RECOMMENDATIONS

ON SETTING

ILLUMINATION AND VISIBILITY STANDARDS

IN

SOUTH AFRICAN COAL MINES.

Preface

This report is divided into two volumes.

Volume One

Volume One contains a comprehensive set of recommendations for improving the visual environment in order to reduce the risks identified; guidance is also included on the provision, siting and maintenance of lighting equipment.

Volume Two

Volume Two contains the background to the project, an assessment of international illumination standards, and the methodology followed during the underground site assessments. Volume Two also contains an Appendix, which details the observations made during the underground assessments.

Because of the nature of the underground equipment and operations, there is a significant amount of repetition in this document. However, to ensure that all relevant aspects are brought to the reader's attention, all of the duplicated information has been retained. In this manner sub-sections of the report can be studied on their own without having to read the whole report to identify all of the relevant recommendations. It is suggested that specific sections in Volume One and the Appendix which relate to particular areas of interest be read. Thus, if the reader is, for example, only interested in illumination aspects related to longwall operations, the relevant sections that should be studied are:

(a) *Longwall and shortwall operations* in the 'Dynamic locations' section, Volume One [page 23].

(b) *General Recommendations* in the 'Mobile Machines' section, Volume One [page 35], and

(c) *Shearers* in the 'Mobile Machines' section, Volume One [page 49].

(d) *Shearers* in the ‘Mobile Machines’ section in the Appendix, Volume Two [page A64]

Executive summary

A review of the current illumination standards and guidelines in use in coal mining industries throughout the world was conducted to assess their applicability to conditions in South African coal mines. A literature review was undertaken to identify factors that must be considered in order to ensure a safe visual working environment.

The primary output of this project is a set of recommendations based on what is currently accepted as 'best practice', both within South Africa and internationally. The recommendations are based on comprehensive underground observations of current visibility and lighting conditions and were presented to industry representatives for comment, prior to finalisation. The recommendations are contained in Volume One of this report. Volume Two contains background material, a summary of the literature review and detailed results of the underground observations.

The objective of the recommendations is to assist in the identification of potential hazards that can result from poor visual environments across a comprehensive range of the operational situations most frequently encountered in coal mines. Recommendations are made for improving the visual environment in order to reduce the risks identified and guidance is included on the provision, siting and maintenance of lighting equipment.

The recommendations focus on three main areas:

1. **Static Locations:** areas of the mine that are of a long-term fixed nature and hence it is likely to be practical to recommend the installation of comprehensive, permanent lighting fixtures and other aids to improve the visual environment. [Pages 4 to 21, Volume 1; pages A94 to A134, Volume 2].

2. **Dynamic Locations:** primarily production areas, which are likely to move on an almost daily basis. Hence, it is less practical to provide fixed lighting installations. [Pages 22 to 34; Volume 1, pages A135 to A159, Volume 2].

3. **Mobile Machines:** a broad sample of typical mining machines is covered and the visual environment of both the operators and the workers is considered. [Pages 35 to 99, Volume 1; pages A1 to A93, Volume 2] A method for determining sight lines on mobile equipment is also included [Page 103, Volume 1].

Within the above areas, the underground observations identified the major tasks undertaken, their critical visual requirements and the associated potential visual limitations and potential hazards. Recommendations are made on:

- **potential improvements to illumination/visibility**, for example, improving reflectance of walls in static locations, painting obstructions in highly contrasting colours, upgrading headlights/rear lights on mobile machines, providing portable light units where mine area lighting is poor;

- **potential improvements to sight lines**, for example, modifications to canopies, provision of improved wing/side mirrors, provision of height-adjustable seating;

- **additional considerations which could compensate for limitations in the visual environment**, for example, provision of high visibility clothing, provision of audible warning devices, provision of clear advance warnings of hazardous roadway conditions.

This document provides a source of information that will allow direct and effective action to be taken at both corporate and individual colliery level to improve the visual working environment. This should in turn lead to improved safety and a reduction in the number of accidents arising from poor visual environments and lighting standards. It is important to bear in mind that the recommendations are not prescriptive and that each situation must be subjected to a specific risk assessment. The recommendations must be used as a guide to good practice and the information is presented in a form that is designed to act as an aid to all members of the coal mining community when conducting such risk assessments for specific situations.

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Introduction

These recommendations on the setting of illumination and visibility standards in coal mines have been derived from the results of the SIMRAC sponsored project COL451 “Assessment of world-wide illumination and visibility standards in coal mines”.

Past accident records rarely indicate poor illumination or visibility as the primary cause of accidents. However, there is little doubt that visual conditions will have a significant impact on accident potential. For example past European studies have shown accident rates decreasing by as much as 60% when the overall levels of illumination were increased.

Whilst it is easy to assume that visibility can be improved by simply increasing surrounding illumination levels, this is often not the case. Levels of illumination are only one of the many factors that determine the quality (and safety) of a visual working environment. Research has shown that to ensure a safe visual environment a wide range of factors must be considered. These include:

- **Lighting Variables**
  - Illuminance level
  - Light distribution
  - Colour rendering
  - Glare
- **Task Variables**
  - Size & distance
  - Contrast
  - Surface reflectance
  - Movement
  - Colour
- **Workplace Variables**
  - Visual field constraints
  - Postural constraints
  - Safety hazards
- **Visual Perception Variables**
  - Ophthalmic abilities
  - Age
  - Adaptation
  - Depth perception
  - Colour vision

The wide range of interacting variables shown above has in the past led to the setting of a diverse range of illumination standards for underground coal mining by various countries throughout the world. However, compliance to any prescribed lighting standard will not necessarily ensure a safe visual working environment. Given the wide range of variables that need to be considered, providing a prescriptive approach to alleviating visual problems underground is impractical. In addition, attempting to use a prescriptive approach does not fit with the risk assessment philosophy enshrined in the Mines Health & Safety Act (1996).

The objective of these recommendations is to assist in the identification of potential hazards that can result from poor visual environments across a comprehensive range of the operational situations most frequently encountered in South African coal mines. Recommendations are made for improving the visual environment in order to reduce the risks identified and guidance is included on the provision, siting and maintenance of lighting equipment.

The primary objective of this document is to provide a source of information which will allow direct and effective action to be taken at both corporate and individual colliery level to improve the visual working environment. This should in turn lead to improved safety and a reduction in the number of accidents arising from poor visual environments and lighting standards. It is important to bear in mind that the recommendations are not prescriptive and that each situation must be subjected to a specific risk assessment. The recommendations must be used as a guide to good practice and the information is presented in a form that is designed to act as an aid to all members of the coal mining community when conducting such risk assessments for specific situations.

Layout of the Recommendations

The recommendations are divided into three main sections. These are:

4. **Static Locations:** these include areas of the mine that are of a long-term fixed nature and hence it is likely to be practical to recommend the installation of comprehensive, permanent lighting fixtures and other aids to improve the visual environment.

5. **Dynamic Locations:** the locations addressed in this section are primarily production areas which, by their very nature, are likely to move on an almost daily basis. Hence, it is less practical to provide fixed lighting installations.

6. **Mobile Machines:** this section addresses a broad sample of typical mining machines and considers the visual environment of both the operators and the workers in areas were the machines typically operate.

Each of the entries in the above sections is divided into sub-sections that follow the logical progress of a typical risk assessment process. The sub-sections used and the objectives of each of them are as follows:

- **Tasks Considered:** this provides an indication of the scope of the recommendations made and hence indicates the likely validity of the particular section in relation to the risk assessment being conducted.

- **Critical Visual Requirements:** this identifies the visual targets that must be seen if a safe and efficient visual environment is to be provided.

- **Potential Visual Limitations:** provide an indication of the visual limitations most frequently encountered in typical coal mining environments that impact on the critical visual requirements.

- **Potential Hazards:** lists the significant hazards that are likely to result from the visual limitations and hence may need to be addressed to ensure a suitable and sufficient risk assessment is conducted.

- **Recommendations:** these provide an indication of the range of control measures that should be considered in order to ensure that all that is reasonably practical is done to eliminate or mitigate the risks arising from the potential hazards.

- **Additional Considerations:** in addition to the recommendations that relate directly to the quality of the visual environment there may be additional measures that can be taken to further assist in the mitigation of hazards. Where this is the case, typical examples are given.

