom T.F., Dr Visser-Uys P., LGI, University of Pretoria, Ref: GAP 638c, 2000

SUMMARY:

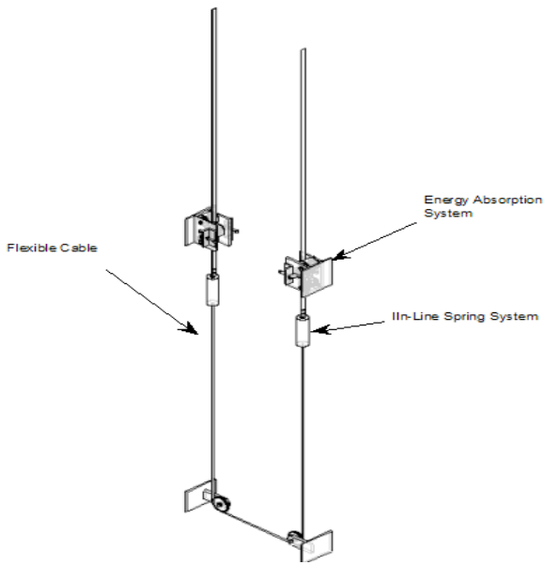
The occurrence and cause of overwind and underwind events in underground mining were investigated in conjunction with devices, which are at present being applied to prevent and control such incidents.

Proposals for in-shaft systems to protect personnel from excessive deceleration forces and subsequent injury or death in the event of underwind/overwind are discussed. The conclusion of the technology study is that a mechanical safety device is necessary to support current systems.

Different concepts were generated for both the overwind and underwind protection systems. These concepts were evaluated against system requirements and specifications drawn up with the aid of a functional analysis study. The preferred concepts were then designed and built for testing in the 1:10 scale shaft model at the University of Pretoria. Both the overwind and underwind protection systems that have been developed were successfully demonstrated on an experimental scale. The relevant SIMRAC Technical Committee has accepted the following systems:

Overwind protection system:
The system makes use of an alternative detaching mechanism. The existing detaching mechanism ("humble hook") is activated by a new mechanism at the beginning of sets of "Jack catches" placed in a specific area below the spectacle plate. When the conveyance enters this area of "Jack catches" the detaching mechanism detaches the cable from the conveyance. The conveyance is then decelerated under gravity and when it stops, it is caught by the "Jack catches" to prevent it from falling.

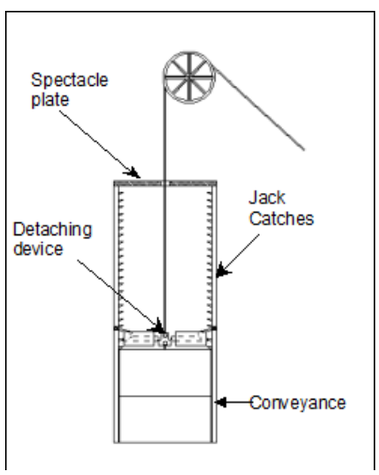




Layout of the overwind protection system with alternative detaching mechanism at bottom of the jack catch area.

Underwind protection system:

The system makes use of energy absorption strips being pulled through rollers. These strips are connected by means of cables to both sides of the conveyance. Four systems are used per conveyance. Between the cable and the energy absorption mechanism a compression spring that fails to safety is placed inline with the cable to absorb the initial impact force while the absorption strip is being accelerated.



Layout of underwind protection system: Energy absorption strip with in-line compression spring

CONCLUSION:

Overwind and underwind incidents are of concern and end-of-wind protection devices should be installed to prevent injuries or loss of live to people travelling in conveyances. Both the overwind and the underwind protection systems can be installed in vertical as well as incline shafts. The protection systems can be retrofitted in most existing shafts.

Full-scale tests need to be done for both the overwind and underwind protection systems to prove and demonstrate the integrity of the systems.

9. Performance requirements for locomotive braking systems

By Vermaak P., Page T.P.T., du Plessis A.G., Kempson W.J., Smythe C.P.F., Turgis Technology (Pty) Ltd, Ref: SIMGAP 635, 2000

SUMMARY:

Accidents involving rail-bound equipment account for the greatest number of underground accidents away from the face. Although brake related accidents were in the minority, it is obvious that any equipment weighing over 60 tonnes must be capable of being stopped within a safe distance if serious incidents are to be avoided.

The focus of the project was to determine the degree to which current practice in underground mines ensures the safe use of rail bound haulage equipment. The project investigated the specifications, design and braking performance of underground locomotives, excluding those used on high speed main haulages. In addition, a survey was carried out on the most widely used types of locomotives and the braking systems. The survey provided an insight into the knowledge of the mine personnel of the rail bound systems on their mines. For a comparison with local practice, international standards, systems and legislation were acquired.

The project indicated that the matter of mine locomotive braking requires attention. Some of the issues that were identified were:

- An almost complete lack of local specifications;
- A lack of knowledge on the part of mine personnel of the rail bound equipment on their mines or in their care;
- The nominal mass of the locomotives in use being substantially different to the actual mass. This issue affects the ability of the locomotive to stop the train;
- Braking systems which can be rendered ineffective by the failure of a component in the transmission system,
- A complete absence of regular brake performance testing;
- Failure to regulate the hauled mass of trains or the ratio of un-braked hauled mass to mass of the locomotive which will affect the braking performance of the train;
- The absence of legislation, Codes of Practice or Procedures to address the un-braked hauled mass;
- Unacceptable delays in applying certain types of emergency brakes;
- The lack of training in, and the inability of locomotive drivers to, control skids;
- The difficulty in testing emergency brake systems due to the inherent braking action of the service brakes and/or locomotive controllers;
- Potential problems limitations to braking effort associated with the prime movers and/or hydraulic systems on hydrostatically driven locomotives;
- Failure to apply written instructions or equip the track with speed restriction signs where the visibility is below the stopping distance of the train.
- Failure to comply with the Minerals Act requirements for the employer to provide assurance on locomotive brake performance. Refer to Section 9.1.

Positive aspects identified during the project are:
- The attention being paid to legislation concerning rail bound equipment by MRAC;
- The compilation of SABS Codes of Practice for underground track and locomotive controllers; and
- The performance of the test equipment designed by LGI for the project.

The project left little doubt that more attention needs to be paid to locomotive braking. This includes:
- Compiling specifications for underground locomotives;
- Attention to design details and quality control by manufacturers;
- Technical and awareness training of train operation and maintenance teams, as well as production personnel involved with train operations, where applicable; and the compilation of mine Codes of Practice and Procedures.

Of all the equipment used to mine and transport ore, track bound haulage systems are most commonly overlooked provided that the production is not affected. In order to reduce incidents involving this equipment or to prevent potentially disastrous accidents, it is essential for more attention to be paid to the equipment.

The Project Team hope that this project will achieve that end.

CONCLUSION:

The results of the tests indicate that a minimum average rate of retardation of 0,18 m/s^2 may be used in locomotive mechanical brake design provided that:

- Brakes are maintained at exceptional standards.
- Hauled mass to locomotive mass ratios are maintained at 6:1.
- Locomotive driver's reaction times are kept below 2 seconds.
- Dynamic and hydrostatic brakes be tuned to operate at a retardation rate of 0,14 to 0,16 m/s^2.

10. Rail bound equipment coupling systems and designs in use in the Gold and Platinum sector

By van der Walt P.G., Dr Naude J., Lubbe S.W., Hutcheson P.J., Prof Meyer J.P., Spencer K.C., Turnberry Projects (Pty) Ltd in association with Alexander Forbes Risk Engineering and the Engineering Faculty of RAU, Ref: GAP 703, 2000

SUMMARY:

One of the findings of SIMRAC Project GAP 520 dated March 1999 ('Investigate safety of rail vehicles and systems operating in South African gold mines') was that about 20% of accidents involving locomotives and rolling stock were during coupling and de-coupling operations. In most cases, a worker's limb is squashed between the buffers of the units being coupled/de-coupled.

This project was a general study of the existing coupling systems and a general assessment of the coupling systems against the ergonomics requirements for safer operation or use. The project team met with the major South African users and manufacturers of buffers, hoppers, locomotives and other rolling stock, collecting information on the types of buffers used, coupling procedures, designs of coupling systems, accidents, etc. The team also carried out intensive discussions with European manufacturers and users of coupling systems. A patent search of coupling systems was carried out in both the South African and USA Patent offices. The legislation appertaining to underground rail transportation in South Africa, the UK, the USA, Canada and Australia was investigated.

Arising from the engineering assessment and risk evaluations carried out by the project team was that the gold and mining industry in South Africa is largely standardised on a link and pin type coupling system for underground rolling stock, where underground transport is carried out in an environment with

- Good quality trackwork
- Standardised rolling stock
- Well maintained rolling stock and buffers
- Skilled and well trained operators
- Effective and reliable communication between driver and guard
- A culture of safe working practices then the system of links and pins as used by the industry for many decades would probably be adequate.

It would appear that finger and hand accidents are largely caused during coupling, with very few accidents occurring during uncoupling. The drooping of buffers and sagging of the links appears to be the biggest single contributor to accidents - but is a symptom of the problem rather then the root cause. The operator has to, in the very confined area between the cars or hoppers, exert significant mechanical effort from an unbalanced position to wrestle the link into a position in which it will engage the mouth of the buffer. It is in this position, with the train moving that most accidents occur.

The slotted holes in the link and pin system do however result in severe backlash, which leads to high impact loading, which results in:

- Distortion of the chassis and loosening of the bolts attaching the buffer to the chassis;
- Plastic deformation of the buffer mouth and pin locating hole, the link and it's slots and the pins
- Premature failure of the resilient rubbers

CONCLUSION:

The use of dedicated well-trained tramming teams should significantly reduce accidents. Coupling designs should be modified or alternatively new couplings developed that minimise backlash and that can withstand the resultant impact forces experienced without plastic deformation. Some conceptual alternative designs were developed. Systems used should allow for coupling and un-coupling to take place such that the guard can stand outside of the line of the vehicles whilst they are in motion.

