EXECUTIVE 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:

? 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 was evaluated to determine the content of such data which was appropriate for local use.

The findings of the project team are that:

? Local rail system accident rates are substantially higher than those of the selected other 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 system equipment and components, although national standards for locomotive controllers and rail track are currently being prepared.
? In general manufacturers do not work to any written standards of their own, but manufacture equipment to meet the requirements of individual mines or mining houses.
? 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 within the last 20 years.
? Rail system accidents account for approximately 10 per cent of all accidents, all fatal accidents and all accidents involving injury.
? Of interest is the fact that the percentage of accidents involving rail systems has declined over the past decade and a half. This might be due to changes in mine manpower structures or could be the result of the implementation of the recommendations of the 1984 symposium on underground transport.
? Approximately 85 per cent of rail system accidents are ascribed to some form of human error.
? In approximately 80 per cent of the accidents the victim was to blame for the accident.
? Worker discipline and safety awareness is generally of a low standard.
? Supervisors were observed to exhibit undisciplined behaviour themselves and in general were not seen to reprimanding workers who were not working in accordance with Regulations, Codes of Practice or instructions.
? 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.

Suggestions have been made for changes to legislation, additions to Codes of Practice and for matters to be considered for the compilation of a national standard for rail equipment and components.

Most of the accidents resulting from people travelling in or on vehicles, coupling and hitting obstructions are caused by human error. However, in some cases the equipment design or maintenance is to blame.

Based on the frequency with which accidents are caused by human error, a major focus on those aspects leading to such a high incidence is proposed.

Observed worker performance indicated a very low level of discipline among workers which can only be partially addressed by the inspectorate or management. Safety is not only the responsibility of management and the Department of Minerals and Energy. Workers should be encouraged to take responsibility for their own and their colleagues’ safety. In this regard management and the workers, with the encouragement of their trade unions, should actively promote safer working practices on rail systems.

With reference to matters concerning human error related accidents, the following matters require attention from management:

? Improving workers’ cognitive skills during training, in preference to rote learning.
? Requiring locomotive drivers in training to first complete a prescribed time as guards.
? Applying stricter disciplinary measures when workers, and in particular supervisors, are found to be working unsafely.
? Carrying out regular audits of the rail transport systems in the mine, focusing in particular on those issues which result in most accidents. In this regard, observations during night shifts indicated that this is the time when conditions are at their worst.

In addition, the trade unions should encourage their members to:

? Adhere to the Regulations and Codes of Practice intended to ensure their safety.
? Adopt a process of self policing.
? Accept the need for, and application of, stronger disciplinary measures against offenders.
? If possible adopt a more co-operative role together with management, as compared to a confrontational attitude, to promote a safer working environment on the mines.

Table of Contents
Executive Summary .......................................................................................... 1
List of Figures .................................................................................................. 8
List of Tables .................................................................................................. 9

1 Primary output ................................................................................................. 9
1.1 Survey ........................................................................................................... 9
1.2 Recommendations ....................................................................................... 9

2 Underground rail transport accidents - the historical perspective ............ 9

3 Analysis of available accident statistics ...................................................... 10
3.1 Accident reports ........................................................................................... 10
3.2 Data capture ................................................................................................... 11
3.3 Analysis methodology ................................................................................... 11
3.4 Activities ....................................................................................................... 12
3.5 Category or job of the person involved in the accident............................... 13
3.6 Type of vehicle or machine involved ............................................................. 13
3.7 Type of injury ................................................................................................. 13
3.8 Site of the accident ........................................................................................ 13
3.9 The Inspector’s reason for the accident ......................................................... 13
3.10 Time of day when accidents occurred ......................................................... 13

4 Results of the analyses ................................................................................... 14
4.1 Contextual relationship between accidents involving rail mounted equipment and all accidents on gold and platinum mines ......................... 14
4.2 Activities ....................................................................................................... 14
4.2.1 Ranking of all rail accidents ........................................................................ 15
4.2.2 Ranking of fatal rail accidents ..................................................................... 15
4.2.3 Combined ranking ....................................................................................... 16
4.2.4 Comparison with the study by T J Binks (Binks T. J. 1984: 197-216) ............ 17
4.3 Category or job of the victim ......................................................................... 17
4.4 Type of vehicle or machine .............................................................. 17
4.5 Type of injury .................................................................................... 18
4.6 Site of the accident ........................................................................... 18
4.7 The inspector’s opinion of the reason for the accident ................. 18
4.8 Conclusions from the detail accident report form, section B ...... 19
4.9 Time of day when accidents occurred ............................................ 19
4.10 Comparison with study by T J Binks (Binks T.J. 1984: 197-216) . 20
4.11 Comparison between the South African accident statistics and those of other countries .................................................................................................................. 20
4.12 Results of detailed analysis of enquiry files ............................ 21
4.13 Matters requiring further investigation ............................................. 22
5 Workers’ attitudes ............................................................................. 23
5.1 Comments on statistics and observations ...................................... 23
5.2 Addressing the high incidence of human error ............................... 23
6 Introduction to regulatory framework .............................................. 24
6.1 South Africa ...................................................................................... 24
6.2 United Kingdom ................................................................................ 24
6.3 Australia ............................................................................................. 25
6.4 United States of America ................................................................. 25
7 Format for regulations ......................................................................... 25
8 Standards ............................................................................................ 26
8.1 South Africa ...................................................................................... 26
8.2 United Kingdom ................................................................................ 26
8.3 Australia ............................................................................................. 26
9 Comparison of international requirements ...................................... 26
9.1 System management .......................................................................... 27
9.1.1 Code of practice and/or manager’s rules ....................................... 27
9.1.2 Train control, signals and communications ............................. 27
9.1.3 Pedestrians .................................................................................. 27
9.1.4 Clearances ................................................................................... 27
9.1.5 Refuge holes ................................................................................ 27
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1.6</td>
<td>Fencing of walkways</td>
<td>27</td>
</tr>
<tr>
<td>9.1.7</td>
<td>Track inspection</td>
<td>27</td>
</tr>
<tr>
<td>9.1.8</td>
<td>Propelling</td>
<td>27</td>
</tr>
<tr>
<td>9.1.9</td>
<td>Transport of persons</td>
<td>28</td>
</tr>
<tr>
<td>9.1.10</td>
<td>Loading and discharge areas</td>
<td>28</td>
</tr>
<tr>
<td>9.2</td>
<td>Locomotives</td>
<td>28</td>
</tr>
<tr>
<td>9.2.1</td>
<td>Brakes</td>
<td>28</td>
</tr>
<tr>
<td>9.2.2</td>
<td>Brake performance</td>
<td>28</td>
</tr>
<tr>
<td>9.2.3</td>
<td>Deadman’s device</td>
<td>28</td>
</tr>
<tr>
<td>9.2.4</td>
<td>Unauthorised starting</td>
<td>29</td>
</tr>
<tr>
<td>9.3</td>
<td>Rolling stock</td>
<td>29</td>
</tr>
<tr>
<td>9.3.1</td>
<td>Couplings</td>
<td>29</td>
</tr>
<tr>
<td>10</td>
<td>Discussions with regulatory and standards organisations</td>
<td>29</td>
</tr>
<tr>
<td>11</td>
<td>Mine visits</td>
<td>30</td>
</tr>
<tr>
<td>11.1</td>
<td>Methodology</td>
<td>30</td>
</tr>
<tr>
<td>11.2</td>
<td>Observations</td>
<td>31</td>
</tr>
<tr>
<td>11.2.1</td>
<td>System management</td>
<td>31</td>
</tr>
<tr>
<td>11.2.2</td>
<td>Codes of practice and/or manager’s rules</td>
<td>31</td>
</tr>
<tr>
<td>11.2.3</td>
<td>Pedestrian access</td>
<td>31</td>
</tr>
<tr>
<td>11.2.4</td>
<td>Supervision and discipline</td>
<td>32</td>
</tr>
<tr>
<td>11.2.5</td>
<td>Track standards</td>
<td>33</td>
</tr>
<tr>
<td>11.2.6</td>
<td>Clearances</td>
<td>34</td>
</tr>
<tr>
<td>11.2.7</td>
<td>Propelling</td>
<td>34</td>
</tr>
<tr>
<td>11.2.8</td>
<td>Locomotives</td>
<td>35</td>
</tr>
<tr>
<td>12</td>
<td>Rolling stock</td>
<td>36</td>
</tr>
<tr>
<td>12.1</td>
<td>Materials cars</td>
<td>36</td>
</tr>
<tr>
<td>12.2</td>
<td>Mineral cars</td>
<td>36</td>
</tr>
<tr>
<td>12.3</td>
<td>Man carriages</td>
<td>36</td>
</tr>
<tr>
<td>13</td>
<td>Other issues</td>
<td>37</td>
</tr>
<tr>
<td>13.1</td>
<td>Couplings</td>
<td>37</td>
</tr>
<tr>
<td>13.2</td>
<td>Loading and discharge areas</td>
<td>37</td>
</tr>
<tr>
<td>13.3</td>
<td>Training</td>
<td>37</td>
</tr>
<tr>
<td>14</td>
<td>Issues to be addressed based on the visits to mines</td>
<td>39</td>
</tr>
</tbody>
</table>
15 DME ‘Proposed Code of Practice for Trucks and Tramways’ ................................................................. 40

15.1 Walking/Standing/Lying ........................................................................................................... 41
15.2 Derailment/Rerailing/Trackwork .......................................................................................... 41
15.3 Collision/Obstruction ........................................................................................................... 41
15.4 Travelling on .......................................................................................................................... 41
15.5 Coupling .................................................................................................................................. 42
15.6 General comments .................................................................................................................. 42

16 Proposed regulations and codes of practice ........................................................................ 42

16.1 System management .............................................................................................................. 42

16.1.1 Regulations or contents of Codes of Practice .................................................................. 42
16.1.2 Communications .............................................................................................................. 42
16.1.3 Transport of explosives and abnormal loads .................................................................. 43
16.1.4 Control of train movements ............................................................................................ 43
16.1.5 Signals ............................................................................................................................... 43
16.1.6 Training .............................................................................................................................. 43
16.1.7 Runaway protection devices ............................................................................................ 43
16.1.8 Track systems ................................................................................................................... 43
16.1.9 Clearances ........................................................................................................................ 43
16.1.10 Track inspection ............................................................................................................. 44
16.1.11 Locomotives .................................................................................................................... 44
16.1.12 Passengers ....................................................................................................................... 45
16.1.13 Lights ................................................................................................................................ 45
16.1.14 Maintenance .................................................................................................................... 45
16.1.15 Couplings ......................................................................................................................... 45
16.1.16 Diesel engines .................................................................................................................. 45
16.1.17 Diesel locomotive workshops, service bays and filling stations ........................................ 45
16.1.18 Battery charging/changing stations ................................................................................. 45
16.1.19 Trolley systems ............................................................................................................... 46
16.1.20 Haulage lighting .............................................................................................................. 46
16.1.21 Propelling ......................................................................................................................... 46
16.1.22 Conveyance of persons .................................................................................................. 47
16.1.23 Parking ................................................................................................................................ 47
16.1.24 Marshalling ...................................................................................................................... 47
16.1.25 Discharge areas ............................................................................................................... 47
16.1.26 Loading areas ......................................................................................................48
16.1.27 Conduct of persons ..............................................................................................48
16.1.28 Guards ...................................................................................................................48
16.1.29 Re-railing ...............................................................................................................48
16.1.30 Load retention .......................................................................................................48
16.2 Proposed standards.................................................................................................48
16.2.1 Locomotives .........................................................................................................49
16.2.1.1 Brakes ................................................................................................................49
16.2.1.2 Safety devices ....................................................................................................49
16.2.1.3 Driver’s cab and controls ..................................................................................49
16.2.1.4 Lights ...................................................................................................................50
16.2.1.5 Diesel exhaust systems ......................................................................................50
16.2.1.6 Traction batteries ...............................................................................................50
16.2.2 Track standards ....................................................................................................50
16.2.3 Rolling stock ..........................................................................................................51
17 Implementation of the recommendations of the Association of Mine resident Engineers symposium ........................................ 51
17.1 Discipline ..................................................................................................................51
17.2 Locomotive design with respect to driver’s comfort .............................................51
and driver’s field of vision ...............................................................................................51
17.2.1 Driver’s comfort ....................................................................................................52
17.2.2 Driver’s field of vision ...........................................................................................52
17.3 Trackwork .................................................................................................................53
17.3.1 Track construction .................................................................................................53
17.3.2 Track system maintenance ...................................................................................53
17.4 Tramming procedures and controls .........................................................................54
17.4.1 Pre-use inspection of locomotives and hoppers ..................................................54
17.4.2 Lights .....................................................................................................................54
17.4.3 Signalling ................................................................................................................54
17.4.4 Traffic control system ..........................................................................................54
17.4.5 Pushing and pulling of a train ..............................................................................55
17.4.6 Tramming through ventilation doors ....................................................................55
17.4.7 Ambient lighting ...................................................................................................55
17.4.8 Precautions against noise ....................................................................................56
List of Figures

List of Tables

Table 4.1 : Decline in Accident, Fatality and Injury Rates of all Accidents and Rail System Accidents ................................................................. 14

Table 4.2.1 : Ranking of all Accidents Involving Rail Systems .............................................. 15

Table 4.2.2 : Ranking of Fatal Accidents Involving Rail Systems ........................................... 16

Table 4.2.3 : Ranking of the Most Important Causes of Rail System Accidents ...................... 17

Table 4.9 : Time of Day when Rail Accidents Occurred .......................................................... 20

Table 4.10 : Comparison of Time of Day Rates for this Project and the Binks Study ............... 20

Table 4.12 : Comparison of Region 3 and Region 2 Fatal Statistics ....................................... 22
1 Primary output
In terms of the contract for the SIMGAP 520 Project, the primary outputs are as follows:

1.1 Survey
A survey of underground rail systems in South African mines, drawing comparisons with appropriate international standards.

1.2 Recommendations
Recommendations for additional measures to further improve rail vehicle safety. These recommendations to include:

- Recommendations for changes to legislation, if appropriate.
- Recommendations for mine Codes of Practice.
- Training recommendations and guidelines.
- Recommendations regarding the design, specification, installation, operation and maintenance of underground rail systems.

2 Underground rail transport accidents - the historical perspective
Quoting from the Opening Address given by the President of the Association of Mine Resident Engineers at the time of a Symposium into underground transport held in 1984, the following was said:

"At meetings of the Management Committee of the Mine Safety Division held towards the end of 1981 and early 1982, consideration was given to the following suggestions:

(i) That investigation into different types of locomotives, fittings and attachments, and the effectiveness of illumination for underground trains be combined on an industry wide basis in order to arrive at solutions and recommendations.
(ii) That information be obtained from mines on the question of: Whether drivers had sufficient vision from the cabs of locomotives, and the general design of locomotives from an ergonomic viewpoint."