Because of the nature of the underground equipment and operations, there is a significant amount of repetition in these recommendations. However, to ensure that all relevant aspects are brought to the reader's attention, all of the duplicated information has been retained. In this manner sub-sections of the report can be studied on their own without having to read the whole report to identify all of the relevant recommendations. Two of the three main sections relating to static locations and mobile machines contain a summary of generic recommendations that apply to all of the relevant locations/equipment. Thus, if the reader is, for example, only interested in illumination aspects related to longwall operations, the relevant sections that should be studied are:

(e) *General Recommendations* in the 'Mobile Machines' section

(f) *Shearers* in the 'Mobile Machines' section, and

(g) *Longwall and shortwall operations* in the 'Dynamic locations' section.

Static locations

The dimensions, layout, equipment and tasks conducted in static locations will vary considerably from mine to mine and even within a given mine. The locations studied during the project and addressed in this section should be used primarily as an indication of the type of issues that should be considered when identifying hazards, assessing risks and setting mine standards.

General recommendations

The following recommendations are applicable to a wide range of mine locations.

Orientation of tubular florescent lights

There are three basis arrangements that are commonly used for the positioning of florescent luminaires in mine roadways. These are:

1. A single row of luminaries down the centre, or to one side of the roadway with each luminaire orientated in line with the roadway.

2. A single row of luminaries down the centre of the roadway with each luminaire orientated at right angles to the roadway

3. Two rows of luminaires, one on each side of the roadway, spaced such that the luminaires are on alternating sides and orientated in line with the roadway.

Arrangement 1 results in large variations in illumination along the length of the roadway. Arrangement 2 produces an improvement in the distribution of light along the line of the roadway but provides lower light levels on the walls. This arrangement also has a tendency to create glare and when used in vehicle roadways can result in the creation of a distracting strobe or flicker effect.

Arrangement 3 provides the most even distribution of light and hence is the recommended option even though it may initially require additional materials and installation work. However, care should be taken with this approach in conveyor roads to ensure that the structure does not create excessive shadow areas on the walkway.

Other issues

High visibility clothing with reflective elements should be adopted as standard workwear for all underground workmen. For example, white helmets, white overalls and reflective waistcoats should be worn. (The use of dark blue overalls at some mines was observed during the project; this is not recommended.)

White or brightly coloured/reflective brattice cloth should be used wherever possible to improve reflectance levels in the mines,

Whitewash or light coloured stone dust should be used throughout the mines to aid underground illumination through improved reflectance.

Visitors on the mine should be required to wear a form of clothing that clearly distinguishes them from the regular section workers. This will provide an effective warning to the vehicle/machine drivers of the presence of people who may not be familiar with, or slow, in taking the normally expected course of evasive action.

Cap lamps are available with a faceted design of reflector which provides output levels significantly higher than the conventional units. Consideration should be given to the introduction of these units particularly to those involved in the performance of visually critical tasks where the provision of other suitable sources of illumination is impractical.

Clear advance warnings should be given of abrupt restrictions in the height and width of roadways. The display signs providing such warnings should preferably be reflective and comprise clear attention-gaining characteristics such as yellow and black chevrons.

Structures in roadways should be painted in a colour that contrasts with the background environment.

The adoption of good care and maintenance practices is essential if the benefits from mine lighting systems provided are to be fully realised. Central elements of such practices are:

- Regular formal inspections whereby defective units are either immediately repaired or reported.
- Prompt repair of reported damaged units.
- Regular and routine cleaning, preferably following stone dusting operations.

- Workmen should be encouraged to report any defects, and their participation in the process should be rewarded by prompt remedial action.

Consideration should be given for the provision of portable light units in production areas where it is difficult to provide effective permanent lighting. The units should provide an appropriate level of peripheral illumination to enable inspections and preparation work to be undertaken more safely and reliably prior to the main heading machines being used. Spot lights are not recommended for this purpose and care should be taken to ensure that the units are not used in a way which is likely to impair the visual performance of machine operators and other workmen.

Specific recommendations are given on the following pages for:

Inclined shaft & shaft station

The following hazards and potential recommendations were derived from studies of an inclined shaft and shaft station. The shaft is used for transporting men and materials into/from the mine, and includes a rope haulage system for supplies, a chairlift system, and steps for men to use when the rope haulage is operational and the chairlift system is not in use. The shaft station is used for boarding and alighting the chairlift, as well as unloading supplies from the rope haulage system.

Inclined shafts with conveyors and a roadway for vehicles, are treated in a similar way as main roadways in these recommendations, as the tasks, hazards and recommendations are similar.

Tasks considered

- Walking down inclined shaft
- Riding chairlift
- Boarding/alighting chairlift
- Loading operations

Critical visual requirements

- Moving chairlift, when boarding or alighting.
- Stationary chairlift, whilst walking stairs.
- Moving mobile machinery at shaft station (LHDs, tractors etc.).

Potential visual limitations

- Defective or broken light units along length of the incline and at shaft station.
- Light units covered in dust.
- Poor reflectance from roof and walls.

Potential hazards

- Slipping and falling down stairway.
- Walking into stationary chairs whilst walking stairway.

- Slipping, tripping and falling whilst alighting or boarding chairlift.
- Manual handling causing injuries whilst loading/unloading.
- Struck by mobile machines in or around shaft station.

Recommendations

Good illumination is critical at boarding and alighting points. Provide light levels of 20 to 40 lux where the general illumination levels in the shaft tend to be low (5 lux). Higher levels may be desirable but care should be taken to avoid glare.

Glare or light adaptation may also be a significant problem around the surface entrance to the shaft. This can be alleviated by providing high lighting levels (e.g. 250 lux) at the top entrance which reduce gradually as progress is made into the mine.

Consider provision of additional lights above stairway. A minimum level of 5 lux is recommended for typical walking areas. Where steps need to be negotiated this level should be increased to around 10-15 lux

Improve reflectance of walls and roof to assist in the even distribution of available light. Whitewashing is often a practical solution in these situations.

Paint edges of steps white, yellow, etc. to improve contrast/reflectance.

Paint chairs white, yellow, etc. to improve contrast/reflectance. (chairs observed were painted blue and hence contrast with the background was poor))

Additional considerations

Good housekeeping standards should be maintained, for example, removal of loose debris from steps, regular cleaning and maintenance of lights, etc.

Conveyor transfer points

The following potential hazards and recommendations arise from studies of conveyor transfer points, where mineral is transferred to another conveyor belt via chutes. An attendant works at each transfer point to deal with spillage from the belts and any blockages that may occur at the chute.

Tasks considered

- Shovelling spillage
- Crossing over belt

Critical visual requirements

- Spillage from the belt
- Steps, handrail and floor of platform crossing conveyor.
- Conveyor rollers and framework

Potential visual limitations

- Dust from the transfer point obstructs a clear view.
- Colour of conveyor framework and platform does not always contrast with background.

Potential hazards

1. Slipping, tripping and falling over obstacles on the floor.
2. Striking part of the upper body on the conveyor rollers and framework.
3. Slipping, tripping and falling while negotiating platform.

Recommendations

Paint areas on belt framework where belt attendant regularly works with light colours.

Paint platform with light colours.

Airborne dust should be controlled so that it has no minimal impact on the visual environment

Regular cleaning of painted surfaces to maintain contrast with the background environment.

Underground workshops

The following potential hazards and recommendations were derived from studies of various underground workshops, including diesel workshops, boiler shops, etc. Operations in these workshops include routine maintenance and breakdown repairs to mobile machinery underground, as well as machining and fabrication operations. These recommendations are generally applicable to all forms of workshops underground.

Tasks considered:-

- Routine maintenance and breakdown repairs to a wide range of underground mobile machinery.
- Lightweight machining and fabrication operations.

Critical visual requirements

The following is a summary of the critical visual requirements of workmen in workshops.

- Floor conditions
- Tools and equipment
- Working/walking surfaces
- Steps and platforms
- Components and features of the machines and equipment being maintained

Potential visual limitations

Some of the more general visual limitations in underground workshops are as follows:

- Illumination is provided by lights suspended from the roof. Since most maintenance tasks are carried out either underneath or inside vehicles the majority of these tasks are undertaken in deep shadow.
- Light is obstructed by raised engine covers, vehicle chassis members, limitations in the size of access openings and the location of components therein, and the positions adopted by maintenance crew. As a result workmen remove their caplamps and hard

hat, so they can use their caplamps as portable light units, and place their heads inside machine enclosures.