11. Design and development of a quiet, self-thrusting blast hole drilling system

By Ottermann R.W., von Wielligh A.J.,
University of Pretoria, Ref: GAP 642, 2001

SUMMARY:

Noise is a generic hazard common to all commodities and, to a greater or lesser extend affecting, all operations within mining. More people are exposed to the risk of noise- induced hearing impairment than to any other occupational hazard. Pneumatic percussion drills are a major contributor to noise-induced hearing impairment in mines. The design and development of a quiet, self-thrusting blast hole drilling system will reduce this risk. During this project such a drilling system was developed, tested and demonstrated.

The primary output of this project is a quiet, ergonomically, reliable blast hole drilling system, which is us ed to drill suitable blast holes by workers responsible for drilling these holes. The system has to be safe and reliable with reduced hearing loss and higher productivity.

After a problem survey was conducted a functional analysis was done from which a specification was drawn up. Although the current regulations state that a worker may be exposed to a maximum equivalent noise level of 85 dBA for 8 hours per day it was calculated and decided that an appropriate design level for the sound power level for the “quiet” rock drill would be 90 dBA as workers do not drill the full 8 hours.

Different concepts were generated and evaluated. The preferred concept was presented to the SIMRAC technical committee for approval after which a detail design was done. An experimental development model (XDM) was built and surface tested. A design review was done and five prototype quiet rock drills were manufactured. These rock drills were tested on surface as well as underground. A marked reduction of sound levels was achieved with the quiet rock drill.

The quiet rock drill consists of a standard Seco S215 pneumatic rock drill encapsulated in a composite material tube. The tube is pushed onto the rock face by a pneumatic cylinder and is sealed at the rock face by means of a flexible material. A lead screw mechanism, powered by a geared air motor, thrusts the drill forward. The exhaust air, dust, water and rock shavings as well as oil and grease are removed from the tube via an exhaust pipe a distance away where the air and water is dumped.

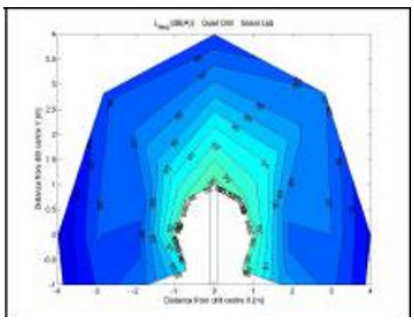


Sectioned solid model of the assembled prototype quiet rock drill.



Quiet rock drill being tested underground

A penetration rate not worse than that of existing drills was achieved with the quiet rock drill. This was one of the main design criteria for the project. Although sound levels of below 90dBA (the other main criteria) were not achieved directly adjacent to the quiet rock drill in the stope, it is envisaged that these levels will be achieved with an improved revised design.



Sound levels around the prototype quiet rock drill tested on surface.

CONCLUSION:

The testing of the prototype quiet rock drill identified certain shortcomings including the weight and manoeuvrability, which will have to be addressed during further development of the drill. The noise levels also have to be further reduced.

As a tendency exists for the introduction of drill rigs in mines it is also recommended that the quiet rock drill be incorporated in drill rigs. A drill rig with the quiet rock drill will have to be designed, built, tested and evaluated. The use of the quiet rock drill in a drill rig will solve the problem of manoeuvring, as size and weight will not be a problem on a rig.

12. Risk assessment of hoisting with and without a safety detaching hook

By Dr. Wainwright K.A., Anglo Technical Division, Ref: GAP 701, 2001

SUMMARY:

In the late 19th century, steam winders with poor control led to many hundreds of overwinds per year. The current status on South African mines is that the frequency of overwinds is about five to ten per year, and these are nearly always slow speed overwinds in which no injuries or fatalities occur.

Detaching hooks have two functions. Firstly, to detach the rope from the cage in the event of a high speed overwind. This function minimises the damage to infrastructure, but is not a safety function in that it does not prevent fatalities. The second function is to latch into the spectacle plate once the rope has detached, and secondly; to provide a means of holding the cage, preventing it from falling down the shaft. This is a safety function, in addition to the jack-catches, that helps prevent fatalities, but only in low speed overwinds.

The enquiry into the Vaal Reefs accident, in which 104 people died, resulted insubsequent studies revealed that it is also possible for detaching hooks to be opened due to an object falling down the shaft and striking only one of the detaching hook re-lease lugs at relatively low energy. More recently, in a similar accident, a detaching hook was also opened by a locomotive falling down a shaft. In this case, the cage was fortunately empty. It is possible that there have been other accidental hook detachments in the past that have not been reported, either because there was no loss of life, or because the role this mechanism played in the sequence of events was not realised.

For this study, a HAZOP study and risk assessment study were carried out using the results of a survey of existing accident reports and the knowledge and experience of a panel of experts drawn from the mining industry. The approach adopted was to compare the statistically probable number of fatalities in the South African mining industry under conditions where detaching hooks are used, as opposed to the scenario that they are not used.

CONCLUSION:

From the point of view of risk to life, the main accidents in which the detaching hook plays a role are the accidental complete hook opening (as in the Vaal Reefs 2 Shaft accident) and the high-speed overwind, when these involve a cage carrying passengers. In the double-sided hook opening scenario the hook is a disadvantage because its presence allows the accident to happen. In the high-speed overwind, the hook is an advantage, because if it were not present the rope would break anyway. The latching of the hook in the spectacle plate provides an additional protection against the cage subsequently falling down the shaft, when otherwise there would only

be the jack-catches in present shaft arrangements. On the basis of the data available to this study, the hook is more likely to be a disadvantage than an advantage, and is estimated to cause roughly three times as many deaths as it saves.

The main reasons are that:

- Double-sided detachments are estimated to be more likely than high-speed overwinds in which the jack-catches fail.
- The fact that some passengers are killed in the initial impact with the crash beams following a high-speed overwind means that fewer are left to be saved by the detaching hook.

The main uncertainty in the assessment is whether the Vaal Reefs 2# and the BCL accidents were really the only incidents of double-sided hook opening to date. This is statistically unlikely, because only one in 17 such events would normally involve people. The study therefore assumes that other detachments have occurred but have gone unreported because there were no fatalities. If this is not so (i.e. if the Vaal Reefs 2 Shaft and BCL accidents were really the only incidents of double-sided hook opening to date) then the balance of risks would be in favour of retaining the hook. Other uncertainties have been assessed, and are considered unlikely to affect the conclusion that the hook is, on balance, a disadvantage with respect to safety. Even if the estimated frequency of hook openings is halved, this would not change the conclusion. The susceptibility of detaching hooks to accidental opening by falling objects can be reduced by various modifications. One of these modifications as been applied to over 50 percent of detaching hooks since the 1995 Vaal Reefs disaster. These modifications have been implemented voluntarily by the industry without any requirement by legislation. The modified design however has only been subjected to a limited number of low energy strike tests, and although improvements are indicated, these have not yet been thoroughly demonstrated. Work can also be done to improve the survivability of high speed overwinds in the absence of a detaching hook, which would further strengthen the conclusion that it is safer to hoist without a detaching than with one.

If a detaching system could be constructed that was demonstrably unable to open accidentally due to falling objects, then the balance of risk to safety would favour their retention. This is because overwinds continue to occur. However, in all likelihood other risks would be introduced due to its inherent opening mechanism. On the other hand if overwinds could be eliminated then detaching hooks would be redundant. Reducing the number of overwinds that occur, on a sustainable basis, could reduce the level of risk to the point where the balance of risk to safety would favour hoisting without detaching hooks, even if hooks are modified or redesigned to totally prevent accidental opening due to falling objects.

The team then investigated the causes of accidents for these occupations. By far the most significant reason was ‘a lack of adherence to standards’. One possible reason for this was that workers did not have sufficient knowledge and skills with regard to the hazards. The project team therefore spent considerable time observing training in practice at three different mining groups. Their conclusion was that workers are well trained and are competent to work safely underground.

The liberal use of ‘a lack of adherence to standards’, given as a cause of accidents in the SAMRASS data, was a concern to the project team. It seemed a catch-all reason that could minimise detailed accident investigations. However, it was what the data reported. It also pointed to behavioural and organisational issues, rather than technical failures and this was consistent with other findings of the research. The project team therefore felt confident in accepting this data, although they acknowledge that further research and better accident recording might be required to fully understand the true causes hidden behind this reason.

At this stage the research was redirected towards other factors that impact on performance and

adherence to safety standards. From a variety of sources, a highly complex set of organisational, environmental and individual factors was identified. These interact in a variety of ways to ultimately determine the way people perform. The corner stones were found to be individual self-confidence and the operational wherewithal to perform assigned tasks. This insight enabled the project team to compile Table 14 that is a list of the most appropriate learning areas for each of the occupational categories identified earlier.

The project team explored several techniques currently in use by the mines that are aimed at addressing these issues. Although many of the programmes were found to have value, most were used in an ad hoc manner without a concrete understanding of what they were addressing. Although table 15, which lists learning techniques and approaches, was constructed, the team concluded that individual mining operations need to measure and understand their own particular circumstances before they are in a position to embrace any of these techniques.

13. Develop tele-controls for self-thrusting percussion drilling machine and associated interface

By Ottermann R.W., von Wielligh A.J., Burger N.D.L., Dr. Kononov V.A., RE @UP, University of Pretoria, Ref: GAP 702, 2001

SUMMARY:
The purpose of this project was to develop tele-controls such that drill operations can be effected from a distance. The controls were fitted to the quiet rock drill prototype and demonstrated to be working.

The pneumatic percussion drill is a major contributor to noise-induced hearing impairment in mines. The design and development of telecontrols for drills so that the operator can be positioned away from the drill will reduce this risk. The tele-control of rock drills has the added advantage of increased safety to the drill operator by his positioning away from the rock face. During this project such a system was developed, tested and demonstrated.

After a literature survey was conducted, a functional analysis was done from which a specification was drawn up. Different concepts were generated and evaluated. The preferred concept was presented to the SIMRAC technical committee for approval after which a detail design was done. An experimental development model (XDM) was built and commissioned. The XDM was successfully tested and demonstrated on surface.