Further it was reported that “Accordingly it was agreed that the whole question of underground locomotive transport accidents be investigated by a special sub-committee which was duly instituted”. The results of these investigations formed part of the proceedings of the Symposium.

Since the Symposium, the mines have had 16 years in which to implement the recommendations made at the time. However, rail accidents continue to constitute a unacceptably high percentage of accidents on gold and platinum mines in South Africa.
In the light of the above, one focus of this project was to determine:

- what improvement in accident rates had been achieved;
- how many of the recommendations had been implemented;
- had the pattern of accidents changed, and if so in what way; and
- what can be learned from the developments over the past decade and a half.

3 Analysis of available accident statistics

3.1 Accident reports

The introduction of the Detail Accident Report Form MA-P-005 by the Department of Minerals and Energy was intended to provide additional information on the causes of mine accidents. The format of these Report Forms supports the inclusion of additional information which can be used to define accidents in some detail. However, due to the way in which they are being completed at present, identification of the exact causes of an accident, and the consequent measures that are needed to address such causes, are not readily apparent.

It is obvious that action was taken in mid-1995 to require the compilers of the reports to include more information than had been the case previously. Nevertheles, the type and extent of injury and the cause of the accident is still difficult to determine in many instances. As an example, if an accident resulted from re-railing a derailed vehicle, it is impossible to determine with any certainty whether the cause of the accident was:

- inadequate training;
- use of the wrong equipment, and if so, the availability of the correct equipment; or
- failure to follow laid down procedures or instructions.

To some extent this information can be deduced from Section 4.7 of the report dealing with the Inspector’s opinion of the reason for the accident.

The derailment in turn may have been caused by:

- track design;
- poor maintenance of the track;
- poor maintenance of the vehicle;
- excessive speed;
- wrong switch setting;
- incorrect coupling heights;
- spillage; or
- materials on the track.

While the mine concerned will be aware of the reasons for the accident and would presumably take steps to prevent a re-occurrence, for the purpose of reducing accidents industry-wide it is necessary to be able to identify trends. By so doing, campaigns for eliminating accidents throughout industry can be initiated.

Two typical “Detail Accident Report” forms, one of the less complete type and the other showing the detail in the more complete type are shown in Appendices A1 and A2.

Appendices B, C and D contain tabular data which is a précis of the information provided by the authorities responsible for health and safety in mines in the United Kingdom, Australia and the United
States of America. The information was in more detail than that shown in the Appendices. These tables indicate that much more detail is provided in the accident reports in these countries.

3.2 Data capture
Analysis of the accident reports for the period 1984 to 1997 indicated that some of the reports contained easily identified inaccuracies. As an example, an accident which occurred while loco batteries were being changed in a battery bay was listed under the category of “Diesel locomotive”. In other cases, inaccuracies were inferred from the information supplied in the report.

Such mistakes do not appear to be confined to the South African accident reports, since one of the accidents in the USA reports in the appendix states that fractured fingers resulted when a person’s foot was caught between couplings.

It is understandable that errors will occur in the accident reports, particularly in the light of the large number of mine accidents that occur locally. It is also acknowledged that, by virtue of the far greater number of local mine accidents compared to the abovementioned countries, the addition of more detail will necessitate a very substantial effort by the data capture staff, as well as more time being spent on the reports by the Inspectorate.

However, accurate and more detailed reporting will ensure that accident preventative measures are correctly focused. Failure to do so will mean that further projects of this type will need to be undertaken periodically to obtain the sort of information which should be readily acquired from an analysis of the accident reports.

3.3 Analysis methodology
Visits to mines in an attempt to identify reasons for accidents can at best only be partially successful. In the first instance, the presence of observers can have an effect on the work practices of the persons being observed. Secondly, the visits can only provide a “snap shot” of the ongoing operations.

In order to provide a better appreciation of the reasons for accidents, approximately 2000 Accident Report Forms were analysed.

Prior to 1988 accidents involving rail mounted vehicles and machinery were included in a category with free-steering vehicles, both underground and on surface, as well as other mineral and material transport systems. An attempt was made to normalise the results for the period 1984 to 1987 by including the accidents of other transport systems in the post-1987 data, and using the amended figures to derive a factor based on the original and amended results. This factor was then used to arrive at more representative pre-1987 data. However, this approach yielded results which were insufficiently reliable. Consequently, only the data for the period 1988 to 1997 was analysed in detail.

The following information was extracted from the reports:

? the activity at the time of the accident;
? the category of person involved in the accident, namely whether the person was part of the train operating team, a passenger in a train, a pedestrian or someone connected in some way with the horizontal transport system;
? the type of vehicle or rail mounted machine which had caused the accident;
? the type of injury sustained by the victim;
? the site where the accident occurred;
? the reason given by the inspector for the accident; and
? the time of day when the accident occurred.
3.4 Activities

The activities at the time of the accident were categorised as follows:

1. Coupling - injuries received while coupling vehicles.
2. Collision - a collision between a moving vehicle and another vehicle.
3. Derailment - injuries to persons who might have been on the train or next to the track caused by a derailment.
4. Re-railing - injuries to persons while re-railing derailed equipment.
5. Walking - injuries to persons who were either walking or standing next to or on the track. (Note - It would have been desirable to distinguish between these two activities, namely, walking or standing, but insufficient information on the report form precluded this.)
6. Lying - sufficient information was supplied to determine that in some cases the injured party had been lying on or next to the track. In some cases the report stated that the person was asleep at the time of the accident.
7. Obstruction - injuries to persons as a result of a collision with some part of the transport system, such as a partially open ventilation door or a loading chute, or with some permanent structure, the sidewall or the hanging.
8. Material on - injuries to persons through being struck by material being transported on a train.
9. Material off - injuries to members of the train operating team or a passenger on the train being struck by material at the track side.
10. Falling - injuries resulting from people falling into a excavation forming part of the transport system.
11. Trackwork - injuries to persons working on the track. This did not include injuries caused by the trackwork, but only injuries that were caused by being struck by a vehicle.
12. Tipping - injuries that occurred at the tip but excluding injuries listed as “Working on hopper”.
13. Machine parts - injuries caused by parts of the vehicle. This category excluded injuries caused by a part of the vehicle during another event such as a collision or a derailment.
14. Working on hopper - injuries resulting from work in a hopper, such as clearing large rocks or mud from a hopper.
15. Moving vehicle - injuries resulting from a person boarding, or alighting from, a moving vehicle.
16. Battery changing.

A statistically insignificant number of injuries resulted from the following activities:

? Crossing - this could involve a person being struck while crossing the track or crossing between cars in a train.
? Falling off - injuries caused by a person falling off a vehicle.
? Loading - injuries caused during the loading or off-loading of material onto or from a vehicle.
? Maintenance - persons being injured while maintaining a vehicle or component of a vehicle.
? Switching - injured while operating a rail switch.
? Spragging - persons injured while spragging a vehicle.
? Tramming - injuries caused during hand tramming of a vehicle.
? Starting diesel engine - injures to persons starting a diesel engine.

However, despite the low number of incidents incurred in the above activities, some of the activities resulted in fatal accidents.

In addition, although the South African statistics indicated that the above causes were of less importance, some of the activities, in particular loading, was a reasonably major cause of accidents in other countries for which data was available.
3.5  Category or job of the person involved in the accident
In most cases the job category of the person, or what the person was employed to do at the time of the accident, could only be inferred from the details given in the accident report. The inferred conclusions would undoubtedly result in some inaccuracy, but any such errors would not necessarily change the general trends that the analysis would identify.

As an example, a person recorded as having been walking or standing next to the track was not considered to be a member of the train team. That person may have been a passenger waiting for the train to stop, but was assumed to be someone walking to their place of work. A closer examination of the results of the analyses, as well as observed work practices during underground visits, indicated that this assumption was probably incorrect.

3.6  Type of vehicle or machine involved
The accident reports were studied to determine the type of vehicle, or in some cases, the type of rail mounted machine that caused the accident.

3.7  Type of injury
In the majority of reports it was possible to determine the type of injury sustained by the victim with a reasonable degree of accuracy. In certain cases the accident report form gave enough supporting information to deduce that injuries to the trunk were caused. In this respect the greatest degree of inaccuracy might have occurred since in many cases the report purely stated “Crushed”.

The seriousness of the injury was less simple to deduce unless the report stated that the person was permanently disabled or that a fatality had arisen.

3.8  Site of the accident
The places where the accidents occurred were analysed to determine whether this could have a bearing on the preventative measures needed to reduce the accident rates. The classification of the accident site was as follows:

- haulage;
- development end;
- cross cut;
- station or tip;
- reef drive;
- collection drive;
- return airway; or
- workshop.

3.9  The Inspector’s reason for the accident
In Section B - Regional Detail, of report Detail Accident Report MA-P-005, the inspector states the Department’s opinion of the cause of the accident. The causes are categorised. In addition, the inspector’s decision on whether a contravention of a regulation occurred is noted. Approximately 1700 reports were analysed to attempt to deduce the major accident causes. In addition, the analysis extracted information on the number of contraventions of regulations that, in the opinion of the Inspector, had occurred.

3.10  Time of day when accidents occurred.
This information was extracted in recognition of the differences in manpower numbers underground during the different shifts, and the differences in the supervisor to worker ratio that occur at different
times of the day. In addition, other matters such as unfamiliarity with the route or fatigue could also be factors at the start and end of a shift respectively.

For the purpose of this exercise, the accidents occurring in each three hourly period starting at midnight were grouped together.

4 Results of the analyses
4.1 Contextual relationship between accidents involving rail mounted equipment and all accidents on gold and platinum mines

During the period 1988 to 1997, accidents involving rail mounted vehicles and machines on gold and platinum mines accounted for:

- 12 per cent of all reported accidents;
- 10 per cent of all fatalities; and
- 12.5 per cent of all non-fatal accidents.

It is important to note that the statistics for rail bound accidents in terms of the number of accidents, injuries and fatalities has improved to a greater extent than the overall accident statistics for all accidents. Refer to Graphs 1, 2 and 3 in Appendix E.

Table 4.1 below summarises the results of 1997 against those of 1988. Note that these dates were not selectively applied but indicate the general trend which can be seen in the graphs.

<table>
<thead>
<tr>
<th>Percentage decline in:</th>
<th>All accidents</th>
<th>Rail system accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Fatalities</td>
<td>40</td>
<td>47</td>
</tr>
<tr>
<td>Injuries</td>
<td>30</td>
<td>66</td>
</tr>
</tbody>
</table>

The Vaal Reefs accident is an aberration which does not follow the overall trend. The positive trend with regard to rail system accidents could be ascribed to improvements resulting from the symposium referred to in Section 2. However, other factors, such as the increased average depth of operating mines, could change the pattern of mine accidents, which in turn could result in the incorrect inference that rail accidents have decreased in relative terms.

Despite the improvement in accident rates, a comparison with statistics available for other countries indicates that the South African accident rate is still extremely high. Refer to Graph 5 in Appendix E. In addition, the accident rates for platinum mines, for the limited period, mid-1995 to 1997, are substantially lower than those for gold mines. (Prior to mid-1995, at which time the statistics for the mines in Bophutatswana were incorporated into the SAMRASS system, the statistics are suspect due to possible under-reporting by the Bophutatswana Inspectorate.)

4.2 Activities

The most important single cause of accidents was the coupling of two vehicles, which accounted for 20 per cent of the accidents. The other major activities which resulted in injuries were walking next to the line, derailments, re-railing and collisions which together accounted for 51 per cent of all accidents.
Graphs 6 and 7 in Appendix E indicate the percentages of rail system accidents related to the various activities.

4.2.1 Ranking of all rail accidents
In accordance with the activity categories which were used for the analysis, the rankings in terms of frequency of occurrence of the more significant causes of all reportable accidents were:

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Activity</th>
<th>Percentage of all Rail Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coupling</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Walking</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Derailment</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Re-railing</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Collision</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Travelling on</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Trackwork</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Obstruction</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Tipping</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Lying</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Falling</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Machine parts</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Material off</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Material on</td>
<td>2</td>
</tr>
</tbody>
</table>

4.2.2 Ranking of fatal rail accidents
The frequency of occurrence of fatal accidents showed a completely different pattern to that above. The following is the ranking of fatal accidents. In addition, for comparison purposes, the results of a limited 24 month study undertaken from 1981 to 1983 by Binks (Binks T.J. 1984: 203) are shown.
### Table 4.2.2

**Ranking of Fatal Accidents Involving Rail Systems**

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Activity</th>
<th>Percentage of all Rail Accidents</th>
<th>Study by Binks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Walking</td>
<td>20.5</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Travelling on</td>
<td>18.5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Collision</td>
<td>13.5</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Derailment</td>
<td>5.5</td>
<td>41</td>
</tr>
<tr>
<td>5</td>
<td>Obstruction</td>
<td>5.5</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>Tramming</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Falling off</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Coupling</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Falling</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Trackwork</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Switching</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Changing batteries</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Note - In 18 per cent of the fatal accidents it was not possible to determine the activities of the victims from the accident reports. This highlights the inadequacies of the reports in the present form. Due to this shortcoming of the accident reports, an in-depth study of the enquiry files for the fatal accidents was undertaken. The results of this investigation are contained in section 4.12 below.

### 4.2.3 Combined ranking

Combating the circumstances that result in a fatal accident are of obvious importance. However, frequently occurring non-fatal accidents cannot be ignored. As an attempt to rank the activities in terms of both the seriousness as well as the frequency of accidents, the inverse of the above rankings in each table was added together for each activity, yielding what is referred to as a “Rank Number”. In other words if an activity is ranked first of 14 activities, the inverse ranking is 14. The Rank Number in the table below is expressed as a percentage of the highest ranking, by equating the highest Rank Number to 100 and using the same factor on the other Rank Numbers.

This approach yields the following overall ranking.

### Table 4.2.3

**Ranking of the Most Important Causes of Rail System Accidents**
<table>
<thead>
<tr>
<th>Ranking</th>
<th>Activity</th>
<th>Rank Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Walking</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Derailment</td>
<td>84</td>
</tr>
<tr>
<td>3</td>
<td>Collision</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Travelling on</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>Coupling</td>
<td>76</td>
</tr>
<tr>
<td>6</td>
<td>Obstruction</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>Re-railing</td>
<td>44</td>
</tr>
<tr>
<td>8</td>
<td>Trackwork</td>
<td>44</td>
</tr>
<tr>
<td>9</td>
<td>Falling</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>Tipping</td>
<td>24</td>
</tr>
<tr>
<td>11</td>
<td>Lying</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>Machine parts</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Material off</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>Material on</td>
<td>4</td>
</tr>
</tbody>
</table>

The above ranking identifies the activities which should receive most attention if accident prevention strategies are to be optimised.