- As few underground workshops have maintenance pits, there is limited illumination to components underneath vehicles.

- Poor reflectance from walls.

Potential hazards

Poor illumination makes a significant contribution to the following potential hazards in a workshop:-

- Injuries (to hands) through being in contact with sharp objects, and trapped or struck when using tools.

- Components and substances falling on men working underneath vehicles.

- Head injuries caused by working without hard hat.

(There is also the hazard of a worker being caught without both the portable caplamp and self rescue unit in the event of an emergency.)

Recommendations

Improve reflectance properties of walls, particularly the lower sections, to aid light distribution when working under machines.

Improve general lighting levels by mounting light units on to the walls as well as the roof. Tests have indicated that florescent tubes mounted vertically to the walls

- provide a more even distribution of light across a workshop
- illuminate many areas that were previously in dark shadow, and
- provide significantly better levels of illumination beneath vehicles

There is the potential for this solution to introduce glare problems and care should be taken to minimise these effects. If such care is taken, the advantages gained in terms of improved illumination should significantly outweigh any slight problems of glare.

An alternative solution would be to provide portable light units.

Additional considerations

Consider easily removable bonnets and hatches on vehicles.

Provision of suitably designed access pits fitted with lights for working beneath vehicles.

Underground roadways

The following potential hazards and recommendations were derived from studies of various haulage roads, pedestrian walkways and junctions underground. They generally apply to all mine roadways, including back-bye areas, roadways into and within a section and inclined shafts where mobile machines operate.

Tasks considered

- Pedestrians walking and working in roadways.
- Pedestrians entering production areas.
- Mobile machines negotiating bends, junctions and ventilation doors
- Mobile machines travelling in roadways used by pedestrians or approaching areas where pedestrian activities take place.

Critical visual requirements

The following critical visual requirements were identified for drivers of mobile machines.

- Workmen and obstacles sufficiently far ahead of the vehicle for them to be detected and to enable the vehicle to be stopped before collision.
- The corners of turnings: from ground level to a point level with the top of the vehicle.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Workmen in the process of entering production areas.
- Equipment parked or abandoned along the sides of a roadway.

The critical visual requirements of pedestrians walking or working in roadways include:

- Floor conditions- particularly within sections where the movement of vehicles has cut deep tracks and ridges in soft floor.
- Mobile vehicles, particularly near turnings and in production areas.
- Cables on floor within sections.

Potential visual limitations

The following potential visual limitations were identified generally for drivers of mobile machines.

- Obstructed lines of sight to the front, off-side and rear of the vehicle.
- Limited provision of mine lighting at crossings.
- Important visual targets obscured by dust.
- Restricted illumination levels provided by mine lighting.
- High visibility reflective clothing not worn.
- Headlight output diminishes at low engine speed.
- Lines of sight and illumination to the corners of junctions and the potential collision points on the vehicle are obstructed.
- No illumination or reflective warnings on parked/abandoned vehicles/equipment.

The following potential visual limitations were identified for pedestrians walking or working in roadways.

- Blind spots at each turn whilst walking through the junction.
- Restricted illumination levels particularly within sections.
- Abrupt reduction in lighting levels when entering unlit production areas.
- Approaching vehicles obscured by dust.
- Limitations in effectiveness of lights provided on mobile machines.
- Blinded by sharp lights provided on mobile machines.

Potential hazards

1. Collision of mobile machine with people, sides of roadways and other objects or plant in the path of the vehicle.
2. Collision of mobile machine with workmen, loads and plant when entering turns.

3. Pedestrians slipping, tripping and falling in the roadway.

4. Workers struck by cables (e.g. shuttle car) under tension.

5. Workmen accidentally walking in front of machines when entering sections.

Recommendations

Improved light maintenance.

Better standard of lighting.

Investigate the possibility of using brightly coloured electrical cables.

Reduce problem of adapting to abrupt change in lighting levels when entering production areas by:

- Extending distances from waiting areas to entrance to sections and gradually reduce lighting levels up to the point of entering the section
- Improving reflectance levels from walls immediately inside the sections through more effective use of whitewash, stone dusting and the use of light/brightly coloured brattice cloth.
- Providing portable light units.
- Modifying entrances to prevent workmen stepping directly onto shuttle car routes.

Additional considerations

Better standard of housekeeping and roadway maintenance.

Detailed audit and remedial action taken on the wearing of high visibility clothing with reflective strips.

Consider prohibition of vehicles travelling in periods of high pedestrian activity.

Provision of refuge points.

Maintenance to provide or restore audible warnings on vehicles.

Grade roads.

Chemically treat roadways to reduce dust levels. (Some mines are using chemicals to consolidate loose ground conditions which is effectively reducing respirable dust hazard potential and significantly improving the visual environment.)

Provide reflective, or other, warning signs on vehicles/equipment likely to be parked in roadways.

Underground electrical sub-stations and fuel storage bays

The following potential hazards and recommendations were derived from studies of various underground electrical sub-stations and fuel storage bays. These two static locations are considered together because of similarities in their construction and arrangement and the similar visually related hazards that exist in the two areas.

Tasks considered

- Electricians undertaking inspections and maintenance on electrical equipment.
- Refuelling locomotives
- Refuelling a wide range of trackless vehicles
- Pedestrians walking and working in fuel bays and adjoining roadways.

Critical visual requirements

The following is a summary of the critical visual requirements of the drivers of mobile machines that operate in the areas under consideration: (A more detailed list of the requirements for each type of machine is given in the 'section on mobile machines'.)

- Workmen and obstacles to be detected sufficiently far enough ahead for them to enable the machines to be stopped before collision.
- The corners of turnings into fuel bays from ground level to a point level with the top of the machine.
- Workmen, obstructions and equipment located in the entrance to the above turnings.
- Track, switches and robot/signals sufficiently far enough ahead for the drivers to identify potential hazards.
- Shunters, guards other workmen and obstacles in close proximity to the machines to be detected before moving off.

The critical visual requirements of pedestrians walking and working in these areas include:

- Floor conditions- both within the sub-stations and storage bays and in the roadways outside these areas.

- Railway tracks.
- Mobile machines, particularly near turnings and the entrances to sub-stations and storage bays.
- Tools and equipment left on the ground.
- Fuel dispensers and control valves.
- Doors and door sills
- Steps and platforms
- Access panels on electrical enclosures and components located therein

Potential visual limitations

The following potential visual limitations were identified for the drivers of mobile machines operating in the areas under consideration:

- Limited provision of mine lighting at switches and turnings
- Defective robots and signals
- View of roadways and tracks obscured by ground water
- High visibility clothing not worn
- Lack of adequate warnings of parked equipment and supplies stacked in the travelways
- Poor reflectance from walls

The section of the recommendations on mobile machines deals in detail with the visual limitations associated with the design aspects of the individual types of machines.

The following major potential visual limitations were identified for pedestrians walking and working in the areas under consideration.

- In sub-stations and fuel bays, lights are not located in areas where tasks are undertaken.
- Poor reflectance from walls
- Defective mine and vehicle lights
- Lack of audible tramming alarms on vehicles

- Large areas of dark shadow in places critical to safe operation e.g. in doorways and at turns and crossings.
- Lights covered in dust
- Blind spots in electrical enclosures – causing electricians to remove their caplamps and helmets, so they can use their caplamps as portable light units, and place their heads inside the enclosures.
- Equipment not painted in colours that contrast with background environment

Potential hazards

1. Locomotive derailments
2. Collision of mobile machines with people, sides of roadway and other objects or plant in the path of the machines.
3. Pedestrians walking and working in the areas slipping, tripping and falling as a result of oil/fuel spillage, failure to board-in between rail tracks, obstacles submerged in water, general proliferation of tripping hazards, etc.
4. Workmen in fuel bays fall off platforms and are trapped by doors.
5. Electricians injured working in enclosures.
6. Electricians caught without both caplamp and self rescue unit in an emergency.

Recommendations

Improved light maintenance

Better standards of mine and vehicle lighting

Consider lighting arrangements similar to those recommended for workshops.

Improve reflectance properties of walls to aid light distribution in working areas and roadways generally.