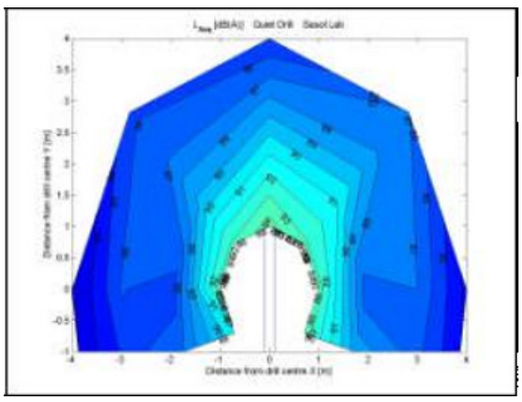


Electronic control unit inside assembled XDM



Hand held controller

The design of the quiet self-thrusting rock drill, developed during project GAP 642, was used and the tele-controls incorporated into it. The tele-con-trol system consists of a hand held con-troller and the electronic unit in the drill unit, with which different valves are controlled. Radio con-trol is used as communication between the hand held controller and the drill unit. A generator, pow-ered by an air motor, is incorporated in the drill unit to charge a battery, which supplies electricity to the electronics.



Sound levels around the prototype quiet rock drill tested on surface.

CONCLUSION:

Tele-controls were successfully developed and demonstrated for the quiet, self-thrusting blast hole drilling system (GAP 642). The specified design criteria as set out in the system specifications were met. A considerable reduction in sound levels was achieved with comparable penetration rates to standard pneumatic drills. With the tele-control rock drill the operator can be positioned away from the drill where the noise levels are acceptable. This has the added advantage of increased safety to the drill operator by standing away from the rock face.

As this was an experimental development model (XDM), no durability tests were performed and the electronics were also not built to withstand underground conditions. In order for this technology to be used underground the electronics have to be designed and packaged to withstand underground conditions. As a tendency exists for the introduction of drill rigs in mines it is also recommended that tele-controls be incorporated in drill rigs.

14.Best Practice - Conveyor Belt Systems

By Dreyer Nel P.J., Anglo Technical Division,
Ref: GEN 701, 2001

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 pre-empt 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. A 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.



15.Technology transfer of winder ropes research

By van Zyl M., MIKE VAN ZYL INCORPORATED, Ref: GAP 637, 2002

SUMMARY:

In the early 1980's, winder ropes research in South Africa gained new momentum when it was decided to investigate the validity of the regulations governing the strength of winder ropes. Although knowledge of, and experience with winder systems and winder ropes were available at the time that the research effort started, very little was actually written in the form of reports that could have been used as motivation for changes to the regulations.

Originally the research was sponsored collectively by the mining industry through the Chamber of Mines, and later through government levies raised and administered by the Safety in Mines Research Advisory Committee (SIMRAC). The CSIR (a semi-government organisation) was the initial co-ordinator of the research. Due to their intimate involvement in the project, both the CSIR and Anglo American Corporation also sponsored their own winder ropes related investigations from time to time. The reports on these "privately" sponsored investigations were made available to the research effort.

By the year 2000, more than 100 research reports had been produced.

These reports either had some bearing on the new rope load factors that were included in the South African regulations, or were produced because of the changes introduced to the regulations. In total, the reports consist of more than 5 900 pages.

The main part of this document describes the events and history that led to the creation of this vast amount of research. The research reports that were produced are listed and a summary of the contents of each report is given in an appendix.



The author struggling through the mass of papers, reports and minutes of meetings that were produced in the 15 year period that was reviewed.

Principal findings:
The research described in this report produced and established the following:

- New rope load factors and regulations for drum winder ropes were established.
- A code of practice for rope condition assessment was produced, rope discard criteria were investigated and magnetic rope testing instruments were evaluated.
- The winder code of practice that would allow better utilisation of drum winders as well as deep shaft hoisting was established.
- A code of practice for shaft sinking winders was established and used to sink two very deep shafts.
- New rope terminations were introduced.
- Winder and rope dynamics are well understood.
- Rope deterioration on a drum winder is far better understood.
- Uncertainties like winder motor fault torque and slack rope have been investigated.
- A large information base has been established.

CONCLUSION:
A large part of the SIMRAC investigations were concerned with rope discard and rope deterioration in order to verify and refine the requirements in the mentioned codes of practice. None of the recommendations in the SIMRAC reports has been implemented.

16. Learning outcomes and effective communication techniques for hazard recognition learning programmes in the transport thrust area

By Krige P., Turgis Technology (Pty) Ltd, Ref: GAP 857, 2002

SUMMARY:
The brief of this research was to identify the hazards associated with underground track bound transportation on Gold and Platinum mines, describe the learning that is necessary to recognise these hazards and then to determine the most suitable techniques for transferring this learning to individuals.

Prior to the commencement of the research, the project team had expected that the final outcomes might resemble a checklist of learning techniques and learning outcomes. This was not to be. Instead, a complex interaction of organisational and individual factors emerged. The research found that measuring and understanding this interaction is key to designing learning programmes that will significantly impact on safety performance.

The early stages of the research utilised the data from the SAMRASS database and findings from previous SIMRAC research reports.The previous reports were particularly helpful in identifying the major hazards associated with underground transportation accidents. These

are summarised in Table 4 in the report. From the SAMRASS data the project team was able to isolate the most vulnerable occupation categories, with regard to transportation accidents. The team then investigated the causes of accidents for these occupations. By far the most significant reason was 'a lack of adherence to standards'. One possible reason for this was that workers did not have sufficient knowledge and skills with regard to the hazards. The project team therefore spent considerable time observing training in practice at three different mining groups. Their conclusion was that workers are well trained and are competent to work safely underground.

The liberal use of 'a lack of adherence to standards', given as a cause of accidents in the SAMRASS data, was a concern to the project team. It seemed a catch-all reason that could minimise detailed accident investigations. However, it was what the data reported. It also pointed to behavioural and organisational issues, rather than technical failures and this was consistent with other

findings of the research. The project team therefore felt confident in accepting this data, although they acknowledge that further research and better accident recording might be required to fully understand the true causes hidden behind this reason.

At this stage, the research was redirected towards other factors that impact on performance and adherence to safety standards. From a variety of sources, a highly complex set of organisational, environmental and individual factors was identified. These interact in a variety of ways to ultimately determine the way people perform. The corner stones were found to be individual self-confidence and the operational wherewithal to perform assigned tasks. This insight enabled the project team to compile table 14 that is a list of the most appropriate learning areas for each of the occupational categories identified earlier.

The project team explored several techniques currently in use by the mines that are aimed at addressing these issues. Although many of the programmes were found to have value, most were used in an ad hoc manner without a concrete understanding of what they were addressing. Although table 15, which lists learning techniques and approaches, was constructed, the team concluded that individual mining operations need to measure and understand their own particular circumstances before they are in a position to embrace any of these techniques.

17. Criteria for the safe use of commercial vehicles to transport personnel in the underground environment

By Giliomee C.L., Dr. Nell S., Prof. Fourie G.A., Land Mobility Technologies (Pty) Ltd, GA Fourie and Associates, Ref: GEN 702, 2002

SUMMARY:
This report details the research done into the use of commercial vehicles (bakkies) in the underground mining environment. The research was prompted by concern from the DME about the use of non-flameproof vehicles in fiery mines. Although flame proofing is of primary concern in this document, general safety requirements for bakkies used underground are also addressed.

Statistics from the SAMRASS database indicates that vehicle-related accidents account for a significant number of accidents, injuries and fatalities in mines. The current situation in the mines was determined through visits to the mines. A questionnaire was filled out by the mines regarding the use of bakkies underground. Some of the industry role players were also visited to determine the level of support and competency in industry. Two SABS standards pertaining to flame proofing and braking respectively were evaluated and DME documentation relating to the use of bakkies underground are also discussed. General vehicle safety, from a vehicle-engineering point of view, is also addressed.

The research indicated that although the SAMRASS database is very comprehensive, there is not distinguished between bakkies

and other personnel transporting vehicles, which makes the accident statistics difficult to interpret. The accident statistics may therefore be misleading, as far as non-flameproof bakkies are concerned.

It was also concluded that all the mines visited during this project follow a different approach when selecting, implementing and maintaining non-flameproof (as well as flameproof) bakkies. It appears as if some of the mines do not go through the same development and research effort, as did the pioneers of non-flameproof bakkies. All the mines have a sound driver training program in place and monitor the use of bakkies carefully. It is also very noticeable that at most mines, although the non-flameproof vehicles are still new, few accidents and almost no fatalities or injuries were recorded since the introduction of non-flameproof bakkies. From the response of the mines to the questionnaire, it can be concluded that the mines will go a long way to retain exemption to use these vehicles.

Some of the industry role players are very skeptical about the non-flameproof vehicles and most of them feel that proper guidelines and specifications should be provided for these vehicles.

The SABS 868 flame proofing standard has been revised several times and it was found that some of the issue levels contains conflicting information. This standard also makes no provision for non-flameproof vehicle requirements. The SABS 1589 braking standard used for underground trackless mining vehicles was found to be more lenient than that used for commercial vehicles, such as bakkies, in terms of stopping distance and mean fully developed acceleration.

The DME documentation regarding non-flameproof vehicles was revised several times the in past few years and although none of the documents provided sufficient guidelines, it was found that the documentation became less prescriptive with regards to braking, temperatures and emissions. Non-flameproof vehicles found at the mines are generally in very good condition and conform to strict safety standards, although healthy and safety can be improved in various areas.

According to the Mine Health and Safety Act (MHSA) (Act 29 of 1996), the manager must draw up codes of practice (paragraph 9), supply training (paragraph 10) and assess and respond to risks (paragraph 11). This will entail performing a Hazard Identification and Risk Assessment (HIRA) for each new vehicle model introduced in the mine. This report supplies some examples of significant risks and suggests possible ways to address it, but since each mine is unique, a thorough HIRA has to be performed for all non-flameproof vehicles.

As part of this study, a quick reference guide was compiled, which summarises the decision making process when implementing bakkies in mines. This guide highlights the steps in the process and stresses the importance of an effective HIRA and the associated tasks that follow that.



CONCLUSION:

Many mines have already successfully implemented non-flameproof vehicles. Although statistics indicate that vehicle-related injuries account for a significant part of the total number of accidents, injuries and fatalities, it was found that accidents involving non-flameproof vehicles were minimal. Initial indications are that well developed non-flameproof vehicles are safe to use in non-hazardous areas in fiery mines. The standard safety specifications of commercially available bakkies in most cases exceed those found on flameproof personnel transporters. Non-flameproof bakkies are less expensive than flameproof bakkies in terms of procurement cost and maintenance, although the development cost might be more.