**4.2.4 Comparison with the study by T J Binks (Binks T. J. 1984: 197-216)**

Interestingly the number of fatalities resulting from derailments had decreased from 33 workers per two year period during 1981 to 1983, to an average of three per two years for the period 1987 to 1997.

During the same period the number of accidents attributed to track bound vehicles declined from an average of 0.17 per 1000 employees per annum from 1980 to 1984 to 0.099 for the period 1987 to 1997.

Of more importance, however, is the decrease in the accident and fatality rates for track bound accidents compared to all accidents. These figures show a decrease in injuries from an average of 20.6 per cent to 12.5 per cent for injuries, and 13.5 per cent to ten per cent for fatalities. The figure for fatalities for the period 1987 to 1997 includes the fatalities in the Vaal Reefs accident. Excluding that accident, the fatality figure is eight per cent of the fatalities from all accidents.

It is therefore possible that the Symposium recommendations accounted for the approximately 40 per cent improvement in the accident rates for track bound accidents relative to all other accidents.

**4.3 Category or job of the victim**

Members of the train teams were the victims in 49 per cent of the accidents where there was reasonable certainty what the victim was doing at the time of the accident. The next most vulnerable person was either walking or lying next to the track which accounted for 21 per cent of the accidents. However, the detailed investigation into the files for fatal accidents indicated that the train team were the victims in 72 per cent of the accidents. See section 4.12.

**4.4 Type of vehicle or machine**

Hoppers were listed as the vehicle involved in 58 per cent of the accidents, with battery and diesel locomotives accounting for 30 per cent, and material cars for 12 per cent of the accidents. Accidents involving loaders and drills were statistically insignificant.
In terms of fatal accidents the following vehicles or machines were implicated in the accidents:

- Hoppers: 35 per cent;
- Battery locomotives: 24 per cent;
- Diesel locomotives: 9 per cent;
- Material cars: 9 per cent.

4.5 Type of injury
27 per cent of the reports gave no indication of the type of injury or the injured body part. Of the reports where sufficient information was given 38 per cent of the injuries were reported as either “Struck” or “Crushed”. These injuries were taken to have involved the torso although the possibility exists that legs or heads were injured. Fingers, hands or arms were identified in 37 per cent of the cases, legs in 22 per cent and heads in three per cent. The high number of injuries to fingers, hands and arms is accounted for by the frequent occurrence of coupling accidents.

The reports dealing with the fatal accidents listed “Struck/Crushed” for 62 per cent of the accidents. In 32 per cent of the reports the injuries were not stated, whereas the rest of the fatal accidents were reported to be due to head injuries.

4.6 Site of the accident
Haulages with 47 per cent, cross cuts with 30 per cent and stations and tips with 13 per cent were the most significant accident sites. A large number of the coupling accidents occurred in the haulages or cross cuts. Being struck by material on a car or next to the track occurred frequently, while tipping was the most frequent cause at the tips or stations.

Most of the fatal accidents occurred at the following sites:

- Haulages: 68 per cent;
- Cross cuts: 15 per cent; and
- Reef and collection drives: 6 per cent each.

4.7 The inspector’s opinion of the reason for the accident
The results of the analyses are shown in Appendix F.

The reason for arranging the data by region is that apparent anomalies exist between the different regions.

It is accepted that the classification of the accident cause is subjective to some extent. However, the degree to which the opinions on accident causes differs by region cannot be solely due to differences in work practice, discipline or equipment design.

For reasons of confidentiality, the regions are not identified by name but are numbered from 1 to 4.

Firstly, according to the information in the reports, the regional inspectors in Region No. 1 did not identify any contravention of regulations. By comparison, in Region No. 2 the inspectors identified contraventions in 28 per cent of the accidents, while in Region No. 3 and Region No. 4 5 and 9 percent respectively were the result of contraventions. This may be due to faulty recording, in which event it would once again demonstrate the weakness of the system. Otherwise it would appear that the discipline in the mines in Region No.1 is particularly good or that the inspectors are particularly lenient.
A further anomaly is that the many accidents involving coupling are usually classified as “Failure to use safety or protective devices/equipment/systems” in Region No. 1, whereas many of these accidents are classified as “Failure to comply with recognised good practices/standards/procedure” in both Region No. 2 and Region No. 3.

The cause which incurred most contravention opinions was “Failure to comply with instructions” at 74 per cent. Since such a failure is a blatant contravention in terms of the regulations, it must be assumed that the failure to judge all such cases as a contravention was either due to recording errors, or that, in the opinion of the inspector, the victim’s injuries were such that further punitive action was unnecessary.

It is also apparent that 95 per cent of the “Failure to comply with instructions” opinions occurred in Region No. 2, with Region No. 3 mines accounting for the remaining five per cent of the cases. This supports the view that the regulations are more stringently applied in the Region No. 2 than in the other regions.

It is highly desirable for the inspectors in the various regions to have a consistent approach, and to report information accurately in order to realise the objective of the Detail Accident Reports.

4.8 Conclusions from the detail accident report form, section B

Ignoring the apparent anomalies, the following conclusions can be drawn from the report forms:

? In the opinion of the inspectors, the majority of the accidents, namely 84.5 per cent, result from the failure to comply with recognised good practice, failure to use safety devices, lack of caution and failure to comply with instructions. The conclusion that can be drawn from these causes is that human error or worker attitudes play a major role in accidents of this nature.

? Categories which indicate weaknesses in management are categories 4. to 7., 9. to 12., 14. and 16. These categories accounted for 11 per cent of the accidents, with “Lack of clearance” accounting for 60 per cent of these. The other categories accounted for only 4.5 per cent of the cases.

? The above must be seen in the light of accusations by unions that management is treated leniently by the Inspectorate. However, even allowing for some degree of bias, it would appear that worker attitudes towards health and safety appear to be a major cause of accidents.

It is alarming to note that, in the opinion of the inspectors, lack of discipline and human error played such a major part in these accidents. During the mine visits, sufficient evidence of these factors was observed to substantiate the inspectors’ views.

4.9 Time of day when accidents occurred

The following table indicates the time that all accidents and fatal accidents occurred according to a sample of this information that was obtained from the Department of Minerals and Energy.

<table>
<thead>
<tr>
<th>Time</th>
<th>0:00 to 3:00</th>
<th>3:00 to 6:00</th>
<th>6:00 to 9:00</th>
<th>9:00 to 12:00</th>
<th>12:00 to 15:00</th>
<th>15:00 to 18:00</th>
<th>18:00 to 21:00</th>
<th>21:00 to 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>307</td>
<td>231</td>
<td>321</td>
<td>573</td>
<td>279</td>
<td>135</td>
<td>122</td>
<td>216</td>
</tr>
</tbody>
</table>
Most accidents occurred during the period from 06:00 to 12:00. This period would coincide with the maximum underground manpower period. The time when most fatal accidents occurred was less predictable. The period during which the highest number of fatal accidents occurred was from 0:00 to 3:00, with the period 09:00 to 15:00 accounting for a relatively large number of incidents.

However, if the ratio between fatal and non-fatal accidents for the various time periods is determined, it is apparent that the times that an accident will most likely result in a fatality are the periods from 15:00 to 18:00, and between 21:00 and 06:00. It is of interest to note that these periods coincide with the times that supervision and manpower is minimal under normal circumstances, but that the horizontal transport systems are operating at peak output.

### 4.10 Comparison with study by T J Binks (Binks T.J. 1984: 197-216)

Binks (Binks T.J. 1984: 204) did not state the time period over which he extracted the figures for his similar study. Consequently a comparison of the number of accidents is somewhat meaningless. The percentage of accidents which occurred during the various times were calculated and appear in Table 4.10 below for the Binks study (Binks T.J. 1984: 197-216) and the figures given in Table 4.9 above.

<table>
<thead>
<tr>
<th>Time</th>
<th>0:00 to 3:00</th>
<th>3:00 to 6:00</th>
<th>6:00 to 9:00</th>
<th>9:00 to 12:00</th>
<th>12:00 to 15:00</th>
<th>15:00 to 18:00</th>
<th>18:00 to 21:00</th>
<th>21:00 to 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. (1)</td>
<td>10.1</td>
<td>11.2</td>
<td>15.6</td>
<td>32.2</td>
<td>15.5</td>
<td>4.4</td>
<td>3.7</td>
<td>7.3</td>
</tr>
</tbody>
</table>

It is apparent that in the Binks study (Binks T.J. 1984: 197-216) most accidents occurred during the period 06:00 to 15:00, with very few occurring from 15:00 to 0:00. The reason for the difference between his figures and those for the period of this study cannot be explained, other than possible changes to work practices. Unfortunately Binks (Binks T.J. 1984: 197-216) did not produce comparable fatality figures, which might have yielded useful results.

It is however noticeable that the “off peak” shifts have recently contributed to far more accidents than was the case during the 70’s to early 80’s.

### 4.11 Comparison between the South African accident statistics and those of other countries

A comparison between South African accident statistics and those of other countries was a prerequisite for this project. Graphs 5, 6 and 7 in Appendix E show comparative data for the countries for which information was available.

In making any comparison, it is necessary to take cognisance of the differences in the application and operation of rail systems in mines in those countries in order to prevent the wrong conclusions being drawn from the comparisons.
Firstly, the data for the United States of America and Australia is for a combination of coal and hard rock mines. The United Kingdom data relates to underground rail systems on coal mines as well as on the cross-channel tunnel construction operation.

Rail transport on coal mines is not used for mineral transport, but is confined to men and material conveyance. The material conveyed by rail in coal mines consists to a large degree of heavy machine components used on coal shearer long wall systems. These components consist of the shearer itself, as well as self-advancing hydraulic chocks, armoured face conveyors and other drives and coal handling components. These are very heavy items of equipment which have to be loaded under relatively restricted conditions. Consequently, the loading operations are somewhat hazardous and could potentially result in incidents involved with loading activities being far higher than for a typical gold or platinum mine.

Furthermore, in most overseas coal mines, pedestrian traffic along rail routes is not permissible whilst trains are running, other than small numbers of authorised personnel. Thus incidents involving pedestrians will be restricted to persons working on the rail system.

For a full appreciation of the information it is important to note that the definition of a lost time injury resulting from a mine accident varies. In the USA and Australia, an injury is defined as anything requiring treatment and in which any time is lost. In the case of the UK, 3 days lost is considered to be a lost time injury.

Graph 5 in Appendix E gives a comparative indication of the number of accidents per 1000 employees per annum in South African gold and platinum mines with the data for the United Kingdom, Australia and the United States of America.

In Graph 6 the percentile ratio of incidents related to a particular activity and the total number of rail related accidents is shown. This figure indicates that “Walking” in the case of the UK, boarding or alighting from a moving vehicle in the case of the USA and “Loading”, “Collisions”, “Obstructions” and “Travelling” are the major activities resulting in accidents.

It must be remembered that the frequency of occurrence in these countries is well below that in South Africa.

In order to take the lower incidence of accidents into account, a factor derived from the ratio of accident rates in South Africa versus those in the other countries is used to normalise the accident rates in those countries. Graph 7 shows the comparative statistics adjusted for the accident rates in the various countries.

4.12 Results of detailed analysis of enquiry files

Since the information supplied in the “Detail Accident Report” forms was insufficient to get a complete indication of the causes of accidents, it was decided to undertake a detailed investigation into fatal accidents involving rail systems. This investigation required the perusal of the files of the enquiries held by the Department of Minerals and Energy.

Table 4.12 is a summary of the information contained in the enquiry files. The data for the various regions showed some discrepancies. The information in the table indicates the statistics compiled for two regions.

The inspector’s findings for the cause of the accident were questionable or wrong in a number of instances. The following two accidents are indicative of this.

Accident No 1.
A locomotive which had run out of fuel was being pushed downgrade by another locomotive, without the locomotives being coupled together. When the foremost locomotive ran away the reason for the accident was given as the towing valve being closed. It is however necessary for this valve to be closed if the locomotive is being towed or pushed. The failure to couple the locomotives together was the real cause of the accident.

**Accident No. 2**
A pedestrian was struck by the locomotive battery when the battery dislodged after the rail broke. In the opinion of the project team the rail was under-rated for the load. The inspector’s opinion was that the rail breakage was unforeseen.

| Table 4.12 | Comparison of Region No. 3 and Region No. 2 Fatal Statistics |
| Comment | Region No. 3 | Region No. 2 |
| Time of Day: | | |
| Day shift | 60 % | 83 % |
| Afternoon shift | 17 % | 0 % |
| Night shift | 23 % | 17 % |
| Loco involved ? | 96 % | 88 % |
| Lack of discipline | | |
| Finding | 53 % | 53 % |
| Possible | 96 % | 94 % |
| Lack of training | 7 % | 7 % |
| Mine specific | 23 % of mines contributed to 47 % of accidents | 11 % of mines contributed to 29 % of accidents |
| Train team involvement | | |
| Driver | 30 % | 29 % |
| Guard | 37 % | 47 % |
| Deceased to blame | 50 % | 83 % |

This investigation once again supported the view of the inspectors that most accidents are due to lack of discipline.

In addition the high number of train team members involved in fatal accidents indicated that guards could well be the majority of the persons struck while walking, particularly when the accident happens during the off-peak shift times.

**4.13 Matters requiring further investigation**
As mentioned above, the accident analyses were intended as the primary means to focus on those matters requiring attention. Further investigations were intended to identify the reasons for the issues identified by analysis of the accident reports, as listed below:

1. Why the highest ranked accident activity involves persons walking or standing next to the track.
2. Whether the high ranking of walking in conjunction with the high number of train personnel involved in accidents means that in many cases the train operating team is involved in these incidents, and if so, why this should be the case.
3. Why most fatal accidents occur during the night time periods when manpower is minimal.
4. Why derailments are such a major cause of accidents and fatalities.
5. Why coupling activities are the most common single cause of all accidents.
6. Why collisions and hitting obstructions cause so many incidents.
7. Whether the measures to prevent injury to train personnel resulting from collisions and hitting of obstructions is adequate.

5. Workers’ attitudes
5.1 Comments on statistics and observations
As stated in Section 4.8 above, in the opinion of the inspectors 81.5 per cent of accidents were a result of human error or worker attitudes. Allowing for some degree of bias or incorrect judgement, this figure still indicates that the attitudes of workers contributed greatly to the high accident rate.