For electrical enclosures, consideration should be given to the following:

- The interior walls should be painted with a bright coloured or reflective paint and flameproof internal lights provided to enhance all-round illumination levels inside the enclosure.

- Sealed inspection windows should be provided to facilitate visual routine inspections without the need to remove covers.

Paint platforms, doors and other equipment in a colour that contrasts with the background environment.

Additional considerations

Maintain better standard of housekeeping and roadway maintenance to reduce tripping hazards.

Maintenance system to restore defective lights.

Provide audible warning devices on vehicles

Provide in-fill boarding between rail tracks in pedestrian areas to reduce tripping hazards.

Dynamic locations

The dimensions, layout, equipment and tasks conducted in dynamic locations will vary considerably from mine to mine and even within a given mine. The locations studied during the project and addressed in this section should be used primarily as an indication of the type of issues that should be considered when identifying hazards, assessing risks and setting mine standards.

Specific recommendations are given on the following pages for:

Longwall and shortwall operations

The following potential hazards and recommendations were derived from studies of shortwall and longwall faces with chainless haulage systems. The machines considered were operated from both fixed on-board and remote control stations. Detailed assessments of shearers are given in the section on mobile machines. The following assessment considers longwall and shortwall face operation from the perspective of face workers generally rather than the machine operators. It also considers gate end stage loader operations.

Tasks considered

- Uni-directional/bi-directional shearer operations.
- Trimming-out into the maingate and tailgate roadways.
- Advancing the face conveyor.
- Advancing powered supports.
- Travelling through face-line.
- Monitoring and maintaining satisfactory operation of stage loader

Critical visual requirements

- Roof and clearance between the top of the drum and the canopies
- Floor line and base of the drum
- Coal face and roof
- Floor of the travelway
- Machine operators and other face workers
- Powered roof support rams
- Operator’s machine display and emergency stop control
- Length of face conveyor

- Roof between the canopies
- Stage loader chain and discharge of product onto section belt
- Spillage and ground conditions around stage loader

Potential visual limitations

- Insufficient illumination to clearly see the roof and face.
- Dust obstructs clear view of the roof and face.
- Insufficient background light to facilitate good peripheral vision.
- Difficulty in rapidly identifying single emergency stop controls due to their lack of attention-gaining characteristics.
- Lines of sight to machine operators and maintenance crews on thin seams restricted by machine, spillplates and support legs.
- Working in thin seams, postural limitations restrict view of machine operators and other workmen and prevent portable/caplamps from being directed at other important visual targets.
- Insufficient illumination to clearly see stage loader chain and belt in gate road from designated monitoring station.

Potential hazards

1. Face workers struck by material projected by the drum or breaking away from the face and roof.
2. Face workers hit by sheared-off roofbolts when trimming-out the gate ends.
3. Face workers caught and trapped between supports and machine.
4. Slipping, tripping and falling in the travelway.
5. Collision of machine with major obstructions.
6. Trapped by movement of powered roof supports.

7. Struck by material falling between canopies when supports are advanced.

8. Stage loader attendant struck by lumps when leaving the protection of designated monitoring station to overcome visual limitations.

Recommendations

- Background lighting should be provided to facilitate good peripheral vision. In particular, illumination levels of minimum 5 lux should be provided within the travelway and in the area of the cable trough and the shearer controls and displays.

- Where 'prop-free-front' supports are used, lights should be mounted to the underside of each canopy directly above the travelway.

- Where 'six-leg' supports are used, lights should be mounted to the underside of alternate supports directly above the travelway and to the underside of the remaining intermediate supports directly above the pan-sides.

- Additional sources of illumination should be provided at the stage loader to enable monitoring activities to be undertaken from a place of safety. These light sources should be mounted directly onto the feeder breaker. By creating a satisfactory visual environment from such light sources, this environment can be maintained when the feeder breaker is advanced provided that good care and maintenance practices are followed.

Additional considerations:

The conditions associated with face operations can considerably limit the options available to illuminate and improve sight lines to the important visual requirement areas. The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment:

- A major cause of poor visibility is dust. Water spray systems provided to suppress dust for health reasons could therefore also make improvements to visibility. In selecting a water spray system consideration should be given to one or a combination of the following alternatives:

- ◊ Suppression at source using a wet cutting system where water is released close to the picks.
- ◊ Providing sufficient air velocities through the face to carry dust away from the machine more efficiently.
- ◊ Directing dust away from operating positions through use of external spray systems.

Production headings

Detailed assessments of loading, cutting, roofbolting, face drilling in conventional drill and shot-fire sections are given in the section on mobile machines. The following potential hazards and recommendations were derived from studies of manual operations undertaken in these areas prior to the use of the machines.

Tasks considered

- Entering headings and carrying out preliminary inspections
- Examining for gas
- Examining for misfires
- Barring down the roof and sides.
- Setting temporary supports
- Marking the face
- Hand drilling

Critical visual requirements

- Obstacles on the ground
- Mobile machines in approach roadways
- Loose material on the face and sides
- Fractures and loose conditions in the roof
- Socket holes and traces of unfired explosive
- Machine operators and other face workers
- Steps and floors on working platform
- Drill alignment and face markings

Potential visual limitations

- Glare from headlights on machines in approach roadways.
- Absence of lights and tramming warnings on machines in approach roadways.
- Insufficient illumination from portable caplamps to see visual targets.
- Insufficient light from portable caplamps to provide adequate peripheral vision.
- Working platforms are not painted in a colour that contrasts with the background environment.
- Dust from operations in adjacent headings obstructs clear view of areas critical to safe operation.
- Dust from drilling operation obstructs view of drill and working platform.
- High visibility clothing not worn.
- Electrical supply cables in approach roadways covered in coal dust/buried by mud.

Potential hazards

1. Injured by falling coal.
2. Tripping and falling over obstacles on the ground (lumps and hidden cables).
3. Failure to detect misfires.
4. Falls from platform.
5. Caught up on drill.
6. Hit by mobile machines in approach roadways.

Recommendations

- Consideration should be given to the provision of portable flameproof light units to provide an appropriate level of peripheral illumination to enable the above tasks to be carried out safely and reliably. Spot lights are not recommended for this purpose and care should be taken to ensure that the units are not used in a way

which is likely to impair the visual performance of machine operators and other workmen.

- Working platforms should be painted in a colour that contrasts with the background environment and should be provided with hand rails to prevent workmen from falling off.

- Lighting provision on mobile machines should be modified to comply with the recommendations given in the section on mobile machines.

- The general recommendations on the use of high visibility clothing with reflective strips should be applied.

Miner’s boxes and waiting Places

The following potential hazards and recommendations were derived from studies of miner’s boxes and section waiting places. The roadways in which these are located constitute main travelways for workmen, officials, and staff entering and leaving the sections. In many of these areas, miner’s boxes, artisan’s toolboxes and switchgear units are coupled together and transported as a mobile unit to sections. These recommendations apply to all such areas.

Tasks considered

- Clerical tasks by mining crew
- Storing and removing tools and equipment from lockers
- Connecting power cables for section
- Maintenance of switchgear.

Critical visual requirements

- Desk in miner’s box.
- Storage areas.
- Access panels within electrical switchgear.

Potential visual limitations

- Lights are not located around areas where tasks are undertaken.
- Electricians have to remove their portable/caplamps and hard hats to work on switchgear; they use their caplamps as portable light units and place their heads inside machine enclosures.

Potential hazards

- Slipping, tripping and falling in roadway.

- Slipping, tripping and falling whilst stepping up or down from the miner's box or other storage area.

- Electricians injured whilst working on the switchgear.

- Workers injuring their hands whilst storing and removing equipment and tools from the boxes.

Recommendations

Lights should be in positions where they will effectively illuminate the tasks undertaken, the working area, desk and work tops, and walking areas.

Where possible, light sources should be mounted directly on to the equipment that is advanced. By initially creating a satisfactory visual environment from light sources mounted on the equipment, it follows that this environment can be automatically replicated in whichever location the equipment is moved provided that good care and maintenance practices are followed.

For electrical panels, consideration should be given to the following:

- The interior walls should be painted with a bright coloured or reflective paint and flameproof internal lights provided to enhance all-round illumination levels.
- Sealed inspection windows should be provided to facilitate visual routine inspections without the need to remove covers.