18. The Ergonomics of Locomotive Design in South African Gold and Platinum Mines

By Smith J.R., Shaba M.N., Marais P., Schutte P.C., Mac Duff L., Malapane N.C., Harper G.S., Romoshebi J., Ergotech Ergonomics Consultants, a business unit of Gerotek Test Facilities (Pty) Ltd in association with the CSIR, Mining Technology, REF: SIMGAP 704, 2002

SUMMARY:

This research report discusses the ergonomics of locomotive designs in South African gold and platinum mines. The purpose of the study was to identify safety aspects of the existing fleet of mine locomotives and rolling stock that could be improved through ergonomics interventions.

In order to obtain this objective it was, firstly, necessary to determine the types of locomotives used at gold and platinum mines. This was followed by the objective and subjective evaluation of the existing fleet to determine the ergonomic aspects affecting human performance and human-machine interaction. The key ergonomics characteristics related to safety and work performance were identified for the mine locomotive, and based on this information, an ideal design was formulated. The practical implication of implementing the ideal design was defined, and the required changes and modifications to improve the safety aspects of the existing fleet were determined. Finally, a practical strategy was devised for the improvement of the current fleet.

Aspects covered during the study included:

- analysis of the locomotive operator tasks.
- identification of the ergonomics aspects and mechanical engineering characteristics of the locomotives, which could affect the safety and task performance for the locomotive operators.
- evaluation of the perceptual assessments of the locomotive operator.
- three-dimensional CAD assessments of the current locomotive designs to determine reach, posture, field of view and control locations for the operator.
- determining the design modifications, which would improve the overall operation of the mine locomotives in South African gold and platinum mines
- formulation of an ergonomics intervention strategy that would address the deficiencies in the current design (based on the anthropometric data for the South African user population, and local mining conditions).

The ergonomics assessment of the existing fleet of mine locomotives at gold and platinum mines highlighted various deficiencies in the design of the working system (most typically at the operator-machine interface). Poorly designed workstations make the operator's tasks more difficult and thus render him more error-prone. A number of safety related design deficiencies were also identified that can be improved through ergonomics intervention.

The ergonomics interventions required to improve the safety aspects of the existing fleet should address the following aspects:

- access to the cab of the locomotives
- forward visual access
- seating and posture
- communication and warning systems
- labeling of controls and displays

- equipment storage
- pre-operational safety and mechanical checks, and
- modification of the park brake.

The ergonomics interventions required to improve the safety aspects of the existing rolling stock should address access, seating and space provisions of man carriages.

In terms of ergonomics, the ideal design for a locomotive is considered to be one that follows the stereotype of motor vehicles. This incorporates the use of hand and foot controls, a body orientation facing in the direction of travel and adequate body support in the form of a well-designed seat. The ideal design also makes provision for two locomotives per train, one at each end.

Practical considerations frequently influence the “ideal” design concepts to ensure safe as well as cost-effective workable solutions. This can be done while still incorporating sound ergonomics. A practical design for a locomotive include an enclosed cab, the use of current railbound stereotypes (i.e. hand control of direction and speed), and as far as the train is concerned, a single locomotive with a guard car at the other end. The guard car replicates the controls and the control system of the locomotive, but is not self-propelled.

In order to reduce the safety risks involved with locomotive operations as a result of poor ergonomics, the following strategy is proposed. Firstly, priority should be given to the implementation of the proposed ergonomic interventions for the existing fleet. The second phase should focus on the development of locomotive cabs, incorporating the proposed ergonomics of the practical design, which can be retrofitted to the existing fleet. Finally, attention should be given to the development of new locomotives according to the ideal design proposals.

It is further recommended that all interested and affected parties (manufacturers and suppliers) be involved in the practical implementation, manufacture and installation of the proposed ergonomics interventions and conceptual designs. This is This is essential in terms of Section 21 (1) (c) of the Mine Health and Safety Act (Act 29 of 1996).

19. Ergonomics guide for locomotives and guard cars in South African gold and platinum mines

By Shaba M., Marais P., Ergotech Ergonomics Consultants, a business unit of Gerotek Test Facilities (Pty) Ltd in association with the CSIR, Mining Technology, Ref: SIMGAP 704, 2003

SUMMARY:
Analyses of projects in the transportation and machinery thrust area have shown that a small number of the projects appear to have found use in industry mainly due to ineffective information dissemination and a lack of impetus upon potential implementation teams. A review of the information dissemination methods by Safety in Mines Research Advisory Committee (SIMRAC) has identified that booklets are effective means of transferring information from research to potential implementation teams.

In the year 2000, SIMRAC commissioned a research project on the ergonomics of locomotive design in the gold and platinum mines in South Africa (GAP 704). A report of this study provided recommendations and a range of data that can be used to improve the ergonomics aspects and the design or selection of mining locomotives and guard cars. The primary objective of this booklet is therefore to consolidate the ergonomics recommendations of that research in a user-friendly format.

Section 21 (1) (c) of the Mine Health and Safety Act (Act 29 of 1996) stipulates that any person who designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation. The ergonomics guides presented in this booklet can be used by the designers or manufacturers of mine locomotives or mine equipment to address some

of the ergonomics requirements. Furthermore, if the manufacturers and mining engineering teams can use the information, fatalities and injuries attributed to mining transportation systems may be reduced.

CONCLUSION:

The ergonomics assessment of the existing fleet of mine locomotives at gold and platinum mines highlighted various deficiencies in the design of the working system (most typically at the operator-machine interface). Poorly designed workstations make the operator's tasks more difficult and thus render him more error-prone. A number of safety related design deficiencies were also identified that can be improved through ergonomics intervention.

20. Ergonomics of mining machinery and transport in the South African mining industry

By Schutte P.C. and Shaba M.N., CSIR Mining Technology, Ref: SIM 02 05 04, 2003

SUMMARY:

Local and international safety statistics indicate that ergonomic factors underlie many of the ac-ci-dents occurring in mines, and could impact neg-atively on the effective and efficient opera-tion of mining machinery and transport systems.

The objective of the study was to conduct an ergonomics evaluation of the mining machinery and transport systems generally used in mining. This evaluation is based on the consideration of the complete ergonomics system to identify the ergonomics-related hazards that could affect the operators' ability to work safely and efficiently

CONCLUSION:

Operators of mining vehicles have a range of conditions to contend with and often have less well-designed cabs and seats than their road transport counterparts. Inadequately sized cabs situated in inappropriate locations on the vehicle, and with poorly designed displays and controls, compound the stresses placed on the operators. Internationally available standards could, together with appropriate anthropometry, be used as a basis for the design of mining machinery and transport systems.

21. Transport and tramming accidents in trackless vehicles

By Fourie A., Fourie and Associates, Ref: SIM 03 05 02, 2003

SUMMARY:

Transport and tramming accidents are the main sources of occupational safety risks, especially on mines other than gold and platinum. This booklet aims to consolidate the findings and recommendations of SIMRAC previous projects OTH202 and COL506.

The end result is an easy to read booklet, leading into a better understanding of the wide - ranging factors that are likely to contribute to transport and tramming accidents. Factors that can predispose the occurrence of accidents are explored, and split into those that are Organization-related (Latent failures), and those that are Operator-related (Active failures). It defines the modes of failure, analyses causes, and suggests corrective action. The overall message is that operators and other victims of accident may not necessarily be the direct cause of accidents. An open-minded approach should be adopted, where the established procedures are critically reviewed, as these have been found to be the major catalysts to most accidents.

22. Develop Discard Criteria for Non-spin Wire Ropes

By Hecker G.F.K., Mechanical Testing and Measurement, Ref: GAP 803, 2004

SUMMARY:

The initial project objective was to correlate the level of internal broken wire indications, obtained using a magnetic rope test instrument, with rope strength loss and then to propose a given indication level at which non-spin ropes are to be discarded.

Guidelines are proposed on how the signal obtained with the magnetic rope test instrument could be processed to obtain a wire break severity trace. This could be used to decide on whether a rope needs to be discarded. With very limited experimental data, however, the correlation between the processed signal and the rope strength was fortuitous at best.

No experimental data became available during the course of the project. Relatively conservative discard criteria were therefore recommended, based on current South African practice and on discussions with rope inspectors and other parties concerned with rope safety.

Based on this, two appendices to the report present recommended changes to the discard criteria and other changes to the code of practice for rope condition assessment (SABS0293) respectively.

Where appropriate, background information is presented to facilitate a decision on how to implement these changes.

After a draft version of the report was circulated in September 2003, some comments were received. The final version of the report contains these comments in an appendix, together with a follow-up investigation and a brief discussion of the comments.

CONCLUSION:
The discard criteria for broken wires in SABS0293 were based on a 10% reduction in strength of a rope. An expectation was therefore created that by complying with these discard criteria, a rope would not fail as long as the rope loads did not exceed 90% of the new rope breaking strength.

Irrespective of how the conclusions and findings in this report are interpreted, winder ropes still have to be inspected and discarded according to the current specifications of SABS0293.

The discard criterion that the number of broken wires in a single strand may not exceed 40% of the number of wires in the strand will, at least for the near future, ensure that non-spin ropes with outer strand damage do not remain in service too long.

23. An investigation into the effects of steel wire rope specimen length on breaking force

By O'Brien T.M., CSIR Division of Mining Technology, Ref: GAP 836, 2004

SUMMARY:
South Africa has a well-entrenched statutory method of evaluation steel wire hoist ropes used for the conveyance of men, material and rock within mines. The system used is characterized by six-monthly destructive tensile testing of samples cut from the conveyance end of the rope and by complimentary in-situ non-destructive testing. This system is internationally recognized and has been adopted by other nations as their preferred method.

However, in defining the discard criteria for the ropes (the no-go condition), work was traditionally focused on examining and testing specimens of a gauge length that was predetermined by the diameter of the rope under consideration. This led other researchers to postulate that if different lengths of specimen were evaluated, different discard criteria would have been formulated (van Zyl, 2000).

This report covers work conducted to evaluate the effects of specimen length on the breaking force, in an attempt to validate or refine the discard criteria of SABS 0293: 1996. Inter alia, this included an examination of the postulation of van Zyl (2000). The methodology employed was to test different length of triangular strand and non-spin rope to destruction, and to evaluate these results against SABS 0293:1996. For each rope construction, specimens were prepared both with and without cut wires, providing a total of 26 triangular strand and five non-spin samples. Unfortunately, anomalous behaviour of the non-spin rope led to the discontinuation of these tests in favour of a greater number of triangular strand rope specimens.