Based on observations made during mine visits in connection with this project, reported in more detail in Section 11, in addition to observations made by team members during mine audits and a number of other projects, it is clear that workers’ attitudes towards health and safety is undoubtedly a major contributing cause of accidents.

With reference to observations on this and other projects, the following issues were apparent:

? A disregard of regulations, mine codes of practice and procedures amongst workers.
? A rejection of methods that were considered good practice elsewhere.
? Compliance with regulations, rules and procedures only when supervisors were present;
? The failure of supervisory personnel to censure workers observed to be breaking rules and procedures.
? Supervisory personnel breaking rules in the presence of workers.
? The use of practices which were known by the workers to have previously caused serious accidents.

By comparison with observed worker attitudes in mines in other countries, the culture of health and safety on South African mines is totally inadequate.

The absence of a satisfactory culture of health and safety in industries in South Africa may be due to one or more of the following:

1. The historical ethnicity of “bosses” and “workers”.
2. The failure to previously involve workers in deliberations on health and safety matters.
3. The inability of workers to recognise potential hazards as well as the consequences thereof.
4. Inadequacy of punitive measures when workers break rules.
5. Failure to identify repeated transgressions through administrative inadequacies.
6. The comparatively lawless nature of South African society as a whole.

5.2 Addressing the high incidence of human error
The factor listed as item 6. above cannot be addressed by industry, but the recent elimination of the conditions listed as 1. and 2. above should, with time, provide a climate more conducive to a better health and safety culture on mines.

The inability to recognise hazardous situations often has its roots in inferior education or limited exposure to mechanised equipment. In the case of the latter, training methods that encourage cognitive skills rather than rote learning, should be developed. Such an approach requires trainers with superior skills to those required for rote learning, and the training of trainers will be a necessity.
In addition, with reference to training, during mine visits the equipment used for training purposes was observed to differ from that in use in the underground production sections. It is desirable to replicate actual conditions, including equipment and systems, in any training programme.

The failure to impose discipline on workers as well as the negative affect that contraventions by supervisors will have on worker attitudes is a matter for mine management to address.

However, it has been recognised that campaigns to reduce mine accidents require a tripartite approach. Such campaigns would be far more productive if the trade unions recognised the part that their own members are playing in accident occurrences. The confrontational approach that unions generally take on health and safety matters appears to be neither justified nor productive in the light of the outcome of the investigations on this project. Undoubtedly, the legislators and management must facilitate health and safety in mines, but compliance with regulations and safe work practices is the responsibility of the individual in many cases. For the unions to expect the mine inspectors and management to impose “policing” and supervisory regimes which can totally eliminate unsafe work practices and non-compliance with regulations and codes of practice is both irresponsible and impractical.

The trade unions should be seen to be taking a more active role in fostering a healthy and safety culture amongst their members. A confrontational approach might be the traditional way for unions to react, but such an approach will do little to improve on the accident rates for accidents in which the victim was the cause of the accident.

6 Introduction to regulatory framework

This section considers the framework under which various countries control the operation of its mine locomotive haulage systems and the design of the associated equipment. Documents collected from the UK, Australia and the USA include Acts, Regulations, Codes of Practice and industry Standards. Despite repeated requests for information, no Regulations or Codes of Practice were forthcoming from Germany. However, the standard for locomotive design in Germany is the same CEN Standard as used in the UK.

6.1 South Africa

In South Africa, basic legislation is provided in the Mines and Works Regulations but there are no nationally adopted Codes of Practice or machinery Standards. The Department of Minerals and Energy have proposed guidelines for Codes of Practice which will have been implemented. However, some confusion exists as to whether these guidelines constitute a requirement for a compulsory Code of Practice in terms of Section 9 of the Mine Health and Safety Act, 1996, Act No. 29 of 1996, as amended by the Mine Health and Safety Amendment Act, 1997, Act No. 72 of 1997.

Some mining houses have generated their own Codes of Practice for the guidance of their mines. These are discussed in Section 7 below.

The Mine Regulation Advisory Committee (MRAC) are currently reviewing all mining regulations, including those for rail transport systems.

6.2 United Kingdom

Statutory Regulations in the UK are currently undergoing a major review with the intention of making the legislation less prescriptive. The existing legislation, the ‘Mines and Quarries Act 1954’, included basic requirements for haulage systems, such as:

- Vehicles should not rub the haulage sides.
- The Manager should make Transport Rules.
Means should be provided to prevent runaways.

The Mines and Quarries Act was later supplemented by more detailed Regulations covering locomotives (1956) and tracks and haulages (1960). The major mine operator, British Coal Corporation, implemented Codes and Rules for locomotive haulage systems based on the Act and these Regulations.

It is now proposed to implement a number of statutory Regulations which impart on the mine owner a duty to provide, operate and maintain a suitable transport system to preserve the health and safety of persons working in the mine. The Regulations will provide a framework of legal provisions which will be supported by Standards, Codes of Practice and Guidance Notes containing the detailed requirements.

6.3 Australia
In Australia, each State has its own Regulations and Standards. Queensland Inspectorate advised that their Regulations relating to underground rail vehicles were “negligible” and the two mines who used rail systems were rapidly withdrawing them.

Western Australia Regulations simply state that if rail mounted locomotive haulages are to be used in an underground mine, the Mine Manager must put in place a plan detailing operating and maintenance procedures, haulage specifications and layout, and the safety precautions to be observed.

Section 103 of the New South Wales Coal Mines Regulation Act 1982 requires Mine Managers to implement schemes for testing of Electrical or Mechanical Apparatus. A document was published by the industry which gave guidance to Managers on the inspection, examination and testing of various types of mining equipment. One example used was a track-bound man car.

6.4 United States of America
In the USA, mandatory health and safety requirements for mines are set out in the Federal Mine Safety and Health Act 1977, which includes, for example requirements for battery charging stations and trolley wire protection. Other requirements are included in the Code of Federal Regulations, 30 CFR parts 57 (metal and non-metal mines) and 75 (coal mines). These Regulations were revised in July 1998.

7 Format for regulations
As stated earlier, in the UK it is intended to introduce a basic set of Regulations imposing a duty on mine operators to provide adequate and safe transport systems. These would be supported by Codes of Practice. This appears to be similar to the system adopted in Australia.

The use of less prescriptive legislation, backed up by practical guidance, appears to be becoming more common, for example the UK Shafts and Winding Regulations 1993 which are supported by an Approved Code of Practice (ACOP), published by HSE, which provides guidance on acceptable braking systems.

The framework allows a degree of flexibility which enables systems to be tailored to suit local conditions and to evolve safely without being constrained to statutory requirements which may have been based on technological capabilities of an earlier period.

MRAC are reported to be considering less prescriptive legislation similar to the trend in other countries.
8 Standards

8.1 South Africa

National standards for underground locomotives and rolling stock do not exist. Currently a number of standards are being drafted, in particular a standard for locomotive controllers and a standard for underground rail systems.

As reported below, South African manufacturers do not work to any recognised written standards but tend to supply the equipment in accordance with the mine’s requirements. In many cases the mine specifications do not appear to be well documented but are based on the equipment previously supplied, with certain amendments or additions as specified by each mine.

8.2 United Kingdom

Until the new Transport Regulations are implemented, the now privatised major UK coal mining operators continue to use the internal standards previously used by British Coal for the design of locomotive systems. Such standards include the Codes and Rules for ‘Underground Haulage by Diesel and Storage Battery Locomotive’ and the handbook ‘Tracklaying for Underground Haulage’.

In 1977, the Health and Safety Executive (HSE) implemented a standard for the approval of locomotives (TM12) which has now been replaced by the adoption of a European Directive which imposes a duty on the supplier of any powered machinery to meet certain Essential Health and Safety Requirements (EHSR’s). Harmonised CEN Standards are being generated for some types of equipment, including locomotives, and equipment complying with such Standards is deemed to meet the EHSR’s. Locomotives are considered by the European Commission to pose special hazards and are subject to third-party examination by a Notified Body until a Harmonised Standard is published.

8.3 Australia

The New South Wales Department of Mineral Resources published a document ‘Guidelines for Safe Mining’, Section 18 of which contains requirements for locomotive haulages, and the Coal Mining Inspectorate publish ‘Designed Guidelines for the Construction of Locomotives’.

9 Comparison of international requirements

There is a wide range of Statutes, Regulations, National Standards and industry Codes of Practice in use at present. Therefore, in the following section, for the purposes of international comparison, any document which is likely to be accepted as a ‘national requirement’ has been considered. For example, in the case of the UK, nearly all the mines which used locomotive systems were operated by British Coal and so their Codes and Rules have been considered here as the national standard.

Appendix G tabulates the main requirements of the Regulations, Standards and industry guidance which have been sourced from each country. The table is not exhaustive but deals with the main items which are seen to affect safe operation of locomotive haulage systems.

The UK documents included many requirements for equipment operating in mines subject to firedamp and so those requirements dealing with prevention of explosions have been excluded.

Although some of the USA Regulations and Australian guidelines refer only to coal mines, many of these would appear to be equally relevant to non-coal mines and so have been included. The reason for the differences between coal and non-coal requirements in these instances is not clear.
9.1 System management

9.1.1 Code of practice and/or manager’s rules
All nations require Rules or Codes of Practice to be implemented, although in South Africa they are only a specific requirement if deemed necessary by the Chief Inspector.

9.1.2 Train control, signals and communications
UK Regulations require a communication system to be installed in any powered transport haulage longer than 900 m.

9.1.3 Pedestrians
South African Regulations and UK Rules require men working on the rail track to wear reflective jackets. Although not a national standard, the major coal producers in the UK require that any person walking in a transport haulage should wear reflective clothing.

9.1.4 Clearances
Minimum horizontal clearances in the UK and USA are 600 mm (i.e. 24”), whereas in South Africa the requirement is 500 mm. In the UK, even if the minimum clearance is available it is necessary to provide refuge holes.

In South African Regulations, the minimum clearance over the locomotive or driver is not specified. Minimum vertical clearances are set at 300 mm in the UK and Australia but USA only requires that small clearances be identified by warning notices.

UK rules specify that clearances should be checked with a template every three months.

9.1.5 Refuge holes
Both the UK and USA have requirements for refuge holes on transport haulages, the spacing of which depends on clearances, curve radius and gradient. There do not appear to be any requirements in Australia. The South African Regulation 18.4.2.2 stipulates that “places of refuge” must be provided where clearances are less than 500 mm. In this event places of refuge shall not be greater than 15 metres apart.

9.1.6 Fencing of walkways
Only South African Regulations refer to fencing of walkways, and then only at the Regional Director’s discretion.

9.1.7 Track inspection
UK Regulations stipulate that the track must be inspected by an official every 24 hours and in Australia regular checks for clearance, obstructions and track condition are called for. Track is also subject to a Planned Preventative Maintenance scheme in the UK for more detailed periodic inspection.

9.1.8 Propelling
Only UK Regulations prohibit propelling of trains (other than during shunting operations). However, in the light of technological advances and the move towards Codes of Practice tailored to suit local conditions, the Inspectorate are now considering authorising individual systems in the event that case can be made for safe operation.
9.1.9  Transport of persons
The transporting of persons on rail systems is allowed in all countries, but only South Africa and the UK specify that approved vehicles must be used. UK Regulations require each car to be fitted with an emergency valve to operate the train brakes, and safety chains to prevent breakaways in the event of a coupling failure.

Only South Africa specifies that passengers must be protected from falling out of the conveyance but in the UK it is now common policy to fit gates, doors or screens to access apertures.

9.1.10  Loading and discharge areas
UK and USA rules require tipping sites to be fenced and it is understood that the Department of Minerals and Energy proposes a Code of Practice in this regard.

9.2  Locomotives
9.2.1  Brakes
By implication or by specific reference, all countries require at least a service brake and an emergency brake. The South African Mines and Works Regulations require locomotives to be fitted, in addition to a service brake, with an independent brake to stop the locomotive if it runs out of control. The UK requirements state that different brake systems may use common components but a single line failure must not render both brakes inoperable.

UK and Australia require at least one brake to be applied by direct mechanical action from the driver, or by spring application, and the UK, Australia and USA (coal mines) require at least one brake system to be automatic or fail safe.

9.2.2  Brake performance
The South African Department of Minerals and Energy proposed a rule which will require a train to stop within an acceptable distance. This appears to be a similar requirement to the old UK Codes and Rules requirement to stop within 60 m, the nominal range of the headlight. However, in the light of experience, the UK now base brake performance requirements on a minimum deceleration of 0.2 m/s², the maximum train load for a particular gradient being calculated using the ‘RLSD formula’ which incorporates this minimum figure. Australia also use a minimum retardation standard but the chosen figure of 0.1 m/s² was deemed by the UK Inspectorate to be too low for the driver to discern if the train was slowing or not.

It is understood that in South African and USA mines there is a rule of thumb of 6:1 for the ratio between maximum trailing load and locomotive weight. The brake performance requirements for the UK and Australia have to take account of the steeper gradients on which steel tyred locomotives are permitted to operate in these countries; 1 in 15 and 1 in 12 for the UK and Australia respectively compared to 1 in 200 in South African gold and platinum mines. Nevertheless, using the UK ‘RLSD formula’ for braking of a ten tonne steel tyred locomotive on a 1 in 200 gradient, assuming a coefficient of adhesion of 0.16, gives a maximum allowable load of 56.5 tonne (see Appendix H) compared to the South African 6:1 ‘rule of thumb’ figure of 60 tonne.

The UK and Australia have regulations for dynamic testing of brakes, both specifying that this should be carried out at least every seven days.

9.2.3  Deadman’s device
Only the UK requires a ‘deadman’s device, or driver-in-position switch, to ensure that the locomotive can only be operated with a driver in position. This is considered to be a very important safety feature and it is understood that the Department of Minerals and Energy proposes a similar requirement.
9.2.4 Unauthorised starting
Only the UK has a requirement for a device to prevent unauthorised starting. It is understood that such a requirement is being considered in South Africa.

9.3 Rolling stock
9.3.1 Couplings
Different coupling heights on adjacent vehicles can contribute to derailments but only the UK appears to specify a standard height, and then only for man carriages although the major coal producer has adopted it for all rail vehicles, by means of purchasing specifications. It is understood that the Department of Minerals and Energy proposes a standard coupling height.

Although the major UK coal mines specify Allen buffing couplings or Willison automatic couplings, which allow vehicles to be coupled without the shunter being exposed to crushing, only the USA Regulations specify that automatic couplings should be fitted to rolling stock (if manufactured after 1971).