  (A major supplier of electrical enclosures is developing a product line to incorporate the above recommendations.)

Additional considerations

Use of light/white (or reflective) brattice cloth material.

Maintain good housekeeping standards to avoid trip hazards.

Tips and feeder breakers within sections

The following potential hazards and recommendations are derived from studies of tip areas. Here shuttle cars discharge coal into hoppers, which transfer it onto main conveyor belts via feeder breakers. Attendants normally work in these areas and are responsible for clearing up any spillage and slurry, breaking up large lumps on the feeder breakers and undertaking general maintenance work. The following assessment considers tip operations from the perspective of both the tip attendants and the machine operators. However, more detailed assessments of shuttlecars are given in the section on mobile machines.

Tasks considered

- Arrival and manoeuvring of shuttlecar at tip.
- Material discharge.
- Attendants monitoring discharge, responding to blockages and breaking large lumps.
- Pedestrians walking in vicinity of tip.
- Attendants shovelling spillage around tip and feeder breaker.
- Maintenance inspections.

Critical visual requirements

The critical visual requirements for shuttlecar drivers manoeuvring around the vicinity of tips are summarised below:

- Tip attendants and other workmen directly ahead and to the sides when approaching and manoeuvring at the tip.
- Presence of other shuttlecars.
- Clearance between the shuttlecar and the structure of the feeder breaker.
- Relative positions of the discharge conveyors and receiving hoppers.

The following critical visual requirements were identified for workmen in the area (principally tip attendants):

- Standing areas around the periphery of the tip.
- Working platforms.
- Coal entering feeder breaker.
- Approaching shuttlecars.
- Shuttlecar cables.
- Spillage
- Aspects of the installation subject to inspection and maintenance.

Potential visual limitations

The following potential visual limitations were identified for shuttlecar drivers:-

- Excessive dust caused by material discharge.
- Sight lines to feeder breaker/tip attendants and the discharge points are obscured when shuttlecars are used which have cabs located on the ‘blind’ side.
- Restricted illumination levels provided by mine lighting at tips and feeder breakers.
- High visibility clothing not worn.
- Defective machine lights and mine lighting installations.
- Narrow spread of headlight beams leave an area of dark shadow directly in front of shuttlecars masking people and objects directly in front of the machine.

The following potential visual limitations were identified for tip attendants:-

- Excessive dust from material discharge.
- Defective machine lights and mine lighting installations.
- Shuttlecar cables covered in coal dust/buried in mud around tip.

Potential hazards

1. Workmen trapped between the shuttlecars and tip or feeder breaker.
2. Collision with people and other objects in the path of the vehicle.
3. Collision of shuttlecar into feeder breakers.
4. Workmen trapped between shuttlecars and the ribside.
5. Attendants fall from platforms.
6. Tip attendant struck by shuttlecar cable under tension
7. Tip attendant falling into tip.
8. Attendants injured while carrying out inspections and maintenance in areas of restricted vision.

Recommendations

Additional light sources to illuminate the whole tip area.

Light sources should be mounted directly on to the feeder breaker. By initially creating a satisfactory visual environment from such light sources, it follows that this environment can be automatically replicated in whichever location the feeder breaker is moved provided that good care and maintenance practices are followed.

As an extension to the above recommendation, light units mounted on adjustable arms should be considered. The adjustments would enable the lights to be set in different positions to provide optimum levels of illumination for the different activities undertaken, including working on/maintenance of tip/feeder breaker.

Properly align and maintain vehicle lights

Additional considerations

Maintain good housekeeping standards

Improve and maintain good road conditions

Mobile machines

General recommendations

The following recommendations are applicable to a wide range of mobile machines.

Headlights should be provided with protective covers or mounted within recesses to minimise risk of damage.

Headlight covers and recesses should not unduly restrict light output and should allow sufficient access for the lenses to be easily cleaned.

Headlight covers should be provided with quick-release fasteners to minimise potential access difficulties and hence encourage regular cleaning and maintenance.

Headlight casings should be easy to dismantle to enable bulbs to be replaced and repairs effected without undue difficulty. In particular, small fasteners which corrode and require special or improvised tools to release them should be avoided.

Flood lights {soft light) should be provided on some equipment to illuminate critical visual targets for operators of machines, for example, floor/walk surfaces for operators operating on foot (gathering-arm loaders, etc), corners of pillars, and cables (shuttle cars, continuous miners, etc).

Mines should more actively reinforce their policies governing headlight maintenance. Pre-shift inspections should include a check on the state of headlights and defective lights should be repaired within a short period, for example, one hour (ideally, the operation of mobile equipment with defective lights should be prohibited).

Artisans should be required to scrutinise and sign-off pre-shift checklists daily – ideally on arrival in a section.

Secure mountings should be provided for all vehicle/machine light units to ensure reliable operation.

Where necessary, adjustable light units should be provided to illuminate places critical to safe operations. These units should be easy to set at the required angle and remain securely mounted during operation of the vehicle.

To avoid confusion among drivers and reduce the risk of collisions, headlights and taillights should be automatically switched/linked to the direction of travel. More specifically, ideally white lights should shine in the direction of motion and red lights at the other end.

To minimise the risk of collisions, the parking of vehicles, trailers, MPV containers and the stacking of supplies in the more frequently used roadways should be positively discouraged. Where such activity cannot be avoided the special precautions should be taken to raise the attention of other drivers of the presence of these obstructions. Considerations should be given towards mounting an automatically re-chargeable battery powered parking light in a prominent position on all vehicles and also fitting all vehicles and detachable units with reflectors all around.

Where feasible, headlights and taillights should be located at the corners of the machines to provide an indication of their width to drivers of other machines.

All vehicles, trailers and detachable units such as containers, skips, miners boxes, personnel carriers, etc. should be painted a light colour to enable them to be clearly identified in areas where general levels of illumination are low.

To reduce glare from cap lamps, other machine headlights and overhead lighting installations, internal walls in cabs should be painted with a matt surface, preferably grey.

Mines and machine manufacturers should collaborate more actively with lighting manufacturers in the development of special purpose machine light to illuminate tasks and places that are critical to safe operation.

To minimise the risk of collisions resulting from a temporary loss of vision, the drivers of mobile machines which are not fitted with windscreens should be required to wear suitable eye protection.

For machines working outbye of the production areas:

Red brake-warning lights should be fitted to the rear of the vehicles to reduce the risk of collisions between vehicles travelling in the same direction.

Engine powered vehicles should be fitted with constant voltage alternators to ensure that output levels from headlights and taillights remain constant regardless of engine speed.

It is undesirable for light output to fall with engine speed which is a characteristic associated with many vehicles currently in use.

Endeavour to have all mobile equipment operating in the mine (or at least in a working section) with cabs located on the same side i.e. left or right side. A mix of such equipment could enhance the risk of collisions when a ‘keep-left or –right’ rule-of-road is applied.

Specific recommendations are given on the following pages for individual types of mobile machine.

All information/symbolic signs should be of reflective material.

Load haul dumpers (LHDs)

The following potential hazards and recommendations were derived from a study of LHDs with driver cabs located centrally on one side of the machine and the driver seated in a sideways position.

Tasks considered

- Moving off
- Negotiating bends, junctions and ventilation doors
- Travelling on roadways used by pedestrians or approaching areas where pedestrian activities take place.
- Operating in congested areas such as tips, material transfer stations, maintenance workshops, etc.
- Travelling on roadways where clearances are restricted by the presence of stored materials, conveyors, power packs, parked vehicles, pipe ranges, etc.
- Ground levelling operations.