CONCLUSION:
In summary,it was found that:

The gauge length of test specimens has a definite influence on the strength of 50 mm nominal diameter triangular strand steel wire rope. This influence:

- Affects both uncut (intact) rope samples and cut wire samples; and
- Acts in the favour of the user who adheres to the discard criteria of SABS 0293: 1996, indicating a greater margin of safety; and
- Validates the findings of van Zyl (2000), i.e. if different lengths of sample had been studied during the formulation of SABS 0293:1996, different discard criteria would have been arrived at;

Test specimens that fail at the end cap (rope termination), display behaviour similar to those of a rope with five cut outer wires. Samples failing in this manner should be retested in the case of statutory rope tests.

From these findings, the principal recommendations are that firstly, a test protocol be drawn up by Standards South Africa to standardize test methods and laboratories with respect to quality assurance. Secondly, since the work covered by this report examines only one diameter of rope, that the test regime be extended to cover other diameters and constructions of steel wire rope.

Finally, whilst no price can be levied on the value of human life, the apparently greater-than-anticipated safety margin with the increase in specimen length may be used as a motivation by South African mines to alter the discard criteria to allow for a longer installed time. A study on the cost implications of such a change is recommended to evaluate any financial benefits and increased safety risk.

24. Investigation into causes of accidents on scraper systems in the Gold and Platinum mining sectors

By Moseme R., Foster P.J., Demana R.L. Rupprecht S.M., CSIR Miningtek and Camborne School of Mines, Ref: GAP 03 05 01, 2004

SUMMARY:
This research report identifies the risk and hazards associated with scraper winch systems that may lead to potential accidents in the gold and platinum sector. The research also suggests whether scraper winch systems are a major safety risk, and if the associated risk is a managerial and an operational issue, or whether further research is required to provide potential solutions to the identified risk.

The initial stage of the research concentrated on an analysis of the SAMRASS database. The analysis indicated that accidents associated with scraper winch systems in the gold sector accounted for 5%, and in the platinum sector for 9%, of all underground mine related accidents. The analysis also indicated an increase in the fatality rates for the platinum sector with a decrease in injury rate for both gold and platinum sector between the periods of 1988 to 2002. The indications therefore were that scraper winch systems do indeed constitute a safety risk in the gold and platinum mining industry
.
A risk profile study was conducted to assess the operational issue. A great deal of further effort is directed at changing people's attitudes towards risk nature and extend of the identified accidents identification and hazard recognition, appropriate associated with scraper winch systems. The results training, adherence to mine standards, as well as of the risk profile shows that significant hazards in the management and supervision of scraper winch the gold sector are due to the scraper/scoop (33%), systems is required. Mining

houses must continue whilst scraper winch rope accidents are significant to be diligent to ensure that standards are for both the platinum (31%) and the gold (30%) sector.

An analysis ofthe activities of workers of the scraper winch accident profile was also investigated. The investigation revealed that winch operators, stope workers, general miners, shift bosses and drillers are prone to scraper winch accidents, in that order. In addition, most injuries occurred at the beginning of the morning shift when most workers are in groups of occupation and fatal accidents occurred mostly during night shifts when there was likely to have been absence of supervision, loss of concentration and awareness amongst workers.

Principal causes of the scraper winch accidents in relation to the workers were due to 'poor adherence to standards and procedures', 'lack of training and its practical application to the actual working environment', 'poor hazard identification skills and perception of risks', and 'management and supervision of working practices and procedures'.

To complement the SAMRASS database underground visits and interviews with mine Personnel associated with the management and operations of scraper winch systems to identify causes of accidents from this perspective. The main finding of the underground observations was that 'rigging', 'signalling devices' and 'winches being started without warning' were identified as the main/significant hazards.

Parallel to the practical investigations, a health and safety risk assessment analysis with respect to the design, installation and operation of scraper winch systems was conducted. The risk assessment confirmed hazards similar to the SAMRASS and underground investigations i.e. being struck by winch (during transportation, installation, operation or removal), ropes, scoops, snatchblock; punctured by rope strands; and entanglements.

Importantly, the risk assessment identified significantshortcomings in scraper winch control measures, limitations in rules and standard procedures, lack of training, lack of routine inspections, and inadequate communication systems. The investigation also highlighted that regulations on scraper winch systems need to be revised, a process that is already underway, and improved controls put in place. A document to give guidance on adequate controls and applications of best practice is also needed.

Overall, the research work indicates that scraper winch accidents are primarily a managerial and operational issue. A great deal of further effort is directed at changing peoples attitudes towards risk identification and hazard recognition, appropriate training, adherence to mine standards, as well as the management and supervision of scraper winch systemsis required. Mining houses must continue to be diligent to ensure that standards are implemented and enforced. Furthermore, risk assessments need to be integrated with the mine standards.

25. Investigation of safety of rail vehicles and systems operating in South African Gold Mines

By Page T.P.T., Morton G.A., Vermaak J.A., Turgis Technology (PTY) Ltd., Ref: GAP 520, 2005

SUMMARY:

The project was intended to:

- Investigate rail system accidents on South African gold mines to determine the major causes of accidents.
- Compare the South African rail system safety record with those of selected international countries.
- Recommend means of improving rail system safety on local gold mines by drawing on appropriate international technology and systems.

In order to acquire information on the causes of local accidents, analysed as:

- Data from the SAMRASS report and individual accident reports were analysed.
- Interviews were held with various role players.
- Literature surveys were carried out and appropriate literature was studied in detail.
- Mines were visited to ascertain the systems in use and identify potential dangerous practices.

In order to assess the international situation:
- Accident data was acquired from selected countries.
- Standards, Codes of Practice and legislation from those countries were evaluated to determine the content of such data, which was appropriate for local use.

CONCLUSION:
Local rail system accident rates are higher than those of the other selected countries. However, since mineral transport is not carried out by rail systems in those countries, the accident rates and accident causes are not comparable.

There are currently no local standards for rail systems, although national standards for locomotive controllers and rail track are currently being prepared.

Generally, equipment is manufactured to customer requirements. In general the mines and mining houses do not make use of detailed specifications for rail system equipment. In most cases rail equipment design has not changed much for the last 20 years. Rail system accidents account for approximately 10 per cent of all accidents. Of interest is the fact that the percentage of accidents involving rail systems has declined over the past decade. Approximately 85 per cent of rail system accidents are ascribed to some form of human error.

Worker discipline and safety awareness is generally of a low standard, and supervisors were observed not to enforce discipline. The single most frequent cause of rail system accidents was coupling of vehicles.

In terms of the seriousness and frequency of occurrence, the single most frequent cause of rail system accidents was coupling of vehicles.

In terms of the seriousness and frequency of occurrence of rail system accidents the following are the most important causes in order of priority.

1. Walking on or next to the track.
2. Derailments.
3. Collisions.
4. Travelling in or on rail vehicles.
5. Coupling.
6. Hitting obstructions of some form.

Most of the accidents resulting from people travelling in or on vehicles, coupling and hitting obstructions are caused by human error.
The cause of “human error” is however debatable.

26. Re-railing of underground rolling stock

By Vermaak P., du Plessis A., Wepener D. Wilson R., SRK -Turgis (PTY) Ltd., Ref: SIM 02 05, 2005

SUMMARY:
The work reported here focused on the re-railing of rolling stock commonly used on South African gold and platinum mines.

The study has found that there are numerous and significant problems attached to the re-railing of heavy rolling stock in confined spaces. Most derailments are caused by poor trackwork and re-railing methods remain rather primitive. In order to address the problem, it is not sufficient to address any single aspect. Rather, it is required to address methods, procedures, risk assessment, training and supervision aspects holistically. Re-railing remains a potentially dangerous task when carried out in limited space as are found underground.

The work has identified and categorised seven methods of re-railing, has evaluated these in accordance with pre-determined criteria, has

analysed these on a method for method basis, and has formulated both conclusions and recommendations pertaining to the subject. The most significant recommendation for short-term improvements is to revise procedures so that they accurately reflect actual or common practice in the mine. If done well, thesecan therefore be effectively used for the retraining of personnel. In the long term, the design, development, testing and implementation of an effective permanently mounted re-railing device on all locomotives is indicated.

RECOMENDATIONS AND CONCLUSION:

Procedure documents should be drawn up for each and every type of rolling stock in accordance with the circumstances prevailing at each mine or shaft as may be the case. Purpose designed re-railing devices are the preferred route to follow and ways and means of overcoming the shortcomings identified should be explored. For locomotives, the design and manufacture of a permanently mounted re-railing device should be considered.

The selection and training of persons who may perform re-railing procedures should be given priority on mines. Re-railing remains a safety critical task with a high likely severity if it should go wrong. Each re-railing procedure should be subject to risk assessment at the operational level. It is not sufficient to rely on a risk assessment performed on the basis of a solid underfoot if this does not exist, and most performed by the manufacturers understandably make assumptions that may include solid underfoot conditions

Standards, procedures and training material

The following specific recommendations are made for inclusion in such documentation:

- Specification of the constraints pertaining to use of the method
- Specification of whom is allowed or permitted to do re-railing and by which method
- Design and specification of jacking points on all rolling stock
- Mandatory reporting of all re-railing incidents
- Consideration of the effects of illumination on the safety of the procedure
- Consideration of the effects of noise on the safety of the procedure
- Consideration of the effects of heat on the safety of the procedure
- Permanent and visible marking of the safe working load of the equipment.

In choosing a method, the following aspects need to be taken into account:

- Mass of the equipment
- Ease of handling of the equipment
- Ease of use of the equipment
- Smoothness of the lifting action of the lifting equipment
- Position of the user when using the equipment
- Ease of availability underground
- Visibility of warning notices.

27. Behavioural causes and remedies associated with transportation accidents – Booklet

By Krige P.D., Turgis Consulting, Ref: SIM 03 05 04, 2005

SUMMARY:

The purpose of this research is to make a contribution towards improving safety standards in the underground transportation area. The scope of the research is limited to horizontal track bound transportation on Gold and Platinum mine. The emphasis of the research is on learning and behavioural causes and remedies for accidents rather than on technical and engineering related causes.