10 Discussions with regulatory and standards organisations
In addition to the mine visits, discussions were held with representatives of the Department of Minerals and Energy, industry associations, the South African Bureau of Standards (SABS) and manufacturers.

Reference was made to the work of the Mine Regulations Advisory Committee (MRAC) which has considered the framework for future regulation of locomotive haulage systems. This Committee included representatives from all sides of the industry, including the Unions although it is understood that at some stage the Unions withdrew.

In making their deliberations on the South African position, as well as reviewing local Regulations, MRAC considered documents from other countries’ mining industries, such as the British Coal Tracklaying handbook, as well as British Regulations. The Committee was of the opinion that the existing regulations, incorporated in the updated South African Mines and Works Act 1957 covered the main hazards, but there was a need for supportive guidance to the industry in the form of Codes of Practice and Standards. The intention was for Codes of Practice to quote standards for the following:

(i) monorail systems;
(ii) controllers;
(iii) track (laying and maintenance);
(iv) motive power;
(v) rolling stock;
(vi) batteries and overhead power supplies; and
(vii) signals and signalling.

It will be the role of the Inspectorate to enforce compliance with the Regulations and Codes of Practice.

The Bureau of Standards representatives confirmed the programme of introduction of new National Standards and the Standard for locomotive controllers was in draft and had been distributed for comment from certain industry bodies. However, due to problems encountered in the past with distribution of drafts to a wider audience, they were not prepared to issue a copy to outsiders, including the project team.
The Bureau had also considered other nations Standards and guidance documents, the draft EN Locomotive Standard and British Coal Tracklaying handbook being examples.

Locomotive and vehicle manufacturers were visited. There appeared to be some frustration that manufacturers were willing and able to supply equipment to higher specifications and with improved safety features than was the norm, but some purchasers were not prepared to pay the additional costs. Nevertheless, manufacturers continued to develop their products and were sometimes able to introduce improvements into the field, either on new equipment or by retrofit programmes.

The manufacturers welcomed the future introduction of national standards because currently purchasers’ specifications or requirements were too diverse.

A vehicle manufacturer was proud to show some portable re-railing clamps he had developed and was attempting to introduce to the mines. Similar equipment was introduced in British Coal’s mines 20 years ago.

11 Mine visits
11.1 Methodology

Underground inspections were made at gold and platinum mines in order to identify factors which could contribute to accidents. In addition a number of the issues identified by analysis of accident reports required further investigation.

During the analysis of the accident statistics it was found that the accident rates for platinum mines were lower than the accident rates for gold mines. Platinum mines were therefore visited to determine whether conditions were different from those at gold mines. During the visits to the platinum mines it was observed that the track, haulage and management of the underground transport system was generally better than on the gold mines. Most of the Binks recommendations and suggestions (Binks T.J. 1984: 208-216) were met at one of the platinum mines. Barricades were erected between travelling and tramming ways, the haulage sidewalls were whitewashed and water in the haulages was well controlled at this mine.

In order to ensure that similar benchmarks were used for each of the inspections, a check list was prepared (see Appendix I). The check list was based on a risk assessment of locomotive systems undertaken in the UK and was modified to take into account the differences between UK and South African systems. The main difference was the emphasis on mineral haulage in South Africa and materials haulage in the UK where most mineral is transported by belt conveyor.

The check list also took account of the accident records from South Africa, the UK and Australia.

Benchmarks for assessment against the check list were taken from appropriate national standards; for example rail gauge tolerances from the British Coal Tracklaying handbook and minimum horizontal clearances from the South African Regulations.

Inspections were undertaken jointly by the UK and South African team members at gold and platinum mines. This actually involved seven underground visits because analysis of the South African accident statistics had shown that some categories of accident were more likely to occur on afternoon or night shifts. Therefore, one mine was visited three times to establish any differences between operations, and attitudes, on morning, afternoon and night shifts.

Due to difficulties in arranging visits to some mines during the period the UK team member was in South Africa, the platinum mines were visited later by the South African representative only.
11.2 Observations

11.2.1 System management
Although at two mines, the conventional management approach was taken, with the transport system being controlled by the Production Department and the Mechanical Department in a supporting maintenance role, at the other mines the whole of the transport system was under the control of a Mechanical Engineer. This new approach can have advantages from the point of view of both efficiency and safety because communications should be simpler, there are fewer areas of conflict and planning downtime is easier.

11.2.2 Codes of practice and/or manager’s rules
One mine was implementing a Code of Practice which covered training, maintenance, equipment design, operational procedures and environmental matters. A risk assessment was in progress. At the other mines, there appeared to be some unwritten rules. At no mine were Rules or Codes seen to be displayed underground.

All mines had a defined limit to the number of cars which could be pulled by locomotives of different sizes, the Code of Practice specifying the maximum load for each type of locomotive at the one mine with a note to the effect that maximum loads should be based on braking performance rather than tractive effort. The other mine operated a rule of thumb ratio of 6:1 trailing load to locomotive weight. Whether or not this rule was actually written down anywhere was not clear; suffice it to say, during the inspections the rule appeared to be obeyed.

In view of the relatively shallow gradients, none being steeper than 1 in 200, it was possible to specify a single overall load limit for each type of locomotive which was valid for all track systems. The calculation in Appendix H shows that the 6:1 load ratio is similar to the latest UK requirements but it depends on the ability of each type of locomotive being able to generate a minimum brake effort of 0,16g.

Formal reporting methods for defects were in place at both mines but faults were seen on locomotives and trackwork which could compromise safe operation (see Track Standards and Locomotive sections).

There were no speed limits for general haulage at any of the mines. The large number of accidents relating to derailment, collisions and striking pedestrians suggests that speeds need to be reduced to suit track conditions and sighting and stopping distances.

11.2.3 Pedestrian access
The largest category of accidents was Walking. There are a number of reasons why pedestrians might be struck whilst walking along a transport haulage, but the first line of defence should be to control pedestrian access.

On one dedicated high speed trolley wire haulage, which had bare conductor wires, pedestrian access was prevented by locked gates with sentries. Otherwise, there appeared to be free access to transport haulages with no apparent means to report the presence of pedestrians. This is contrary to UK coal mining practice where pedestrians are required to request permission from the District Deputy before entering his district. Tannoy systems enable the Deputy to be contacted at any time.

If it is essential that certain persons will have to walk in haulage routes, then they should be highly visible to train drivers as well as to guards when propelling.
Other than train guards and persons engaged in work on a haulage, pedestrians are not required to wear high visibility clothing in South African mines. Adoption of reflective jackets for all underground workers in the larger UK coal mines has been found to be of great benefit.

Although drivers were trained to sound warnings to pedestrians, there did not appear to be any reciprocal signal from pedestrians to confirm that they were aware of the approaching train. Pedestrians do not always get off the track immediately and train drivers are aware of this. If the pedestrian has not heard the warning, by the time the driver realises it, it may be too late to stop the train.

Due to long stopping distances of trains, it is more practicable for pedestrians to get clear of trains than for trains to stop. Nevertheless, when passing pedestrians in the restricted width of mine track systems, it is sensible for trains to slow.

Although there was no specified maximum speed for trains passing pedestrians, it was noted that in general drivers slowed trains down when approaching pedestrians.

Accidents have occurred when locomotives were driven by unauthorised and untrained persons, or have not been under proper control of the driver.

At one mine there were no means to prevent unauthorised operation of locomotives and a Shift Boss was seen driving a locomotive from outside the cab while riding on the coupling. However, some locomotives at another mine were fitted with controllers which required special keys to energise the locomotive.

Collisions can occur when drivers unexpectedly approach another train on the same track. At none of the mines were locomotive movements controlled centrally. There was no means to warn drivers that the track ahead was occupied and there was no communication system to enable drivers to ascertain the location of other trains.

Collisions and derailments can be caused by trains taking an unexpected route at facing switches or crossing trailing switches set against them. At none of the mines visited were there trackside signals to indicate switch settings. Alternatively the switches could be equipped with operating devices which indicate the switch position to an approaching train driver.

11.2.4 Supervision and discipline
The provision of Regulations and Codes of Practice will not ensure the safety of haulages if the workforce do not comply with them. Although the rules are imposed for their safety, members of the workforce may contravene them because they do not comprehend the hazards or they simply take short cuts. It is therefore necessary to implement a strong system regime of supervision and discipline.

Mine Managers have a duty under Regulation 2.9.4 to report any contravention and can impose a fine of up to R20. However, the Mine Regulations Advisory Committee criticised the level of fines as too little to be used as a punitive measure.

In the section dealing with the time of day when accidents occurred, reference was made to the differences in manpower and supervision levels during different periods of the day, and the possibility that this contributed to the accident profile throughout the day. During the underground visits, although on a day shift a Shift Boss was seen driving a locomotive from outside the cab (standing on the coupling), generally the effect of differences in level of supervision were very noticeable.

On the afternoon shift, the mine became noticeably warmer and on walking the track systems it was found that a number of ventilation doors had been left open. On the night shift, the doors were
actually spragged open although they were soon closed when the Section Manager arrived unexpectedly.

On the afternoon shift, arrestors were found to be left open or removed and this was more common on the night shift.

Whereas locomotive drivers invariably sounded the audible warning device when approaching pedestrians on the day shift, there was a tendency not to sound them on the night shift.

On the night shift, even when the Section Manager was present, a guard was seen to couple vehicles whilst the train was in motion. No action was taken by the Manager.

Other unsafe practices confined to the night shift were:
? lack of lights on locomotives and leading hoppers;
? a guard riding on the locomotive coupling; and
? a guard giving no warnings to pedestrians of an approaching propelled train.

11.2.5 Track standards
Derailment, and re-railing, are two of the major causes of accidents and are often associated with poor track standards. At least one mining company had a standard for tracklaying which gave good guidance to mine operators. Generally the tracks seen in main haulage haulages were laid to a good standard from the point of view of gauge, sleeper spacing and cross gradient.

However, a few joints had deteriorated somewhat, with steps up to 10 mm in places on main haulage haulages and 15 mm on one storage siding. A new switch had been installed on a major high speed haulage route which appeared to be of different cross section to the rest of the track, but the fishplates had not been modified to create a stepless joint.

At one place, where a heading was being driven off the main haulage, a rocker-shovel was working on track with excessive cross gradients of greater than ten per cent, the track joints were bad, there being a gap of more than 50 mm between the rails at one particular joint. There were no fishplates on two joints. Fortunately, the worst faults were on the spur rather than the main travelling route.

There was evidence in a number of places that cars had been derailed and had run for some distance off the track. The common cause for this appeared to be spillage of rock along the track. Spilled rock was also found between the switch blade and stock rail at a number of switches which could have derailed a train if the driver, or guard during propelling, did not see the danger with sufficient time to stop.

At some curves there was no gauge widening and on some curves the rails had not been bent to a smooth radius, which are both potential causes of derailment as well as excessive wheel flange wear.

Although track may be laid to a good standard, it invariably deteriorates with time, especially in mines. It is therefore important to implement a strict regime of inspection and rectification.

As in the UK, track inspections were carried out every 24 hours by the Production Foreman at one mine and every 48 hours, by the Shift Boss at the other. However, the faults noted during the visits suggest that rectification was not always undertaken as soon as it should be.

Another cause of derailments is lack of positive setting of switch blades. Apart from one segregated high speed haulage track, none of the switches seen were fitted with either operating levers or means to lock the switches in place. This meant that the train guard usually moved the switch with his foot and in one particular instance it took a number of attempts to propel a train into a stope haulage because the switch kept splitting. Some switches at one mine were fitted with hooks and chains at
each end of the tie-bar to latch the switch one way or the other. However, such a solution could introduce a tripping hazard for pedestrians and may not adequately secure the switch in the closed position anyway.

The Vaal Reefs accident investigation highlighted the need to prevent trains inadvertently travelling into shaft approach haulages. An attempt was being made at one mine to provide fail safe pneumatic operation of a switch leading to the shaft side to ensure that when unattended the switch diverted traffic away from the shaft. However, when demonstrated it did not operate correctly.

11.2.6 Clearances
Despite regulations that specify minimum clearances alongside trains, accidents to persons walking the haulage was the largest cause of fatalities.

At the mines visited, there always appeared to be at least 1.8 m between the rail top and any suspended equipment such as pipes and cables.

However, the minimum statutory horizontal clearance of 500 mm was not always available, often for some distance, even on the main haulage routes. Even where the minimum clearance existed, it was necessary to press the body tight against the haulage wall when trains went past, and in the absence of a requirement for refuge holes, it is considered that the minimum clearance should be reviewed.

Clearances in stope haulages were sometimes considerably less than the minimum required, again without refuge holes being provided.

Materials and spilled mineral alongside the track reduced walkway clearances in many places. In one particular stope haulage, pedestrians had to stand on rock which had accumulated alongside the track to such a level that the dolly wheel on the hoppers fouled. One dolly wheel narrowly missed a pedestrian’s foot.

11.2.7 Propelling
Propelling was allowed at all mines, the appointed guard either riding on the leading car or walking ahead of the train.

Visibility of pedestrians has already been covered in previous paragraphs but good lighting is required to see other obstructions ahead. Regulation 15.3.2 requires a light on the leading vehicle of a train, with an average light intensity in the direction of travel of not less than ten lux at 20 metres from the light. To comply with the Regulation, the light is intended to be moved from the loco to the leading car when propelling. However, the light is not always placed on the leading car. During the mine visits, some propelled trains did not have a light on the leading car, and even when such a light was in use it was often insufficiently bright. Under these circumstances the guard’s cap lamp is the only available illumination in the direction of travel.

It is not clear from the statistics how many accidents involving collisions with pedestrians, trains and other obstructions occurred during propelling operations, but it can be assumed that a number of accidents could have been prevented if the guard was able to see sufficiently clearly ahead, and take effective action to stop the train or warn pedestrians.

Even if a guard sees a hazard ahead, he needs to be able to take positive action to avoid an accident. At no mine did guards have emergency stop controls. If it was necessary to stop the train, they were required to signal to the driver by whistle or lamp when propelling. A number of situations were seen at the mines where the guard was out of sight of the locomotive driver, due to curves, or drivers would have been unlikely to hear whistles because of ambient noise levels.
During one mine visit, a pedestrian was met walking in the opposite direction. This person, who was wearing a high visibility jacket, did not appear to make any visible or audible signal and passed by without comment. The unlit leading vehicle of a propelled train then appeared around the bend and it became clear that the pedestrian was actually the train guard. In other industries, pedestrians are required to acknowledge warning signals.

11.2.8 Locomotives
Although not apparently embodied in Regulations, the front of all locomotives seen at the mines were painted with bright colours to highlight their presence. Such a precaution is likely to assist pedestrians, train drivers or guards, to see parked locomotives on the track ahead.