Critical visual requirements

- Workmen and obstacles to the front, to the rear, in close proximity to the pivot point of the vehicle and at each side of the bucket or load.
- Clearance between the roof and the top of the bucket, load, driver canopy, or the drivers head in situations where driver protection canopies are not used.
- Workmen and obstacles sufficiently far ahead of the vehicle for them to be detected and to enable the vehicle to be stopped before collision.
- The corners of turnings: from ground level to a point level with the top of the vehicle.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Leading corner of the bucket or load.
- The top edges of the vehicle from front to back.
- Roadway signs

- Roadway and ribside conditions

Potential visual limitations

- Obstructed lines of sight to the front, off-side and rear of the vehicle.
- Limited provision of mine lighting at crossings.
- Restricted illumination levels provided by mine lighting
- High visibility clothing with reflective strips not worn.
- Output from headlights obstructed by bucket or load.
- Defective headlights (bulbs expired, mountings damaged, lights misaligned, etc.).
- Limited provision of effective visual warnings on moving or parked vehicles.
- Line of sight restrictions and inadequate illumination from headlights create the temptation for drivers to lean out of the cab to improve their vision.
- Line of sight and headlight restrictions combined with fixed side seating arrangements create the need for drivers to adopt adverse working postures.
- Design of protective canopies can obstruct driver's view of clearance between bucket and roof.
- Headlight output diminishes at low engine speed.
- Lines of sight and illumination to the corners of junctions and the potential collision points on the vehicle are obstructed by the design of the machine.
- Glare from lights of other machines/vehicles

Potential hazards

1. Collision with pedestrians and maintenance staff attending to the vehicle when moving off.
2. Workmen caught and trapped in the pivot space.
3. Drivers and other workmen injured by objects thrown up by the wheels of a vehicle.
4. Collision with people, sides of roadways and other objects or plant in the path of a vehicle.
5. Drivers injured by unseen objects entering cab.

6. Drivers injured when leaning out of a cab.
7. Drivers injured by working in poor operating postures.
8. Drivers strike their heads against the roof or overhead equipment.
9. Collision with workmen, loads and plant when manoeuvring at shaft stations, tips, transfer points, maintenance workshops, etc.
10. Collision with workmen, loads and plant when entering turns.
11. Drivers and other workmen injured by falling roof or equipment dislodged by vehicle bucket, load, canopy, etc.
12. Collision with corners of turns on the off-side.

Recommendations

Illumination:

- At least two headlights should be fitted to each end of an LHD.
- The headlights should be switched automatically to show a bright white light in the direction of travel and a lower intensity red light at the trailing end.
- Headlight illumination in the direction of travel should provide 10 lux at 20m.
- Headlights should be positioned where their output is not obstructed by the bucket, load, or other aspects of the vehicle or work environment. This could be facilitated by the provision of extendible/adjustable mounting arrangements (such arrangements have been successfully tested in British coal mines).

Sight lines:

Line of sight provision on LHDs is particularly poor and is associated with a high incidence of accidents. In the acquisition of new machines consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing sight lines on LHDs can be improved:

- Provision of adjustable height seats that can also be rotated through an angle of +-15 degrees, to face towards in either direction of travel.
- Modification to the profile of the vehicles by, for example, chamfering the corners of engine covers, lowering mudguards, removing and relocating items from the top of the vehicles that obstruct the drivers view.

- Modification to canopies to improve driver's view of potential overhead obstructions.
- Provision of a closed circuit television system for use when carrying abnormal loads.

  (A camera connected to a flexible lead that can be hooked on the front of abnormal loads has been found to be particularly beneficial in identifying people and obstacles located on the off (blind) side.)

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features on the LHD, such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional means of compensating for limitations in the visual environment.

- Provision of visual tramming warnings
- Provision of emergency stops at each corner and articulation point on the vehicle.
- Provision of mirrors at crossings
- Improved mine lighting at crossings
- Use of reflective signs should be used (road, information, symbolic signs)

Light delivery vehicles (LDVs)

The following potential hazards and recommendations were derived from a study of LDVs of the type typified by Land Cruisers, Mega Cruisers, Jeeps etc. These units are essentially adaptations of conventional bakkies or pick-up trucks used on public roads and typically comprise a cab for a driver and passenger and an open back fitted with platform seats. The vehicles are used mainly to transport small groups of workmen in and out of the mine.

Tasks considered

- Moving off
- Travelling in inclined shafts
- Negotiating bends, junctions air doors and robot systems
- Travelling in roadways used by pedestrians and other vehicles
- Travelling where clearances are limited by restrictions in the roadway dimensions and the presence of stored materials, conveyors, power packs, parked vehicles, pipe ranges, etc.
- Undertaking ‘three-point’ turns in roadways.

Critical visual requirements

- Workmen and obstacles in front, to the rear and at each side of the vehicle.
- Clearance between the roof and top of the vehicle.
- Workmen, obstacles and signs sufficiently far ahead of the vehicle for them to be detected to enable the vehicle to be either stopped before collision or the appropriate action taken.
- Clearance between all four sides and corners of the vehicle and potential obstacles
- The corners of turnings: from ground level to a point level with the top of the vehicle.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Workmen being transported in the back of the vehicle.
- Important instruments in the cabs

- Roadway signs
- Roadway and rib conditions

Potential visual limitations

- Obstructed lines of sight to the off-side, rear and passengers in the back of the vehicle.
- Limited provision of mine lighting at crossings.
- Restricted illumination levels provided by mine lighting.
- Defective headlights (bulbs expired, mountings damaged, lights misaligned, etc).
- Limited provision of effective visual warnings on parked vehicles.
- Inadequate illumination from head and taillights.
- Headlight output diminishes at low engine speed.
- Condition of windscreens and mirrors impairs driver vision (damaged, dirty, etc).
- Roadway signs with poor attention-gaining characteristics.
- Inability to see speedometer and other important instrument displays as cap-lamps have to be switched off due to reflections from windscreen.
- Instruments not illuminated.
- Glare from headlights of approaching vehicles.
- Glare from bright white lights fitted on rear of mobile machines/vehicles.
- High visibility clothing with reflective strips not worn.

Potential hazards

1. Collision with pedestrians and obstacles when reversing.
2. Collision with pedestrians and obstacles concealed in dark areas of the roadway in the path of the vehicle.
3. Workmen injured by items thrown up by vehicle wheels.
4. Collision with roof or overhead equipment.

5. Collision with pedestrians and vehicles emerging from side roads.
6. Collisions caused through speeding and loss of control over vehicle.

Recommendations

Illumination:

- Two headlights should be fitted to the front of the vehicle, preferably at each corner level with the top of the engine cover.
- The headlights should provide a minimum illumination of 10 lux at 20m (generally, LDVs travel at speeds exceeding 20km/h). The illumination levels should be adapted to the permissible speed limit and the maximum stopping distance at that speed.
- Two white reversing lights should be fitted to the rear of the vehicle, preferably one at each corner.
- The reversing lights should operate automatically when reverse is selected and should provide a minimum illumination of 10 lux at 10m.
- Speedometers should be illuminated to enable the drivers to read them without using caplamps.

Sight lines:

In the acquisition of new vehicles, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing sight lines of LDVs can be improved.

- Mines to regularly inspect and replace damaged windscreens.
- Windscreen wash/wipe facilities should be provided.
- Mines to regularly inspect and replace damaged wing/side mirrors.
- The rear of the cabs should have a large opening or window and an internal rear view mirror should be provided to enable the drivers to see passengers seated in the rear.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified, such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, use of reflective road/information signs, etc.

Graders

The following potential hazards and recommendations were derived from a study of scoops and graders operating both in production areas and in outbye roadways. The vehicles had centrally located forward facing operating positions just behind the scraper blade.

[The recommendations produced for LHDs are applicable to graders fitted with side seated driving positions and scoops]

Tasks considered

- Moving off
- Negotiating bends, junctions and air doors.
- Travelling roadways used by pedestrians and other vehicles
- Travelling where clearances are limited by restrictions in the roadway dimensions or the presence of stored materials, conveyors, power packs, parked vehicles, pipe ranges etc.
- Reversing into ‘splits’, etc.

Critical visual requirements

- Workmen and obstacles in front, to the rear and at each side of the vehicle.
- Clearance between the roof and top of the driver canopy or, more importantly, the drivers head in situations where driver protection canopies are not provided.
- Workmen, obstacles sufficiently far ahead of the vehicle for them to be detected for the vehicle to be stopped and collisions avoided.
- Clearance between vehicle blade and ground and material being pushed in front of the blade.
- Clearance between all sides of the vehicle and potential obstacles.
- The corners of turnings: from ground level to a point level with the top of the vehicle.
- Workmen, obstructions and equipment in the entrance to turnings.