The research has three primary outputs:

1. A summarised list of the most significant risks to health and safety associated with track-bound underground transportation.
2. Descriptions of the learning outcomes that would need to be achieved to address these risks.
3. Recommendations for the most appropriate and effective communication techniques for hazards and hazard identification in the area of horizontal underground track-bound transportation.

Major risks and hazards related to underground transportation:

- Derailments due to fouling, collision and inadequate track work.
- Lack of clearance from sidewall, parked cars or stacked materials.
- Collision with ventilation doors.
- Run over, while walking ahead of train.
- Illegal riding on locomotives or hoppers.
- Struck by hopper while operating switch.

CONCLUSION:

Human error, rather than technical failure, remains the major cause of underground transportation accidents. The majority of accidents occur away from areas of close supervision. Although transport workers form the largest group of people injured in transportation accidents they comprise less than 50% of the total. Other occupational categories must therefore also be considered.

The transportation hazards identified by GAP520 remain the chief causes of accidents and were used as the foundation for further research in this report.

28. Protection systems for Decline shaft systems

By Wilson R.B., Turgis Consulting, Ref: SIM 04 05 01, 2005

SUMMARY:

Small winders installed in decline or incline shafts and winzes pose a significant risk to the safety of mine workers whose work closely interfaces with these installations. There have been incidences of fatalities and severe injuries caused by runaway conveyances in decline shafts over the years. This project's primary objective was to make recommendations for actions necessary for the reduction of risks posed by potential runaway conveyances in decline shafts. It was thus necessary to understand what was installed, how it was installed, and what risks were associated with the installations, before a recommendation for improvement could be made.

Eleven mines were visited. Confidential inter-views were held with mine officials at the mines visited, to get a feel for the hazards faced in these installations. Sketches of the installations ob-served were done and discussed in some detail in the report. The SAMRASS database was interrogated for the relevant accident statistics. Inspectors of machinery were interviewed and their comments considered in the compilation of the final recommendations. Workshops were held with a pool of experienced consultants, as well as the SIMRAC expert panel members. In addition, a literature study was conducted and previous relevant work by SIMRAC, and mining houses was taken into consideration in the compilation of the guide.

The following were among the most significant findings and inferences:

- Risk is significant in terms of fatalities and injuries per year, based on SAMRASS and anecdotal reports.
- Installations estimated at between 1700 and 2500 – no official record for unlicensed winders is available.
- Large array of safety devices and their deployment.
- Large diversity of layouts.
- Operation highly manual, thus high, hence wider man-machine interface.

The major hazards resulted from the following failures:

- Rope breakages
- Operational control failure
- Winder control failure
- Design shortcomings

Risk alleviation devices available to the industry were discussed, assessed for suitability, and recommended for various applications. This was done through a document entitled: "Guide for the safe design, installation, operation and examination of small winding plant in decline shafts and winzes". The "Guide" carried a sketch and a short description of the operation of the device, as well as a spreadsheet suggesting combinations of de-vices to be installed for safer operations of both licensed and unlicensed winders in decline shafts and winzes.

CONCLUSION AND RECOMMENDATIONS :

The following are the recommendations made from this study:

1. All winders, licensed and unlicensed, must be subjected to diligent professional engineering design processes.
2. All decline/incline shaft systems to consider the use of devices suggested in the “Guide”
3. A professional engineer must approve all safety device designs used in the decline/incline shaft systems.
4. Tank traps to be considered for stopping runaway conveyances in decline shafts, during shaft sinking operations.
5. Future decline/incline designs to consider automation of materials handling procedures in order to reduce man-machine contact.
6. Future systems to consider, where conditions allow, separate and dedicated shafts for man and materials.
7. Stakeholders to decide on the relevance of regulation 16.58 with regards to its applicability to decline/incline shafts and winzes.
8. Strict and diligent maintenance regimes to be adopted for all winders irrespective of their legal status.
9. Relevant training which emphasizes hazard recognition to be adopted for all operators and all those who may have reason to pass through areas where transport systems operate.
10. Upgrade SAMRASS system to improve user-friendliness.
11. Re-categorize data fields and link to enable easier search.

29. Engineering of the Wire Rope Test Database

By Harper G.S., CSIR Mining Technology,

Ref: SIM 04 05 03, 2005

SUMMARY:

The commissioning of the MFL, 15MN tensile test machine at the CSIR Cottesloe laboratory in 1989 was accompanied by the introduction of a computerised, up-to-date, rope test data and record keeping system. Since 1989, all hoist rope data as well as the tensile test results have been entered onto the database, generating a unique record of all hoist ropes used on South African mines. For completeness, the database also includes data provided by Haggie Steel Wire Ropes (the other licensed statutory rope test facility). As a unique history of hoist rope performance, the database provides a centralised record that can be interrogated to verify mechanical performance as well as administrative details. As such, the database is accessed daily by shaft engineers and mine staff responsible for ensuring hoisting safety, and thus plays an essential role in mine safety management.

The value of the database lies in its integrity and much effort has been expended to ensure that this is not compromised. As the volume of data entered into the database has increased, the overall performance has degenerated. To recover the system performance and provide improved reliability and security a decision was taken to convert the database to the Microsoft SQL Server platform. The system has been running efficiently on this system since June 2004.

Previously, to obtain information about a particular rope, engineers, researchers and the DME (Department of Minerals and Energy) inspectors had to contact CSIR Mining Technology. To facilitate the easier access to the information contained in the rope-testing database, the decision was taken to provide a secure internet web-based interface. To maintain data security requirements the interface limits access to specific information based on the log in credentials of the user. This allows mine engineers to access any rope test certificate information they may require from their desk top PC’s whilst allowing researchers and the DME inspectorate more extensive access to rope-testing data and reports.

The website is hosted by CSIR Mining Technology and can be accessed at http://ropetest.csir.co.za. Users may register for access to the site online and will be granted immediate ‘Mine’ level access by default. DME representatives and SIMRAC researchers requiring a higher level of access can have their access level upgraded to the required level on submission of a request to Miningtek@csir.co.za.

At the 'Mine' user level the facilities available include:

- Searching for certificates
- Printing of certificates
- Creation of a rope test application form (During this process the system will identify any ropes overdue for testing)
- Printing of an application for rope testing
- Submission of a request for testing by E-Mail
- Printing of an MD208 form

At the 'SIMRAC' (researcher) access level the user can, in addition to the facilities available to the 'Mine' user, access the following facilities:

- Detail SQL (Standard Query Language) searching of the rope testing results in the following databases:
  - Rope Test
  - New Rope Tests
  - Special Rope Tests
- Viewing of all the detail of the test results with the actual load extension curves.
- Downloading of the actual data of the load extension curves to an Excel Spreadsheet
- Copying of the load extension graph to the clip board for use in user documents

DME users have access to all the preceding features plus access to the following additional features:

- A history of the testing at individual mines with highlighting of tests where the period between samples, the delivery for testing or the actual testing has exceeded the permitted time
- A listing of ropes identified as overdue for testing
- A download (to excel) of the results of all tests conducted in the past six months.

The database accessed by the web site is a mirror of the 'live' database and is updated on a daily basis and therefore will show the results of all tests except those conducted in the past 24 hours.

30. Review and consolidate the Hazard Identification and Risk Assessment (HIRA) relating to trackless mobile equipment and compile a list of significant OHS-related risks associated with the design, selection and use of trackless mobile equipment

By James J.P., Schutte P.C., van Dyk T., Cornelissen R., Naidoo D., Mnisi M., CSIR NRE Mining, Ref: SIM 05 05 02, 2006

SUMMARY:

This research report discusses the key findings of the review and consolidation of the Hazard Identification and Risk Assessment (HIRA) process specific to trackless mobile equipment (TME) at selected South African surface and underground base mineral, coal and platinum mines. The purpose of the study was to compile a list of significant occupational health and safety (OHS) related risks with the design, selection and use of TME.

In order to achieve this output, it was essential to determine the types of TME used at base mineral, coal and platinum mines. Various focus group meetings were conducted at selected mines to determine the current concerns specific to TME design, operation and environmental conditions. Attendees at the focus group meetings included engineers, safety specialists, occupational hygienists, trackless mining managers, and maintenance personnel. Focus groups were followed by the objective and subjective evaluation of the existing fleet of trackless machines to determine the engineering, ergonomics, occupational hygiene, and safety aspects affecting human performance and human-machine interaction. Basic checklists were used during the fieldwork phase to identify OHS-related risks specific to TME de-sign, operation and use.

Aspects covered during the field work included:

- TME engineering design;
- Operator cabin design and vehicle ergonomics;
- Occupational hygiene exposure to noise, dust, diesel fumes, and heat;
- Safety practices in trackless sections, including

evaluation of trackless COP; and
- Driver interviews.

Analysis of fieldwork findings revealed a number of design, operational and environmental concerns with regard to TME. The following significant OHS risks were identified:

Engineering
- Poor TME operator cabin design and/or open vehicle cabins;
- Unrestricted access to electrical components on electrical TME;
- Poor TME illumination design configuration;
- Poor standard of vehicle maintenance leading to hydraulic and/or mechanical failure; and
- Confined space in “retro-fitted” mine vehicle cabins.

Ergonomics
- Unclear controls and displays in TME;
- Restricted vision (obscured line of sight) from the driving position;
- Restricted driver cabin space;
- Difficult vehicle access (ingress/egress) for the operator;
- Exposure to whole-body vibration (WBV); and
- Excessive manual materials handling (MMH) for workshop personnel fitting TME parts.

Occupational hygiene
- Noise exposure from vehicle and underground workings;
- Dust exposure from TME and underground workings;
- Heat exposure from vehicle and underground operations; and
- Diesel fume exposure due to cabin design and operational issues specifically due to poor maintenance.

Safety
- Poor illumination systems on TME;
- Lack of roll-over protection on vehicles;
- Unrestricted movement of trailing cables Poor positioning of fire extinguisher equipment for easy access;
- Poorly maintained fire extinguisher equipment on vehicles;
- TME tyre fires and/or fires in tyre stores;
- Slippery surfaces on TME or in workshops resulting in slips and falls; and
- Poor visibility of TME due to the absence of reflectors and/or warning decals

Various workshops and manufacturer visits were then conducted to discuss the findings of the HIRA conducted at the project mines. These interactions included discussions on the current design process used by South African TME suppliers. The key concern with the current TME is the lack of a South African operator-specific design, with a focus on the local workforce. It is recommended that the design of TME be conducted by considering the anthropometry of the user population, which has recently been collected on the mining workforce, and by using updated human-centred modelling packages, which allow the operator positioning to be simulated to ensure that TME design fits the use requirements for mining purposes. It is further recommended that all interested and affected parties (manufacturers and suppliers) be involved in the practical implementation, manufacture, and installation of any TME interventions and conceptual design changes to trackless machines. This is essential in terms of Section 21 (1) (c) of the Mine Health and Safety Act (Act 29 of 1996).