The accident statistics show that one fatality occurred when a locomotive driver was struck by a piece of steel protruding from the sidewall. It is not clear if the driver was seated in his cab, but other than the locomotives on a high speed trolley system, none of the locomotives seen at the mines were fitted with protective canopies over the driver’s cab.

Although not revealed in the South African accident statistics, in UK mines it has been known for drivers to operate controls incorrectly in an emergency because of differences in control movements and responses between different types of locomotives.

At the mines visited, there was no conformity of controls between locomotive types and no stereotype responses to control movements. However, direction/speed controls on the locomotives seen were designed to return automatically to neutral when released, probably the result of good engineering practice rather than Regulation. Unfortunately, stiffness prevented some controls returning to neutral which highlighted the need for a good system of defect reporting and corrective maintenance.

Accidents have been reported, both in South Africa and elsewhere, in which locomotives ran out of control due to operation by unauthorised drivers or when moving without a driver present.

Locomotives at one mine were being fitted with systems to prevent operation by unauthorised personnel but this was under the initiative of the mine personnel, there being no regulatory requirement.

None of the locomotives seen was fitted with a deadman’s device and it is understood that none had fail-safe brakes. However, a programme of retrofitting fail-safe brakes was being implemented at one mine, again a management initiative.

Although the UK requirement for deadman’s devices resulted from a number of accidents in which locomotive drivers operated the locomotive from outside the cab, mainly whilst shunting, the Vaal Reefs accident demonstrates the need to prevent locomotives moving without a driver.

Runaways, collisions and derailments can be caused by inadequate braking resulting from poor brake design or maintenance. Many of the locomotives seen in South Africa used the hydrostatic transmission for service braking with a secondary disc brake mounted on the motor output, both brakes thus being on the input side of the chain drive to the axles. A single line failure of the chain drive would therefore result in the loss of braking effort.

No routine brake testing scheme was in place at one of the mines. At the other a full description of the necessary testing procedure was set out in the haulage system Code of Practice, including monthly instrument dynamic tests. Mine records may show if the scheme was being carried out.

In order to avoid hitting pedestrians or other obstructions, drivers need a good field of view. Headlights on some locomotives did not appear adequate to illuminate 60 m of haulage ahead of the locomotives.
The design of some locomotives prevented drivers seeing pedestrians on the track immediately in front of the locomotive.

12 Rolling stock
12.1 Materials cars
Overhanging or insecure loads can injure pedestrians or derail a train, and insecure loads can fall and injure pedestrians.

Although there were special rules for the transport of overhanging or oversize loads and rules for tying down loads, a number of hazardous loads were seen at the mines visited, mainly involving salvaged equipment. Problems included:

? inadequate provision for attaching load binders;
? wire load retainers for long loads tied together with string;
? machine components tied down using electric cable; and
? loads overhanging the side of cars by up to 660 mm and showing signs of having scraped air doors and haulage sides en route.

Although packs of chocks were seen tied down with plastic webbing on the surface, underground they were seen loose on flat cars. Apparently the webbing was considered a desirable item for use at home and proposals were in hand for stopping theft of the plastic webbing.

12.2 Mineral cars
Persons falling off trains was a major cause of accidents. Guards were required to travel on the leading car of ore train. At one mine, a hook on seat was provided on the outside of the lead car, overhanging the front coupling. There were no means to prevent the guard falling off the seat. Guards were thus exposed to injury from falling off or were exposed to injury in the event of a collision.

A number of guards travelling in empty hoppers have been killed or seriously injured as a result of being ejected when the dolly wheel struck an object next to the track. Although not a requirement in a national standard, the hoppers at one mine incorporated a locking pin which prevented the hopper tipping and ejecting the guard when he rode in the empty car. However, it was noted that on a night shift the cars were marshalled at the entrance to the stope haulage, because there was only room in the haulage for two cars at a time, and the car with the locking pin was marshalled into a position midway through the train. It is understood that the locking arrangement resulted from discussions between the mine and the hopper manufacturer.

12.3 Man carriages
No information was available regarding passengers being injured and there do not appear to be any regulations regarding man carriages, other than on or in locomotives. However, a number of man carriages were seen during the mine visits although none was in use during the inspection.

All cars were designed to prevent arms and legs protruding when passengers were sitting normally. One set had sliding doors.

The cars were fitted with safety chains to prevent breaking away if the main coupling broke. None was fitted with brakes and there were no means provided either to communicate with the train driver or to apply the locomotive brakes in an emergency.
13 Other issues

13.1 Couplings

Coupling and uncoupling was the major cause of accidents in South Africa. The couplings used at the mines visited were of the type which required a pin to be inserted manually through a coupling bar between adjacent vehicles. The guard or shunter therefore had to reach between the cars in order to couple, although some coupling pins had been extended so that he did not have to stoop. Presumably, most coupling accidents occur due to movement of the cars during the coupling operation.

It was also seen that the height of couplings varied from vehicle to vehicle so that the line of action of the forces between vehicles introduced a moment which was capable of reducing the down force on some of the wheels and thus causing a derailment.

13.2 Loading and discharge areas

Although not identified as a particularly major cause of accidents, loading and discharge areas can be hazardous locations. Ore loading and tipping was only seen at one of the mines and there they appeared to be carried out effectively. However, it was rumoured that at some discharge points it was necessary for the locomotive to ‘take a run’ up to the discharge point to gather sufficient momentum to operate the tipping mechanisms on all the cars.

Some loading points could be operated remotely from a safe place, but others were operated from places immediately adjacent to the ore pass. There was evidence of spillage at some ore passes, but no rocks of significant size were seen at the time of the inspections.

Although there were rules for safe clearing of grizzleys, and there were guard rails around them at both mines, men were seen on grizzleys without harnesses.

13.3 Training

A major strategy in reducing accidents is training. This includes hazard awareness training in addition to operator training.

At the mines visited, the training of drivers and guards was carried out at the mine operators’ own training school.

Once selected for training, guards and drivers undergo the same course and are passed out and authorised to undertake either duty. This is in sharp contrast to UK coal mining practice where a driver can only be entered for driver training having already undergone a comprehensive shunter (guard) course, and then worked as a shunter for some time.

Currently, South African Regulations enable drivers as young as 18 years old to drive trains. It is recommended that consideration be given to increasing the minimum age for drivers to, say, 21 years old to ensure that guards have some experience of haulage prior to upgrading to driver.

One locomotive driver training school was visited and the facilities were found generally to be very good, with typical track layouts being set up in simulated mine track systems. The locomotives on which the training took place appeared to be of the same type as those seen underground although in considerably better condition. For instance, the drive controls returned to neutral when released.

However, although the locomotives were of the same type, the loading box and the tipping arrangement were not. It is understood that arrangements were in hand for the supplier of the underground loading boxes to provide the correct type at some later date but in the meantime, a large number of men would have been trained on inappropriate equipment.
Similarly, the track switches were fitted with operating mechanisms which would not be found underground.

Some of the training course is classroom based, to learn the operating rules, relevant regulations and details of the locomotive and its maintenance. Practical training then follows which includes both shunting and driving duties. It was estimated by the instructor that a driver would typically have about 20 hours actual driving experience during the training course. The courses are of a set length and drivers undergo a test at the end, supervised by the chief instructor.

In the UK, the shunter and driver courses are each a minimum of 20 days. Trainees undertake a standards based assessment which gives some flexibility in the length of training to enable weak areas to be addressed adequately. The trainee’s rate of progress through the course therefore depends upon personal attainment and the ability to demonstrate the acquisition and application of the skills to required standards.

The 20 days basic course allows the driver to drive one type of locomotive. Further training is required before the driver is certificated to drive another locomotive type.

Training is now undertaken underground under the supervision of a qualified instructor which ensures that conditions reflect real situations and equipment. Although the training is underground, the location in which training takes place has to be approved. Drivers would be expected to spend at least 60 per cent of the course time actually driving a locomotive.

Training courses include a component covering accident prevention. This involves the use of relevant case studies. The awareness of the hazards involved in locomotive haulage systems is very important since it gives some purpose to all the rules and regulations. When British Coal operated the majority of coal mines, it issued a booklet on locomotive driving which contained a useful section which illustrated typical types of accidents. Topics covered, of which many are common to the South African industry, were as follows:

- Skidding.
- Driving from outside the locomotive cab.
- Insufficient haulage clearances.
- Derailments (poor track, excessive speed).
- Insecure parking.
- Driving in forbidden areas.
- Driving at excessive speed.
- Unauthorised riding on the locomotive.
- Poorly maintained locomotive.
- Poor signals.
- Not ensuring that the track ahead was clear.
- Passengers jumping from moving trains.
- Men slipping in locomotive haulages.
- Catching feet in switches and crossings.
- Using rods and chains to haul/propel vehicles.

Some of these types of accidents are illustrated with descriptive drawings such as those seen in Appendix K. This type of presentation can be of great benefit, especially where the situation shown can be put into context and trainees are familiar with the concepts of closing speeds and distances. For trainees without such experience, relating such a static representation to a dynamic situation may be more difficult and so a different approach may be appropriate. The virtual reality package
previously demonstrated in the SIMRAC funded FSV project (COL 416) could meet these requirements.

When the mining labour force consisted largely of contract labour the use of rote learning as a training philosophy was unavoidable. However, with greater labour stability, more attention should be paid to encouraging cognitive skills. The desirability of a labour force which is capable of recognising potentially dangerous situations cannot be over-stressed.

14 Issues to be addressed based on the visits to mines

Based on the observations reported above the following issues were identified as requiring further attention:

- Codes of Practice should include means to control pedestrian access to haulage routes.
- All persons walking or working on haulage routes should wear reflective jackets.
- Codes of Practice should require pedestrians to acknowledge approaching trains. If no acknowledgement is given, train drivers should repeat the warning and prepare to stop.
- Codes of Practice should specify maximum train speeds for passing pedestrians where clearances are limited.
- Improvements to, or the provision of, control, signalling and communications systems should be addressed.
- Access to locomotives should be limited by the control of keys issued to authorised drivers only.
- Codes of Practice should make provision for a system of control to ensure that train movements on the same track do not result in the possibility of a collision.
- Positive setting and locking mechanisms should be fitted to all switches.
- Route indication should be provided at switches, for both facing and trailing approaches.
- More supervision should be available on afternoon and night shifts.
- Stricter discipline should be imposed.
- A formal system of track inspection and fault rectification should be set up at every mine, with target times to complete repairs.
- Mine Managers should implement a scheme for ensuring that reporting and correction of defects is carried out effectively.
- Shaft approach routes should be protected by the provision of fail safe route selection.
- The minimum horizontal clearance of 500 mm should be reviewed.
- Codes of Practice should require that the trackside should be kept clear of debris and materials.
- The requirements of Regulation 15.3.2 for the leading vehicles on propelled trains to be fitted with a light with a range at least as effective as the locomotive light.
- Guards should be provided with an emergency stop control when propelling.
- Guards should be provided with adequate means to warn pedestrians of the approaching train.
- Codes of Practice should require pedestrians to acknowledge the guard's warning, and if no acknowledgement is seen, the guard should stop the train.
- The Codes of Practice should require the ends of locomotives to be brightly painted to improve visibility in ambient lighting conditions.
- Red reflectors should be fitted to each end of locomotives.
- Locomotive cabs should be fitted with canopies.
- New locomotives should be fitted with controls conforming to stereotype responses.
- Control layouts should be standardised on new locomotives.
- Locomotives should be fitted with means to prevent operation by unauthorised drivers.
- Locomotives should be fitted with devices to prevent operation if the driver is not correctly seated.
- At least one brake system should operate on fail safe principles.
Locomotives should be fitted with service, emergency and parking brakes compatible with the adhesion available. (Note - For some reason locomotives are excluded from the requirements of Regulation 18.6.1 which calls for an independent brake to be fitted in addition to the service brake.)

If common components are used for different systems, a single line failure should not prevent both systems working.

Regulations should require testing of all braking systems routinely, every seven days, and after any repair or adjustment. The tests should include dynamic testing with a suitable load.

Locomotives should be fitted with white lights on each end to illuminate the track ahead for a distance compatible with stopping distances.

Locomotives and cabs should be designed on ergonomic principles to enable drivers to see an adequate distance ahead as well as close to the locomotive. (Note - Locomotives are excluded from the requirements of Regulation 18.6.2 which calls for audible or visual warning systems on any self propelled mobile machine where the vision of the driver is restricted.)

Automatic or remotely operated couplings should be fitted to rolling stock, including locomotives.

Coupings should be set at a constant height.

Materials cars should be provided with adequate load binder attachments.

Sufficient load binders should be made available.

Load binders should be subject to regular inspection.

Guards should be provided with a secure position to prevent them falling from the train or being struck by haulage protrusions.

Mineral cars used for carrying guards should be provided with means to prevent the hopper opening and ejecting the guard. Alternatively, if such a hopper is provided it should always be the end car of the train.

Transport of persons should only be allowed in purpose designed cars.

Man carriages should be provided with means for the passengers to communicate with the driver or stop the train in an emergency.

Man carriages should be designed to prevent limbs protruding from the car.

Loading equipment should be operated from a place of safety.

Codes of Practice should include a safe working method for clearing grizzleys, including the use of safety belts.

All discharge areas should be fenced off from walking routes.

Driver and guard training should be segregated.

Drivers should only be selected for training after attaining the age of 21 and only after a suitable period of employment as a guard.

Training tracks should reflect underground conditions and equipment used should be of the same type as that used at each mine.

Training should be standards based.

Training should encourage cognitive learning.

Hazard awareness training should be provided to all underground personnel.

Hazard awareness could be improved by means of visual illustration, for example by means of video or virtual reality representation of the working environment.

15 DME ‘Proposed Code of Practice for Trucks and Tramways’

The Department of Minerals and Energy produced a draft proposal for a Code of Practice for rail transport systems. The document incorporates some basic rules for the operation of such systems as well as outlining the responsibilities of key personnel such as Mine Overseer, Shift Boss, Team Leader and Locomotive Driver/Guard.
Many of the proposals recommended in this SIMGAP report were included in the DME document but, having identified the main causes of accidents in South African mines, there are areas which the DME proposals do not seem to cover. However, it is recognised that the DME proposals did not cover equipment standards which have been included in this report.

In the following sections, some of the main omissions are identified, based on the accident causes identified by this project. However, since the basis for the recommendations of this report has already been discussed in some detail, it is proposed only to note the main issues.

15.1 Walking/Standing/Lying
Although the DME recommended the wearing of reflective clothing for persons working on the track, there was no requirement for all persons walking the track to wear it, nor was there any proposal to limit access to the track only to those involved in the transport operation. If the DME allowed widespread access to the track, they did not propose a system to control such access. There was no requirement to provide hazard awareness training to those not involved in the transport system.