- Roadway signs
- Roadway and ribside conditions

Potential visual limitations

- Obstructed lines of sight to the front and rear of the vehicle.
- Lines of sight to the blade and material in front of the blade partially obstructed.
- Inadequate illumination on the blade.
- Restricted illumination levels provided by mine lighting, particularly at crossings.
- Defective headlights (bulbs expired, mountings damaged, lights misaligned, etc).
- Limited provision of effective visual warnings on moving or parked vehicles.
- Inadequate illumination from head and taillights.
- Headlight output diminishes at low engine speed.
- Line of sight restrictions combined with fixed forward seating arrangements create the need for drivers to assume poor working postures when reversing.
- Glare from lights of other mobile equipment/vehicles
- High visibility clothing with reflective strips not worn

Potential hazards

1. Collision with pedestrians and obstacles when moving off, particularly in reverse.
2. Drivers injured through working in poor driving postures.
3. Drivers and workmen injured by items thrown up by vehicle wheels.
4. Drivers without canopies strike their head against the roof or overhead equipment.
5. Collision with pedestrians and vehicles emerging from side roads.
6. Collision with workmen, loads and plant when manoeuvring through areas of high activity.

Recommendations

Illumination:

- Two headlights should be fitted to the front of the vehicle, preferably one at each corner and at least 1m above ground level.
- The headlights should provide a minimum illumination of 10 lux at 20m. The illumination levels should be adapted to the permissible speed limit for the vehicle and the maximum stopping distance at that speed.
- Two white taillights should be fitted to the rear of the vehicle, preferably one at each corner.
- The headlights and taillights should be switched automatically to show a white light in the direction of travel and a lower intensity red light at the trailing end.
- The reverse lights should operate automatically when reverse is selected and should provide a minimum illumination of 10 lux at 10m.
- Additional lights should provide a minimum illumination of 15 lux across the length of the blade and material being pushed in front of the blade. (Two lights with wide angled beams mounted to the vehicle directly above the blade and pointing vertically downwards have been found to be beneficial.)

Sight lines:

In the acquisition of new graders, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved.

- Provision of adjustable-height seats (and canopies) to improve sight lines in both forward and backward directions
- Enhancement of the driver's view of the critical visual areas behind the vehicle through the provision of wing/side mirrors and by chamfering the corners of the engine covers.
- Modification of canopies to improve drivers view of potential overhead obstructions.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for

example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features on the machine such as emergency stops etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as an additional way of compensating for limitations in the visual environment.

- Provision of visual tramming warnings
- High visibility clothing with reflective strips to be worn
- Use of reflective road/information signs

Shearers

The following potential hazards and recommendations were derived from studies of double ended shearers operated on both shortwall and longwall faces with chainless haulage systems. The recommendations produced are equally applicable to uni-directional and bi-directional operations in the range of seam heights typically worked in South Africa. They are also applicable to machines operated from fixed on-board control stations.

Separate recommendations have been produced for remotely controlled versions of these machines and these are given at the end of the section.

Tasks considered

- Starting the machine.
- Shearing the face from the maingate to the tailgate with the leading drum cutting the roof and the trailing drum the floor bench.
- Flitting the machine from the tailgate to the maingate with the leading drum cleaning the roof line and the trailing drum the floor line.
- Trimming out into the maingate and tailgate roadways.
- Advancing ‘snaking over’ the face conveyor.

Critical visual requirements

- Roof and clearance between the top of the drum and the canopies
- Floor line and base of the drum
- Coal face
- Roof in the maingate and tailgates
- Floor of the travelway
- Conveyor extending from the shearer
- Operator’s machine display and emergency stop control
- Cable trough and cable handler
- Co-drivers and other face workers

- Powered roof support rams

Potential visual limitations

- Insufficient illumination to clearly see the roof and face.
- Dust obstructs clear view of the roof and face.
- Insufficient background light to facilitate good peripheral vision.
- Angle viewing affects readability of machine displays.
- Lines of sight to maintenance crews on thin seams obstructed by the machine and support legs.
- Spill plates and cable handlers interfere with lines of sight and caplamp illumination to controls and displays on thin seam machines.
- Difficulty in rapidly identifying single emergency stop controls due to their lack of attention-gaining characteristics.
- Canopies obstruct lines of sight to roofline on thin seams.
- Working in thin seams, postural limitations restrict view of co-operators and prevent caplamps being directed at other important visual targets.

Potential hazards

1. Operators and other workmen struck by material projected by the drum or breaking away from the face and roof.
2. Operators and other workmen hit by sheared-off roofbolts when trimming-out the gate ends.
3. Operators caught and trapped between supports and machine.
4. Slipping, tripping and falling in the travelway.
5. Collision of machine with major obstructions.
6. Trapped by movement of powered roof supports.
7. Workmen caught up and entangled by the machine.
8. Crushed by canopy being lowered on thin seams.

Recommendations

Illumination:

- Shearer operators should be provided with caplamps with the faceted-design reflector. This should improve them appropriate level of illumination to the roof and floor lines of the face and other visual attention areas.
- Background lighting should be provided to facilitate good peripheral vision. In particular, minimum illumination levels of minimum 5 lux should be provided within the travelway and in the area of the cable trough and the shearer controls and displays.
- Where 'prop-free-front' supports are used, lights should be mounted to the underside of each canopy directly above the travelway.
- Where 'six-leg' supports are used, lights should be mounted to the underside of alternate supports directly above the travelway and to the underside of the remaining intermediate supports directly above the pan-sides.

Sight lines:

In the acquisition of new shearers, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved.

- Any interactions between spill plate or cable handler arrangements and the location of the controls and displays which influence sight lines should, where technically possible, be resolved to optimise the operators visual requirements.
- Displays which need to be monitored during machine operation should be located and orientated where they can be easily read by the operators from their working position (Typically, adjacent to the ranging arm). In particular,
  - ◊ displays should be located on the mainframe of the shearer as close to the ranging arm pivots as possible
  - ◊ displays should be angled towards the driving position
  - ◊ apertures within which any displays are located should not impair the operator's line of sight.
  - ◊ self illuminating dials should be provided on all displays

Additional Recommendations:

The conditions associated with face operations can limit considerably the options available to illuminate and improve sight lines to the important visual requirement areas. The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment:

- A major cause of poor visibility is dust. Water spray systems provided to suppress dust for health reasons could therefore also make improvements to visibility. In selecting a water spray system consideration should be given to one or a combination of the following alternatives.
  - ◊ Suppression at source using a wet cutting system where water is released close to the picks.
  - ◊ Providing sufficient air velocities through the face to carry dust away from the machine more efficiently.
  - ◊ Directing dust away from operating positions through use of external spray systems.
- Emergency stop push buttons should be attention-gaining to enable operators to rapidly identify their location. This can be achieved by making them large, mushroom shaped, at least 75mm diameter and brightly coloured (preferably red).
- Ideally emergency stop chains/tripwires should be provided. These chains should run along the entire length of the goaf side of the shearer and be linked to switches which operate when the chains/tripwires are pulled outwards, to the left or to the right by anyone working at the side of the machine.
- Pre-start audible alarm
- Activating the water sprays for a number of seconds before the cutter motors are started to act as an additional warning.
- Maintain high standard of housekeeping to eliminate trip hazards.

Recommendations for remotely controlled shearers

The methods of operating remotely controlled shearers are essentially the same as those outlined above for similar machines which are operated from fixed on-board control stations. The critical visual requirements are also essentially the same. On shearers

provided with fixed on-board control, operator sight lines are often compromised by the need for them to maintain their presence within reach of these controls. Normally these stations are located close to the ranging arm pivots which are less than ideal positions for operators to see the important areas that require their attention. However, one of the major advantages resulting from the application of remote control technology is that it gives the operators the freedom to adopt a potentially infinite range of operating positions which enables them to overcome many of the visual limitations associated with fixed on-board control stations. Unobstructed sight lines to practically all the visual targets can be obtained within a 15m operational range of a remote control station. This facility however has introduced a number of additional potential hazards. For example, in utilising the freedom to adopt the most visually advantageous position:

1. Operators may place themselves in potentially unsafe positions, for example, adjacent to the drum where there is an increased risk of being struck by material projected from the face.
2. The operators of double ended machines may become visually detached from one another thereby jeopardising effective communications
3. Operator's view of important displays on the machine can become obscured.
4. Workmen adopting positions where they are at risk from being injured by the machine may not be detected by the operators if operating distances become excessive.