31. Project Scope for Low-Noise Drilling

By O’Brien T.M., Harper G.S., Mnisi M., Dr Dias B., Naidoo D., CSIR, Ref: SIM 05 05 01, 2006

SUMMARY:
The timeline imposed by the Mine Health and Safety Committee’s (MHSC) milestones set during their 2003 annual summit poses severe limitations on the introduction of new or alternative technologies by December 2008 and December 2013.

In order to meet the 2008 milestone of no more than ten per cent deterioration in hearing among occupationally exposed individuals, any new technology envisioned for use must

already be in the advanced prototype stage of development. The 2013 milestone of less than 110 dB sound pressure levels at any place in the workplace is a marginally better time frame for the introduction of new technology, although the identified equipment would again need to be in a relatively advanced form of concept demonstrator or newly emerging prototype. It is thus inconceivable that the total replacement of the South African de facto tool for hole-making, the pneumatic rock drill, with a new technology will be achieved within this time period.

Further implications of the 2008 and 2013 milestones, at a machine specific level, are the unacceptable noise levels emitted by unsilenced pneumatic machines, rendering these drills immediately in breach of the 2013 milestone. These machines will need to be revisited and modified, by the minimum addition of mufflers, and it may be expeditious to the prevalence of noise-induced hearing loss (NIHL) to impose an immediate and outright prohibition on the use of unmuffled or unsilenced drills.

Of the equipment currently available, only the electric, muffled pneumatic and water-hydraulic drills have the potential to repeatedly emit less than 110 dB in an underground environment. However, the use of multiple drills in a stope, while increasing the incident sound pressure levels, offers an approach to the issue concerning equivalent operator exposure, viz:

- An optimum point exists in the number of drills required to complete the panel versus the equivalent noise level exposure (at higher incident pressure levels for shorter duration) experienced by the drilling crew.
- Placing more drills in a stope will increase the cost of hole production, in terms of increased capital expenditure, maintenance and labour costs.The point above may in fact disregard the 2013 milestone of the MHSC. Unless exemption is obtained in terms of proven equivalent operator exposure, this scenario may not be viable. Further, and implicit in the above discussion is a demand that the workforce is equipped with adequate hearing protection and educated in such a way that the ramifications of ignoring personal safety and of the long term effects of NIHL are understood and internalised.

Examining the spectrum of sound emitted from an unmuffled pneumatic and an electric drill, sensitivity analyses show that the greatest influence on sound pressure levels is obtained by addressing the higher frequencies, i.e. those above 2 000 Hz. This frequency is characterised by ringing of the drill steel, resonance of steel components within the drill and the expansion of air from the exhaust ports of a pneumatic machine. It is also noted that the drill steel is common to all drills, irrespective of the motive power, and concentrated research into this factor may facilitate an immediate and industry-wide acceptable reduction in noise levels.

The outcomes from a facilitated workshop with the affected industry highlighted several key issues, viz:

- Buying-on-price was highlighted as hindering the introduction of quieter drills to the marketplace. Contracts were being awarded, despite the publication of the MHSC milestones, for unmuffled drills, as these are cheaper options to their muffled counterparts.
- Buying-on-price has a minimizing effect on the drill manufacturer's ability to generate funding to support research and development activities. Similarly, manufacturers were not prepared to self-fund the development of alternatives that were unlikely to be purchased by mines. The basic principles of business predominate.
- From the foregoing, access to state research and development (R&D) funding could prevent the symbiotic mine-manufacturer-R&D relationship.
- The basis of measurement by the inspectorate for compliance with the MHSC milestones was raised as a concern, and the need was alluded to for the publication of standard methods and codes of practice. The manufacturers require these in order to gauge development and product compliance, while the mines need

clarity on the ways in which they will be judged.
- The general culture within the mining industry is of concern, and extends beyond the drill operator to include production bonus schemes, supervision of drillers, maintenance of equipment (particularly that of the air-supply lines and provision of adequate air pressure), purchasing procedures, and the management of noise in general.

The workshop concluded with a matrix of results to be achieved against known issues and concerns. The overarching drivers to this matrix are the MHSC milestones, as published, and are taken as the overall desired results to achieve and enabling statements. While the matrix is extensive and all points must be taken cognisance of, the following four functions were derived as the critical minimum that will achieve the greatest benefit:

- Changes to the industry culture;
- The management of time-equivalent exposure to drill noise;
- The application of technologies to reduce noise; and
- The application of appropriate standards, both for the measurement of noise and the specification of equipment.

While technology is only one of the four functions recognised in the holistic noise management process, it can also be seen as having a causal function; i.e. the deployment of alternate technology allows the development of new standards, the management of noise exposure, and the potential to change culture among the users of that technology.

Technology is therefore a key element to the management of noise-induced hearing loss. Addressing the technologies available that hold promise for development and eventual deployment as viable mining tools, it is reiterated for emphasis that work must continue on the currently available pneumatic, water-hydraulic and electric drills. Specific areas for research centre on the need to reduce frequencies in the higher end of the emission spectrum, typically associated with exhaust noise (pneumatic) and the resonance of the steel components. Implicitly included here is the continuation of previously sponsored MHSC work on totally enclosed and remotely operated drills. In terms of emerging or new technologies, a number of areas have been identified for study, with appropriate indications of expediency for implementation.

32. Brake testing of trackless mobile mining machinery

By Ottermann R.W., Burger N.D.L., von Wielligh A.j., University of Pretoria, Ref: SIM 04-05-02, 2006

SUMMARY:
The aim of this project is to develop an in-service brake testing specification for trackless mobile mining machinery of less than 50 ton. The primary output of this project is an in-service brake testing specification for trackless mobile mining machinery to be used as a maintenance tool/aid. Mines with trackless mobile mining machinery will use this specification for the testing and in-service verification of brakes as an input to maintenance to minimize the risk of brake system related accidents, preventing runaways of vehicles, thereby saving lives.

The proposed brake test specification developed during phase 1 of the project was amended to include recommendations of a workshop attended by interested parties from mining houses, Original Equipment Manufacturers (OEM's), the DME and SIMRAC. The test specifications as well as the electronic brake testing equipment were evaluated during tests done at the Gerotek test track. The brakes of five different size vehicles with different braking systems were tested with all the available electronic brake testing equipment and evaluated against the SABS 1589:1994 specification. A risk assessment was done on the Simret 3000 electronic brake tester.

The brake test specification was then implemented at Leeupan Collieries, Kumba. Personnel responsible .for the testing were trained in the test procedure as well as the use

of the electronic test equipment. The mine was visited on a regular basis to evaluate the tests. Tests were also done at Kromdraai Colliery.

The implementation and evaluation of the test specification on the mines provided valuable information on the use of the brake specification. The following is recommended on the use and application of in-service brake testing:

- The in-service brake test specification developed can provide meaningful input for maintenance requirements on vehicle brake systems.
- The information gathered during this project can be used as input during the development of a national standard for the testing of brakes of Trackless Mobile Mining Machinery by the SABS.
- The standard should address the accuracy and repeatability requirements of the brake testing instrument to be used.
- Tests have shown that the test specification is applicable for hydrostatic as well as mechanical drive vehicles.
- Test personnel need to be properly trained in the test procedure and the use of the test equipment.
- Systems need to be put in place to ensure that tests are done at prescribed intervals.
- Proper records of tests need to be maintained. Tracking software can be useful to keep track of the brake performance and indicate maintenance requirements.

CONCLUSIONS:

An in-service brake testing specification for trackless mobile mining machinery was developed during this project. Mines with trackless mobile mining machinery will use this specification for the testing and in-service verification of brakes as an input for maintenance to minimize the risk of brake system related accidents, preventing runaways of vehicles, thereby saving lives.

The status of brake testing of trackless mobile mining machinery in the platinum, iron ore and coal sectors was established by visiting different mines. An investigation into what exists worldwide was done focusing on brake test specifications as well as in-service verification of brakes. From the investigation, electronic brake testing equipment was recommended for the in-service testing of brakes. Different electronic brake testing equipment was evaluated on different vehicles to determine the usefulness of this type of equipment. These tests were conducted at Leeupan Collieries, Kumba. A brake testing specification for trackless mobile mining machinery was compile which did meet the objectives of this study

33. Improvement of Noise-induced Hearing Loss awareness to target audiences in the South African mining industry

By Edwards A.L., Khoza A., Milanzi L., Letsoalo L., Zungu L.,, CSIR, Ref: SIM 11 05 01, 2011

SUMMARY:

The current study aimed to review previous research outcomes relating to Noise-induced Hearing Loss (NIHL) awareness and Hearing Protection Device (HPD) practices, with a view to identifying the recommendations from the previous research, and evaluating whether they were still relevant in the current era and whether current practice in the mining industry had implemented the recommendations from the relevant South African mining industry studies.

The finding of the review was that previous recommendaions were still relevant in the current era and that they, and other more recently identified resources, should be implemented for optimisation of the hearing conservation programmes (HCPs) and practices in the mining industry. The results of the investigation were developed into an eBook of NIHL prevention resources for use by HCP practitioners at mines in all commodities. The checklists identified in the review were adapted for use in the second phase of the study to be used as survey tools to determine what the current practices in the industry were regarding NIHL awareness training and HPD practices, in order to identify the needs and requirements for

optimisation of these practices.

The survey of current practices of NIHL awareness training identified ten criteria by which the NIHL awareness training programmes and practices at mines were evaluated and the gaps identified in the best practices. The identified gaps facilitated the development of the recommendations. Five criteria were identified for the HPD practices and the current practices were evalu-ated against these criteria to identify gaps and develop recommendations. The results are sum-marised in tables 5 to 8 in the main report.