The proposal requires drivers, or guards when propelling, to give a signal when approaching pedestrians and the train is required to slow. However, there is no requirement for pedestrians to acknowledge the approaching train, nor for the train to stop if no acknowledgement is given. The proposal does not require the guard to have means to stop the train.

The DME proposal retained the existing minimum clearance of 500 mm but this is not considered to be sufficient in the absence of refuges. However, it did require refuges to be provided where clearances were less than the minimum.

15.2 Derailment/Rerailing/Trackwork
The proposal does require the Shift Boss and Team Leader to inspect the track and ensure that it meets ‘the laid down standards’, but does not recommend a minimum frequency of inspection.

It is noted that there is a requirement for switches to be operated ‘by means of a suitable toll or device’ but it is not clear if this specifically requires a mechanism which ensures that the switch is latched in position and cannot split.

The proposal requires that every train should carry re-railing equipment but is not specific about suitability of equipment or training in re-railing techniques.

15.3 Collision/Obstruction
Adequate lighting on trains was covered by the proposal, which would assist in the prevention of collisions. The proposal requires the guard to check that the track is clear when joining a main haulage at an intersection but there does not appear to be any proposal regarding control of trains operating on the same track.

The DME proposal does not make any recommendations regarding acceptable braking limits or maximum loads. The Shift Boss is required to check the brakes, but no test procedures or standards appear.

15.4 Travelling on
Guards are required to travel in an ‘approved caboose, guard chair or guard hopper’ but no standards or safety measures are quoted.
15.5 Coupling
There are no requirements for safe coupling procedures, remote coupling facilities or a standard coupling height.

15.6 General comments
The DME still propose a minimum age for drivers of 18 years and that guards and drivers have the same level of training.

16 Proposed regulations and codes of practice
Statutory Regulations for railway systems in mines are already in existence in South Africa in the form of the Minerals Act Regulations as described in Section 6. In this section of the report, changes and additions to the requirements for rail transport systems are considered, based on the need to prevent the types of accident described in Section 4.2.1.

The following proposals are made for South African Regulations or Codes of Practice. Some of the content might be contained in existing Regulations. Regulations and Codes of Practice are grouped under one heading because it will be for those involved in forming the regulatory framework to decide the balance between the two instruments. Proposals for Standards appear in a separate section.

In the main, the proposals have been made following consideration of the accident statistics and observations made during the underground visits, but the Regulations from the UK, USA and Australia have also been taken into account. The proposals listed below, however, are not intended to be exhaustive. Some of the proposals may already be in use in some mines in South Africa, and a summary of existing and proposed Regulations (and Standards) appears in tabular form in Appendix J.

16.1 System management
16.1.1 Regulations or contents of Codes of Practice
Mine Managers shall implement a Code of Practice for each locomotive haulage which shall be displayed at suitable places.

The Code of Practice shall specify the maximum speeds and loads to be allowed, based on a minimum train deceleration of 0.2 m/s², which shall take into account sighting distances and gradients.

The Code of Practice shall require cautionary notices to be placed in track systems where special safety precautions are required.

The Code of Practice shall include a formal system for reporting defects. Drivers and maintenance personnel shall immediately report train and track defects to responsible officials.

16.1.2 Communications
A communications system shall be provided in track systems more than 900 m long.

Persons shall only enter haulages or track systems after authorisation from the district official by means of direct contact or by use of the communications system, except where such systems are designated pedestrian travelling ways.
16.1.3 Transport of explosives and abnormal loads
Mine Managers shall implement a Code of Practice for the transport of explosives or any other loads which require special conditions to be imposed. Special conditions include, but are not limited to, loads which overhang cars or which are likely to reduce the clearances below the specified minimum.

16.1.4 Control of train movements
Drivers shall ensure a safe distance exists between trains travelling on the same track.

Mine Managers shall implement a system to control independent train movements on the same track.

16.1.5 Signals
Only the guard or shunter, if applicable, shall make signals to the driver, except in an emergency.

Mine Managers shall implement a standard system of signals.

The locomotive driver shall sound a warning before moving off, approaching crossings or adjacent trains and where his vision is obscured.

16.1.6 Training
All persons likely to travel or work on locomotive haulage routes shall undergo a suitable accredited hazard awareness course.

Guards shall undergo a suitable accredited training course.

The minimum age for guards shall be 18 years.

Locomotive drivers shall undergo a suitable accredited training course only after successful completion of a guard training course and a suitable period of time acting as a guard in a mine.

The minimum age for drivers shall be 21 years.

16.1.7 Runaway protection devices
Sufficient, suitable gravel drags, arrestors, stop blocks, derailers or other devices shall be provided wherever necessary to protect persons in the haulage from a runaway train or vehicle.

At least one fail safe arresting device shall be positioned on any track which approaches a mine shaft.

Stop blocks, derailers and other devices shall only be removed to allow the authorised passage of trains under control, and shall be replaced immediately after the passage of such trains.

16.1.8 Track systems
Track systems shall be designed, installed and maintained to provide safe operation consistent with the speed and type of haulage.

All debris, unwanted materials and any other material or equipment which is capable of fouling a train or which reduces the clearance to less than the required minimum clearance, shall be removed from tracks and walkways without delay.

16.1.9 Clearances
Minimum vertical clearance in the haulage shall be 300 mm over the locomotive cab canopy, or a standing driver if no canopy is fitted, or 1,8 m above the rail top, whichever is the greater.
In addition to and supplementing Regulations 18.4.2.1 and 18.4.2.2 -
In any area where walkways adjoin track systems, the minimum horizontal clearances shall be such that pedestrians can safely avoid being struck by trains on the track. In this regard cognisance must be taken of the condition of the sidewall, walkway conditions and the possibility of pedestrian traffic in both directions simultaneously. However, the minimum clearance shall be 500 mm in accordance with Regulation 18.4.2.1.

Minimum horizontal clearances between trains on adjacent tracks shall be 900 mm.

Warning notices shall be placed on the approach to temporarily restricted clearances.

Clearance areas shall be kept clear of stored materials and spillage.

Switch throws shall be positioned to provide clearance for switchmen.

Refuge holes shall be provided, at suitable intervals, where the horizontal clearance is less than 900 mm. On straight haulages, spacing shall be at intervals not exceeding 50 m, and in the vicinity of curves, at not less than 15 m.

16.1.10 Track inspection
Track systems and tracks shall be inspected and a report made every 24 hours.

Clearances shall be checked with a template at intervals not greater than three months and a record made.

Track systems and tracks shall be kept free of obstructions.

16.1.11 Locomotives
Locomotives shall be approved by an inspection authority approved by the Chief Inspector.

Locomotives shall be fitted with a means, such as a keyswitch, to prevent operation by unauthorised persons.

Locomotives shall be provided with service, emergency and parking brakes.

The emergency and parking brakes should be applied directly to the wheels or a shaft permanently connected to the wheels.

Locomotives shall be provided with means to apply the brakes automatically if the driver leaves the cab.

The following brake tests shall be carried out:

a) Static functional tests shall be carried out every seven days;

b) Dynamic test shall be carried out every seven days, on a designated test track, under the most onerous conditions; and

c) Examination and test of the braking system shall be carried out after any adjustment, repair or replacement of parts.
16.1.12 **Passengers**
No person other than the driver or an authorised person shall ride in the driver’s cab. Authorised passengers shall only ride in the locomotive if a suitable second seat is provided.

16.1.13 **Lights**
Every train shall display a white light on the front of, and a red light on the rear of, the locomotive.

16.1.14 **Maintenance**
Every locomotive shall be examined externally by a suitably trained person every 24 hours.

At the start of every shift the driver shall inspect the locomotive prior to use.

Mine Managers shall implement a scheme for reporting and rectification of defects.

16.1.15 **Couplings**
Locomotives shall be fitted with impact and energy absorbing couplings.

Couplings, and all parts of the locomotive lying on the line of action of the couplings, shall be designed with a minimum factor of safety of ten based on the locomotive drawbar pull.

Couplings of locomotives and vehicles used on each haulage shall be set at the same height.

Safety chains shall be fitted to man carriages and provision shall be made for them on locomotives.

Couplings shall be designed to enable coupling and uncoupling to be carried out from outside nip points, e.g. by remote operation or automatic engagement.

16.1.16 **Diesel engines**
Diesel exhaust emissions (at loco outlet) shall not exceed:

- CO 0,2 per cent by volume
- NOx 0,1 per cent by volume

Diesel exhaust emissions in the haulage shall not exceed:

- CO 0,01 per cent by volume, however the time weighted average exposure of any worker in an environment where diesel engine exhaust gas is present shall not exceed 0,005 per cent.

Diesel Exhaust gas tests shall be carried out in accordance with Regulation 10.25.4.

16.1.17 **Diesel locomotive workshops, service bays and filling stations**
Two means of egress shall be provided.

Sufficient ventilation shall be provided to dilute exhaust gases. Presently covered by Reg. 10.25.13.

Locomotive workshops, service bays and filling stations shall be constructed of non-flammable materials. Presently covered by Reg. 10.25.13

Locomotive workshops, service bays and filling stations shall be provided with smooth concrete floors with arrangements to minimise and collect fuel and oil spillage. Presently covered by Reg. 10.25.13.
Oil spillage shall be cleaned up with non flammable absorbent and disposed of in a fireproof receptacle.

Every station used for servicing or repairing a diesel powered unit underground shall be provided with effective means other than a pit for inspecting the unit from below. (This requirement, as stated, is in accordance with Regulation 10.25.13. However, the requirement does not appear to be adequate. Facilities for inspecting the locomotives from below appear in adequate. The reason for not allowing pits should be addressed.)

Suitable fire fighting equipment shall be provided. Presently covered by Reg. 10.25.13.

Diesel fuel shall be of a type approved by the Inspectorate.

Only sufficient quantities of fuel and oil for 48 hours operation shall be stored underground. It shall be stored in suitable containers which do not leak. Presently Regulation 10.25.7 limits the fuel storage to 3 days use. Shortening this period might result in transport problems on deep mines.

Regulation 10.25.8 regarding the construction of the diesel storage area should remain in force.

16.1.18 Battery charging/changing stations
In addition to the current regulations, include -

Suitable means shall be provided for the safe handling of batteries.

16.1.19 Trolley systems
Driver’s cabs shall be provided with an insulated roof unless overhead conductors are shrouded.

Overcurrent protection shall be provided as close as possible to the collector.

Collectors shall be suitable for bi-directional operation.

Collectors shall be capable of being raised or lowered from inside the cab.

Backpoling shall be prohibited.

Trolley lines shall be:

- Adequately insulated at doors, stoppings, crossing other power lines.
- Adequately guarded where men regularly work or pass and at man trip stations.
- Adequate provision shall be provided to prevent trains and equipment contacting trolley wires.

16.1.20 Haulage lighting
Lighting shall be provided at stations at which persons enter or alight from man carriages, and at junctions, loading and discharge points and marshalling areas.

16.1.21 Propelling
The leading vehicle shall carry a white light at least as effective as a locomotive light.

The guard, or another competent person, shall assist the driver if the driver cannot see the haulage, obstructions or vehicles ahead.

The guard or competent person shall be provided with a means to stop the train in an emergency.
The guard or competent person shall maintain communication with the driver at all times.

If the driver cannot understand the guard’s, or competent person’s, signal, he must stop the train.

16.1.22 Conveyance of persons
In addition to Regulation 18.3.2:

Each car shall be provided with an emergency brake valve, unless occupants are in direct communication with the driver.

Passengers must not alight from the train until the train has stopped and the guard has informed them that they may alight.

Persons shall notify the guard or driver prior to boarding.

Man carriages shall be fitted with safety chains in addition to couplings.

16.1.23 Parking
In addition to Regulations 18.2.2.1 and 18.2.2.2:

Visible warnings shall be displayed if parked equipment creates a hazard.

Warning flags shall be carried to warn of overhanging loads or any load which will reduce the clearances to below the minimum specified.

The guard or authorised person shall warn any pedestrians or other persons in the haulage or haulage of the approach of the train and ensure that they are in a safe position before allowing the train to proceed.

Unbraked vehicles, or vehicles provided with a parking brake but which parking brake is ineffective, shall be chocked to prevent a possible runaway.

16.1.24 Marshalling
No coupling or uncoupling shall be carried out whilst the train or vehicle is in motion.

No locomotive shall be used to move vehicles on adjacent tracks.

Vehicles with loads overhanging the ends shall not be coupled next to the locomotive.

16.1.25 Discharge areas
Discharge areas shall be fenced off.

Bumpers, chains or other acceptable means shall be provided to prevent vehicles overturning during tipping.

Grizzlies or discharge chutes shall be securely anchored.

Persons shall not position themselves over draw holes unless safety lines or platforms are provided and used.
16.1.26 Loading areas
A safe location shall be provided for persons operating chutes, ore passes or any material discharge system where danger of injury to the person operating such device by the material being discharged exists.

Adequate warning shall be given to exposed persons prior to operating chutes, ore passes or any material discharge system.

Material discharge systems shall be adequately guarded or persons who could be injured by flying fragments shall be suitably protected.

16.1.27 Conduct of persons
All persons employed on the haulage system, or walking along the rail system, shall wear a reflective jacket.

Persons shall not get on or off moving equipment.

Persons shall not go over, under or between cars unless the train has stopped and driver has been notified.

16.1.28 Guards
Guards shall be provided with a secure seat affording protection from obstructions in the haulage and with means to prevent him falling off the train.

Hoppers used by guards shall have means to prevent the hopper from discharging.

Alternatively - Guards shall only travel in purpose designed vehicles.

16.1.29 Re-railing
Special equipment, such as ramps or other re-railing devices, shall be provided at convenient locations throughout each haulage.

Drivers, guards and officials shall undergo training in re-railing techniques.

16.1.30 Load retention
All loads shall be retained by suitable means approved by the Manager.

16.2 Proposed standards
Basically there are no industry-wide Standards in use in South Africa and the following list proposes items which could be considered by South African Bureau of Standards in their preparations for the new Standards discussed in Section 10.

As with Section 14.1 on proposed Regulations and Codes of Practice, the list below is not intended to be exhaustive and some requirements may exist already in individual operations’ own standards.

The proposed and existing Standards are included in the table in Appendix J.
16.2.1 **Locomotives**
(Note! The following requirements are outlines only; more detail can be obtained by reference to the CEN Draft Standard for Rail Locomotives for Use Underground.)

16.2.1.1 **Brakes**
Locomotives shall be provided with service, emergency and park brakes.

Where braking systems use common components, any failure in those components shall not reduce the capability to stop the locomotive safely.

At least one brake system shall operate on fail safe principles.

Brake systems shall be designed to minimise the risk of skidding.

Brake systems relying on accumulated hydraulic or pneumatic power shall not be rendered ineffective by failure of the prime mover.

Service brakes of steel tyred locomotives shall give variable brake effort up to a maximum design demand of:

\[
\begin{align*}
&0.16g - 0.2g \text{ for coupled axles;} \\
&0.13g - 0.18g \text{ for uncoupled axles.}
\end{align*}
\]

Emergency brakes of steel tyred locomotives shall be designed to generate an effort of at least 0.12g.

Parking brakes shall be capable of holding the locomotive stationary, with a safety factor of 2 on the maximum design gradient with the maximum design load.

Means shall be provided to apply the locomotive brakes automatically if the driver leaves the cab.

Sanding equipment shall be fitted to locomotives operating on gradients steeper than 1 in 200.

16.2.1.2 **Safety devices**
An audible warning device shall be fitted.

A minimum of one portable fire extinguisher shall be located within easy reach of the driver.

Diesel powered locomotives shall have a built-in, manually triggered fire suppression system.

16.2.1.3 **Driver’s cab and controls**
The driver’s cab shall be designed on ergonomic principles and shall provide a view of the track, sidewalls and hangings ahead from the distant limit of the headlight range back to a distance of not more than 5 m from the front of the locomotive.

The driver’s cab shall be designed to prevent the driver falling out.

Handholds shall be fitted to aid access and egress if necessary.

Controls shall be placed so that the driver can operate them and see ahead without leaning out of cab.

Locomotive controls shall be so designed as to prevent operation from outside the cab.
Controls shall be marked with their function.

Control movement shall be consistent with response.

The traction control lever or operating handle shall be sprung to return to neutral when released.

A speedometer shall be provided, and marked with a scale appropriate to the speed of the locomotive, if the locomotive is capable of exceeding ten kilometres per hour.

Brake pressure, or hydrostatic drive pressure if hydrostatic braking is used, shall be displayed in the driver’s cab.

The engine oil pressure of diesel powered locomotives shall be displayed in the cab.

Means shall be provided to prevent unauthorised starting.

An interlock shall be provided to prevent start up with the transmission engaged.

An interlock shall be provided to prevent a diesel engine starting with the parking brake OFF.

16.2.1.4 Lights
Locomotives shall be fitted with at least one white headlight and one red rear light.

Headlight range shall provide an average light intensity of ten lux at a distance of 20 metres from the locomotive.

Taillights shall be visible from at least 60m.

16.2.1.5 Diesel exhaust systems
Diesel exhaust outlets shall be designed to divert gas away from the driver and minimise raising dust.

Diesel exhaust gases shall be diluted before ejection from the locomotive.

Diesel exhaust systems shall be designed to prevent the emission of particulate matter.

16.2.1.6 Traction batteries
Traction batteries shall be in robust, vented, fire resistant containers with lockable covers designed to shed water.

Traction batteries shall be securely fixed to the locomotive.

Traction batteries shall be provided with suitable lifting points.

Traction batteries shall be provided with insulated terminals.

Battery disconnect switches shall be within reach of the driver or a remote tripping device shall be provided.

Traction batteries shall be designed for easy access, repair and topping up.

16.2.2 Track standards
Track shall be ballasted and drained using - 38 mm ballast such as crushed limestone, granite or sandstone.
Ballast shall be kept clear of switch blades and wheel flanges.

The rail section shall be an absolute minimum of 19 kg/m or 5 kg/m + 2,5 kg/m for every tonne per axle.

Minimum spacing between sleepers shall be 840 mm.

Rail joints shall be fishplated with a minimum of four bolts per joint.

Curves shall be smooth with a gradual change of radius.

Check rails or cant shall be provided as necessary.

The use of facing switches or turnouts shall be minimised and clear indication of the setting shall be provided which is visible to drivers from a distance greater than the stopping distance of the train.

Switches shall be provided with locking mechanisms to prevent splitting.

16.2.3 Rolling stock
Man carriages shall be designed to prevent parts of the body protruding.

Material cars shall be provided with sufficient suitable points for attaching load retainers.

17 Implementation of the recommendations of the Association of Mine resident Engineers symposium

The Association of Mine Resident Engineers held an underground transport symposium (UTS) from 9 to 10 August 1984. A paper titled “Underground Transport Accidents Investigation and Recommendations” was presented at this symposium. The issues addressed by this paper were compared with the actual conditions on the mines visited to determine whether the recommendations of the paper were implemented.

This section deals with the recommendations made in the paper and highlights the recommendations which were/were not implemented. During the visits it was observed that the platinum mines implemented more of the recommendations than the gold mines.

17.1 Discipline
The UTS recommends that supervisors must understand the disciplinary code and that they apply it when required.

Supervisors understand the disciplinary codes, but do not apply it. The codes are applied when forced to do so, and in many cases, only when a serious accident/event occurred. It was found that when the disciplinary codes are applied, the operating personnel are disciplined and rarely the maintenance personnel.

17.2 Locomotive design with respect to driver’s comfort and driver’s field of vision
The UTS discussed the minimum requirements for driver comfort and driver field of vision.
17.2.1 Driver’s comfort
The recommended requirements of the UTS that are related to driver comfort were investigated. The recommendations are:

- The loco cab should be designed as to ensure that the controls fall easily to hand.
- The driver enjoys a comfortable position which does not induce fatigue.
- An adjustable seat.
- The canopy should be designed as to give the loco driver sufficient headroom.

The investigations revealed that:

- Controls do easily fall to hand. However, the park/emergency brake on diesel and some electric locomotives is not easily reachable and can not be applied within a short period of time.
- In almost all the cases the driver did not enjoy a comfortable position.
- Generally the driver seats were not adjustable.
- Not many canopies were found. In some cases canopies which were installed were removed. The canopies that were found did give the loco driver sufficient headroom.

The minimum requirements of UTS are generally not met. In many cases the locomotives and locomotive designs have been in use unchanged for 15 years or more. In general, very little has been done to improve the ergonomic layout of the locomotive in terms of:

- Introducing canopies on diesel locomotives.
- Introducing comfortable and adjustable driver seats.

17.2.2 Driver’s field of vision
The recommended requirements of the UTS that are related to driver comfort were investigated. The recommendations are:

- The driver should have an unobstructed view of vision from his seated position.
- The locomotive should be coupled with the driver’s cab in front to enable him to see from sidewall to sidewall and along the track.
- An armoured shield should protect the driver during a collision, derailment, etc.
- The guard will be seated in a hopper in front of the train when the train is pushed.
- The guard should have an effective means of signalling to the driver.
- The lighted distance should be such that a moving train can stop within this distance.

The investigations revealed that:

- The loco drivers had an unobstructed view of vision when the loco was in front of the train.
- Some locomotives were fitted with armoured shields. However, many locomotives were observed without any shields or a steel guard which could protect the driver during a collision of derailment.
- Guards could effectively communicate with drivers by means of pea whistles when travelling or by means of pea whistles or bell wires at the tips. In some cases pea whistles were not available or the bell wires were not operational.
- The lighted distance in many cases were not sufficient to allow a train to stop within this distance. Some of the causes for this were:
  - Inadequate lights.
  - No lights.
  - Slippery tracks.
Train pulling or pushing more hoppers that allowed to.
Chain broken on the loco drive leaving only one set of wheels available for braking.
Loco controller not fully operational.

17.3 Trackwork
Although HSEC are of the opinion that the condition of the mainline seen in the mines that were visited was generally better than the average trackwork conditions in UK coal mines, where track can be affected by footwall movement, the “highest possible standards”, required by UTS, are generally not met.

17.3.1 Track construction
The UTS recommended that “the highest possible standard should be demanded at all times”. The UTS therefore recommended:

- A constant track gauge.
- Ballasting of tracks.
- Super elevation of outside rail on curves.
- Sleepers not to be point-loaded.
- Gauge widening on turns.
- Use of huckbolts to join rails.

The following observations were made:

- Varying gauges found throughout.
- Many tracks not ballasted. (Some track installations do not require ballasting)
- 90 per cent using fish plates with normal bolts as huck bolting is perceived to be expensive and huckbolting equipment is not always available. The removal of a huckbolt joint also requires additional effort which makes it unpopular.
- In many cases the outside rail is not elevated or excessively elevated.
- Derailments occurred frequently at certain rail sections. No attempts were made to rectify the situation for three months at one mine.

The track conditions in main tramming haulages between shafts were found to be in better condition than the tracks in the haulages serving mining sections. It was observed that water control in the main tramming haulages was generally good.

17.3.2 Track system maintenance
The UTS recommended that regarding stacking which include:

- Material should not be stacked in main tramming haulages.
- Material stacked in main haulages should be well clear of tracks and opposite the travelling way side.
- Sidewalls should be sliped where clearances are inadequate.
- Obstructions should be clearly marked and preferably well illuminated.

The following observations were made:

- Material dangerously stacked in travelling ways. In many cases no safe stacking area was available or provided for.
- Sidewall clearances were not sliped.
- Fixed obstructions were not illuminated in most cases.
Caution signs were generally not used or available as required by mine standards.

Stop blocks were generally used where persons were working on tracks.

Persons working in tramming haulages were generally not wearing reflective clothing. It was noted that outside contractors working in tramming haulages complied with this requirement.

Poor water control in haulages played a large role in the deterioration of trackwork. Many tramming problems, including accidents, are associated with poor water control.

### 17.4 Tramming procedures and controls

#### 17.4.1 Pre-use inspection of locomotives and hoppers

UTS recommends certain items which should be included in the pre-use inspection sheets for locomotives and hoppers.

All of the recommended items were included in the pre-use checklists studied.

#### 17.4.2 Lights

UTS referred to the requirements of the Mines and Works Regulations which requires a train to have a bright light, shining in the direction of travel, installed on it.

The UTS recommended the following extensions to the then existing regulations:

- The light to be of sufficient strength to illuminate the full distance required to bring a fully loaded train to standstill and should be focused to illuminate the tracks.
- Spare lamps should be kept at suitable places at each level. Dull or damaged lights can then be exchanged immediately.
- The lamp brackets, used to attach portable lamps to the loco or the leading hopper, should be manufactured to suit the various types of locomotives and hoppers that may be in use on a mine.

The regulations have since been amended and now requires a light intensity of ten lux at 20 meters.

The following observations were made:

- In general the lights on trains lit the haulage adequately. However, in some cases the lights were ineffective. In addition the visibility of pedestrians or trackside materials was ineffective due to lack of contrast with the surroundings.
- Spare lights were not always available on levels.
- Lamp brackets were generally manufactured to suit the type of lamp used on the mine.
- Where lights were permanently manufactured to suit locomotives, they were generally found to be in working order.

#### 17.4.3 Signalling

UTS identifies the importance of communication between the operator and the guard and recommends that:

- Standard codes of signals be established. This was found in practice.
- Whistles with different tones be used in congested areas. This was not found anywhere.
- Other methods be used for communication such as bell wires, two-way radios and a suspended hose along the train with a whistle inserted into it. Bell wires were found and two-way radios are used on mines not visited.

#### 17.4.4 Traffic control system

The use of tokens or robots are recommended by UTS.
Token systems were found but no robot systems were found.

### 17.4.5 Pushing and pulling of a train

UTS recommends that:

- Locomotives proceeding hoppers and material cars should be connected by safety chains or safety slings.
- Loco guards be seated in a guard car or hopper chair.
- Locomotives must stop at fouling marks.
- Procedures when approaching a switch must be adhered to.
- Speed be reduced around curves.
- Driver and guard alternate during the shift.

The following observations were made:

- Locomotives generally proceeded hoppers and material cars. No safety chains or slings were found connecting material cars in haulages. Safety slings were found on material cars being pulled up service inclines.
- Loco guards were generally seated in a hopper chair or were walking in front of the train.
- Locomotives did not always stop at fouling marks. In most cases fouling marks were present. Operators were aware of this rule.
- Procedures prescribed by the UTS were generally not followed.
- Speed was generally reduced around curves. However, the average speed around curves was observed to be too high.
- In most cases guards were qualified drivers and alternating occurred on a daily or weekly basis.

### 17.4.6 Tramming through ventilation doors

UTS recommends that:

- Stop blocks on both sides be used.
- When trains are passing through doors they must be kept open by a device.
- Loco guard should walk on travelling way. In many cases the travelling ways at ventilation doors are places where water accumulates and no travelling ways exist.
- Redundant ventilation doors to be removed.

The following observations were made:

- Stop blocks were generally available, but in some cases the stop blocks were removed and doors left open.
- Not many devices were found which could hold open doors.
- Redundant ventilation doors were not identified and it was assumed that all doors observed were in use.

### 17.4.7 Ambient lighting

UTS recommends that:

- Lights be installed at areas such as tips, workshops, battery bays, vent doors etc.
- Whitewashing of haulage sidewalls to improve lighting.

The following observations were made:
Sufficient lighting was observed at these places and in some cases complete haulages were lit.
Whitewashing of haulage sidewalls in unlit tramming haulages was not observed.

17.4.8 Precautions against noise
UTS recommends that:

- Fans be installed as far as possible from tips, loading boxes and switches and be fitted with silencers when close to these areas.
- Diamond drilling to stop when loco passes operation.
- Guard to be at the middle of the hopper being loaded by a loader.

The following observations were made:

- Generally fans were not fitted with silencers. Where fans were installed they generally did not comply with the recommended measures to reduce noise.
- Diamond drilling was not observed. However, where noisy pneumatic drilling took place, the drilling was stopped to let the train pass.
- Guards were generally found in a safe position where loading was taking place.
REFERENCES


**Brewis, K.** 1993. Rail haulage, still important in many mines, is only as efficient as the track it runs on. *Mining Magazine,* January 1993, p. 20 to 25.


**Department of Mineral Resources (New South Wales).** 1983. Guidelines for the implementation of Section 103 “Coal Mines Regulation Act 1982” Mechanical Apparatus.

**Department of Mineral Resources (New South Wales).** Guidelines for safe mining - New South Wales Supplement to National Safe Mining Handbook.

**Department of Minerals and Energy (Republic of South Africa).** Undated. Proposed Codes of Practice - Tracks and Tramways.

**Department of Minerals and Energy (Western Australia).** 1995. The Mines Safety and Inspection Regulations.


**Health and Safety Executive.** 1977. Test and Approval of Diesel and Storage Battery Powered Locomotives and Trackless Vehicles and Diesel Powered Equipment for Underground Use in Mines (TM12).