CONCLUSION:

The findings of the review of previous research directed the selection of the contents for the resource booklet for hearing conservation practitioners in the SAMI. The contents have been developed into an eBook, which has useful tools and links for implementation in the mining industry to improve current awareness training programmes and to provide managers with information to direct the management of NIHL prevention programmes.

The results of the literature review indicate that there is a great deal of materials available for improved awareness and that practitioners need to implement the most useful of these methods and resources in practice. The findings also indicate that much is already known about the reasons for non-compliance with HPD use and requirements for effective awareness training for various target audiences. The information gained from the review wasincorporated into the survey that was conducted at mines concerning the current practices regarding NIHL risk awareness training and HPD use.

34. Track B – Noise Controls: New Technologies (Drilling)

By Brink A.V.Z., Harper G., Prof. Theron N., Heukelman H., Kok J., Ilgner H.J., Johnson D., CMI, CSIR, Ref: SIM 050501, 2012

SUMMARY:

The proposed project deliverables were to:

- Quantify the status of new technologies (plasma and high-frequency or ultrasonic drilling) with respect to their potential development as appropriate blasting and support-hole-making devices, including possible health effects
- Undertake a baseline technical study to establish the feasibility of alternative percussion-actuation techniques and frequency control
- Develop a business case detailing the viability of developing each of these new technologies.

Project Outcomes:

Plasma drilling - Investigated and found not to be ready for commercialization. Plasma drilling is achieved by generating plasma by means of a high-energy electrical discharge though a dielectric medium, typically through low conductive water. A shockwave is generated that may break the rock under compression. Subsequent development by Tetra Corporation has allowed the plasma to be generated in the rock itself, resulting in heating and expansion behind the surface and therefore breaking of the rock in tension.

Ultrasonic rock drilling - Percussive drilling at ultrasonic frequencies with low noise in the audible frequency range was found to be possible but not viable yet.

Ultrasonic rock breaking - It was found that focused ultrasound with a piezoelectric ceramic cannot be used for drilling into rock.

The idea of using ultrasonic waves to accomplish this task was inspected, modelled, tested and evaluated. It was found necessary to focus these waves at a point. These focused waves will have to create enough energy to overcome the fracture energy of 17.5 J/m2. For a focal bowl made of one of the highest-energy-creating ultrasonic ceramics, namely piezoelectric ceramic 4 (PZT 4), the radius needed is 135 km.

Feasibility of alternative percussion techniques - Eight technologies/mechanisms were

investigated. The coil gun approach and the Hydraulic Sonic Water-Hammer are suggested for further investigation.

The potential mechanisms and technologies considered as a possible replacement for a hand-held rock drill include the following:

- Electro-Magnetic, including coil guns
- Electric Discharge
- Ultrasonic / Piezo-Electric
- Magnetostriction
- Hydraulic Sonic Water-Hammer Thermal Laser impact (ablative drives) Thermal expansion Shape Memory Materials

Many of the technologies and mechanisms could be immediately discounted on the basis of general mining, environmental, safety and health constraints. When not discounted immediately a very basic preliminary analysis of the technologies was conducted as described in the report.

Development of a business case - Neither plasma drilling nor ultrasonic drilling is seen as an alternative drilling technology ready for industrialisation in South Africa. The latter technology is simply not technically possible, but as far as plasma (or electric discharge) drilling is concerned, it is the researcher's view that the technology is not ready for large scale industrialisation

Follow-up Work proposed:
Two potentially viable methods capable of replacing the current percussion mechanisms of pneumatic and hydraulic hand-held rock-drills are the coil gun approach and the Hydraulic Sonic Water-Hammer. It is recommended that both these technologies should be further investigated.

35. Noise controls for mining equipment

By Kroch R.C., Ottermann R.W., Heyns P.S., Business Enterprises at University of Pretoria, Ref: SIM 12-05-01, 2014

SUMMARY:
This report presents a summary of project SIM 12-05-01 and constitutes milestone 4 of that project.

Prior to this project, preliminary work was conducted during SIM 05-05-01 where the following was achieved

- Development of a methodology for noise reduction on mining equipment
- Construction of prototype silencers for a demonstration scrubber
- Development and demonstration of an above-ground noise measurement standard
- Development of an underground noise measurement standard
- Development of a methodology for prediction of underground noise level.

This work was described in the report "Noise controls selection and design methodology for mining equipment" (Eksteen & Botha 2012).

A specimen on which to apply the principles contained in SIM 05-05-01 was required, and a scrubber was selected in that project. This project aimed to expand the work done in that project on the scrubber specimen with the following objectives:

- Experimental evaluation and of the application of the developed methodology for the design of noise controls for mining equipment
- Demonstration and application of the developed standard for underground noise measurements
- Projection of underground noise measurements

In fulfilment of these objectives, a number of measurement campaigns were undertaken, both above ground and underground. These

measurements formed input and verification parameters for the projection of underground noise levels.

Using the silencers designed in SIM 05-05-01, and designing second generation silencers after testing the first generation, the sound power level reduced from 116.3 dBW (unsilenced) to 105.0 dBW (first generation silencers) to 101.7 dBW (second generation silencers). The sound power consequently reduced form 0.4W to 0.031W to 0.015W (for the unsilenced, first generation silencers and second generation silencers respectively).

Furthermore, acoustic measurements were done above ground to determine acoustic factors such as direct field and sound power to predict the underground noise. The noise was then measured underground to validate the findings. An acoustic point source (for methodology verification), scrubber and silenced scrubber were measured underground. The finite element model often over predicted the sound level by between 5 – 7 dB. This figure improved significantly when measurements in the acoustic far field were considered, where an accuracy of less than 4 dB were the norm.

CONCLUSION AND RECOMMENDATIONS:

- Use the developed methodology for noise reduction on mining equipment to reduce noise levels in mines.
- Encourage OEMs to make use of the technology developed to reduce noise levels of mining equipment.
- Use the prediction methodology to predict noise levels of mining equipment underground.

36. PDS-Machine Interface Requirements

By Sabatta D., CSIR, Ref: SIM 130502, 2014

SUMMARY:

The goals of this milestone were to investigate the risks associated with PDS-machine interfaces, specifically related to problems caused by differing interface protocols between machinery and PDS suppliers. The identification of these problems was limited to the champion mines that were identified in the initial call for proposals.

After communicating with the champion mines, most reported fully functional PDS installations with no integration issues being experienced. Integration issues related to the installation of vehicle-to-person PDS systems onto rail-bound locomotives were reported at one mine, although these issues were more related to the suitability of the PDS system for rail-bound use, rather than difficulties interfacing with the existing system. Following the absence of any notable integration issues present at the champion mines, we began contacting machine and PDS suppliers to obtain their experiences with the integration process.

The machinery and PDS suppliers provided many examples of fully integrated systems. Many of these however were simply driver warning systems, removing the need to interface directly to the machinery control systems. Each installation is handled on a case-by-case basis by the PDS suppliers, often with modification of their systems to allow integration with the target machinery. These findings have led us to believe that integration issues, while present, are not particularly hard to overcome may have already been largely resolved by the community in the time period between the initial proposal of the project and the delivery of this milestone (>1 year).

Despite the successful installation of PDS systems at many mines, there are two recommendations that can improve the integration process.

1. To improve mine management buy-in to negotiate with the machine suppliers to provide the necessary interface protocols for integration.
2. To investigate the possibility of standardisation of interface protocols to ease the integration process.

CONCLUSION:
We undertook this milestone of the project with the intent of identifying PDS-machine interface related problems currently being experienced at the champion mines. When I failed to find significant problems at the champion mines, I started contacting mining machinery and PDS suppliers to obtain their views.

What I found was records of thousands of operational PDS systems installed onto mining machinery both locally and abroad.

That being said, each of these installations is customised and adapted to the specific case being handled, often by creating additional interface/add-on boards or modifying the default PDS systems to interface to the machines. These findings have led me to believe, that while integration related problems may exist, they are easily overcome on a case-by-case basis, and therefore do not present a significant hurdle in the installation of PDS systems at mines

37. A Global Survey of Systems and Technologies Suitable for Vehicle to Person

By Dickens J., CSIR, Ref: SIM 130501, 2014

SUMMARY:
This one year study was conducted to investigate proximity detection systems (PDSs) and technologies suitable for vehicle-to-person (VTP) collision avoidance on underground rail-bound equipment. The aim of the research was to:

- Determine the requirements for underground VTP PDS.
- Explore the capabilities and limitations of current PDSs.
- Compile a list of candidate technologies or systems for underground VTP PDS on rail-bound equipment.
- Explore, in detail, the promising technologies for a VTP PDS for underground rail-bound systems.

The first phase of the research investigated the capabilities and limitations of current PDSs given the requirements for VTP PDS on underground RBE. The hypothesis, hat no commercially available VTP PDSs exist for underground RBE, was confirmed by the research. No systems designed for rail-bound VTP PDS could be found and PDSs designed for other applications are unsuitable. The second phase investigated the technologies for VTP PDS on underground RBE, as well as identifying and analysing the major issues limiting the use of current systems. The analysis of the issues surrounding VTP PDS and potential solutions produces two main outcomes. The first outcome



is that VTP PDS cannot be seen as the solution to prevent all RBE accidents. There are certain accidents that can be prevented using a VTP PDS and others that can be better prevented using other methods, as shown in Table 1. The second outcome is that VTP PDS can assist in preventing accidents where a worker being struck by a train while walking next to or in front of it, which is identified as the most important cause of RBE accidents.

Ranking	Cause	Control measure
1	Walking near RBE	Hand-held remote for the guard VTP PDS Well-constructed and maintained haulages with sufficient clearance
2	Derailment	Ensure track is laid and maintained to a high standard Prevent excess speed on bad track
3	Collision	Vehicle-to-vehicle PDS Interventions to prevent drivers/guards attempting to get out of the vehicle before a collision Automate ventilation doors
4	Travelling on RBE	Ensure equipment is properly designed to safely transport people Processes to prevent workers illegally riding in hoppers or locos
5	Coupling	Semi-automatic couplers Recognition of coupling hazards PPE

Table 1: RBE accident causes and possible control measures

The result of an evaluation of PDS technologies was that there are four VTP PDS technologies that show the most promise. These are;

- mine-wide vehicle and personnel tracking,
- a system based on
- a system of beacons identifying danger areas,
- a system combining radar, RF and magnetic fields.



"Zero Harm to employees and communities as a result of mining activities"

Notes:





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