The recommendations given above for machines with fixed on-board control stations are also applicable to remotely controlled machines. However, the following further recommendations could be considered as ways of compensating for the additional visual hazards.

- Use of high visibility clothing (preferably reflective waistcoats) to improve the visibility of all members of the face team.
- Remote control transmitters limited to a maximum operating range of 15m.

Locomotives (Locos)

The following potential hazards and recommendations were derived from a study of two types of locomotive. These were the 18 ton (18T) and 25 ton (25T) locos. The 18T unit was provided with a single two-man cab at one end wherein the drivers had a swivelling seat that enabled them to always face the direction of travel. The 25T unit was provided with a one-man cab at each end so that by changing cabs the drivers were again always able to face the direction of travel.

Tasks considered

- General loco movement and shunting operations at stations and sidings.
- Coupling to mancarriages and materials cars
- Shunting operations.
- Passengers boarding and alighting mancarriages.
- Transporting mancarriages and materials cars.

Critical visual requirements

- Workmen and obstacles sufficiently far ahead of the loco to enable them to be detected and the loco to be stopped before collision.
- Shunters, guards, other workmen and obstacles directly in front of the loco to be detected before moving off.
- Couplings and shunters working directly in front of loco.
- Track sufficiently far enough ahead for the drivers to identify potential hazardous track conditions.
- Backwards along each side of the stationary train to see people getting in and out of carriages and signals from guards.
- Loose loads.
- Guards for communications purposes.
- Roadway signs

Potential visual limitations

- Poor lighting at rail stops, points, crossings, etc. and other areas where clear driver vision is essential.
- Headlight output diminishes at low engine speed.
- Defective headlights (bulbs expired, damaged mountings, result in miss-alignment).
- Restricted levels of illumination provided by headlights.
- Condition of windscreens (damaged, dirty etc,) impair driver vision.
- Driver's view of the guard and passengers boarding and leaving carriages on the off-side totally obscured.
- Windscreen damage combined with poor headlight illumination at low travel speeds creates the temptation for drivers to lean out of the cab to improve visibility.
- Drivers required to leave seat to see passengers boarding and alighting carriages on the near-side.
- Narrow windscreens restrict driver's forward view to the near-side of the roadway. Furthermore, the high sills on these windows restrict their view of the couplings.
- Limited provision of effective visual warnings on the rear unit of trains.
- Driver's view of the track ahead obscured by the presence of ground water.
- Inability to see speedometers as cap lamps have to be switched off due to reflections from the windscreen.
- Instruments not illuminated.
- Driver's view of the guards frequently obstructed.
- Glare from the rear lights of locos parked/travelling in same direction.

Potential hazards

1. Passengers in the act of climbing in and out of carriages injured when train moves off.
2. Derailment through failure to identify defective track ahead.

3. Derailment and collisions through over-speeding.
4. Collision into back of stopped trains.
5. Shunters trapped when coupling loco to carriages and materials cars.
6. Collision with obstacles ahead
7. Drivers injured when leaning out of cab.
8. Collision with other types of vehicles at crossings.
9. Struck by items entering the cab through broken or missing windscreens.

Recommendations

Illumination:

- Locomotives should be provided with at least two headlights for use in each direction of travel.
    - One headlight should be mounted low down to illuminate the track and couplings.
    - One headlight should be mounted high up to illuminate the roof and shine over the top of materials cars during shunting operations.
- A minimum of 10 lux in the direction of travel should be provided at a distance equal to the maximum stopping distance of the loco or at a distance of 5m from the loco, whichever is the greater. This illumination level should be achieved across the profile of the haulage.
- A red light should be fitted at each end of the loco operating as follows:
    - ◊ Headlight/taillight switching should be linked with the direction control to show white light in the direction of travel and red light at the other end.
    - ◊ When the direction control is in neutral, red taillights should appear at both ends if the engine is running.
- All displays that need to be monitored while the loco is in motion should be self illuminating to enable the drivers to read them without using caplamps.
- A red light should be mounted on the end of the last man-riding carriage or materials car in a train.

Sight lines:

In the acquisition of new locos, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved:

- Mines to regularly inspect and replace damaged windscreens.
- Windscreen wash/wipe facilities should be provided.
- Where necessary, wing/side mirrors should be provided to enable the drivers to look backwards along each side of the train without having to leave their seats, lean out of the cab, compromise any safe driving practices, etc.
- Where necessary, mirrors should be fitted to provide the drivers with a clear view of the couplings.
- In order to meet the critical visual requirements ahead of the loco, windscreen designs should enable all drivers to see:
    - ◊ Right across the roof and floor and up both sides from ground level to the roof of the haulage at a minimum distance of 5 metres and beyond.
    - ◊ The head of a stooped miner (1.3m above the floor) directly in front of the loco.
- Ideally important displays that need to be monitored while a loco is in motion, should not be more than 40° below the horizontal, or more than 20° above horizontal measured from the drivers, eye position. Its outer edges should not be more than 30° to either side of the drivers' eye positions.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment.

- Horns should be provided which can be clearly audible over the stopping distance of the loco but not so loud as to deter drivers from using them.
- Audible pre-tramming alarms should be provided.
- Greater control over boarding and alighting activities.
- Radio links between drivers and guards.
- Provision of interlock between driver control and mancarriage doors.
- Existing loco windscreens could be modified to improve driver's vision.
- Use of large reflective type signs.
- Use of high visibility clothing fitted with reflective strips.
- Provision of two-way mirrors at junctions/crossings.

Multi-purpose vehicles (MPVs)

There are essentially two types of MPVs. On the traditional type, the driver is provided with a forward facing seat in a cab located centrally on the right side of the vehicle. On a more recent type, the driver is located centrally on the vehicle. MPV trailers are used to transport a variety of detachable units (loads) such as closed containers, open skips, stone dusters, portable miners boxes, personnel carriers, etc. The following potential hazards and recommendations were derived from a study of both types of vehicle and the range of detachable units.

Tasks considered

- Reversing and attaching loads.
- Moving off
- Negotiating bends, junctions and ventilation doors
- Travelling roadways used by pedestrians or approaching areas where pedestrian activities take place.
- Operating in congested areas such as tips, material transfer stations, maintenance workshops, production sections, etc.
- Reversing to stone dust pumping stations.
- Travelling on roadways where clearances are restricted by the presence of stored materials conveyors, power packs, parked vehicles, pipe ranges, etc.
- Reversing into ‘splits’ to attach or detach loads or to turn the vehicles for travelling in the opposite direction.

Critical visual requirements

- Workmen and obstacles directly in front, to the rear and at each side of the vehicle when manoeuvring.
- Workmen standing behind the vehicle or load.
- Clearances between the roof or overhead structures and the driver canopy and load.

- Workmen and obstacles sufficiently far ahead of the vehicle for them to be detected and collisions avoided.
- Clearance between all four sides, corners and wheels of the vehicle and potential obstacles.
- The corners of turnings: from ground level to a point level with the top of the vehicle or load, whichever is the higher.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Clearances between load and trailer cradle arms, load anchor points and trailer hydraulics.
- Roadway signs.
- Roadway conditions.

Potential visual limitations

- Obstructed lines of sight
- Restricted illumination levels provided by mine lighting, particularly at crossings.
- Headlight output diminishes at low engine speed.
- Defective headlights (bulbs expired, damaged mountings, etc.) result in misalignment.
- Restricted levels of illumination provided by headlights.
- Obstructed lines of sight to the front (particularly towards the off-side) and rear of the vehicle.
- Restricted sight lines to the vehicle pivot points.
- Limited provision of effective visual warnings on moving or parked vehicles.
- Forward facing driving position restricts driver’s view of load when travelling forward.
- Line of sight restrictions and inadequate illumination on the load, cradle arms and anchor points create the temptation for drivers to lean out of the cab or leave their seats to improve their vision to the rear when attaching and detaching loads.

- Inadequate illumination combined with limitations in the design of some protective canopies restricts the driver's view of clearance between load and roof.
- Detachable units such as large containers, personnel carriers and miner's boxes completely obstruct the driver's view of the roadway in advance of the units when reversing.
- Driver's view of passengers boarding and alighting personnel carriers totally obscured.
- Inadequate provision of taillights

Potential hazards

1. Collision with pedestrians and maintenance staff when moving off, particularly in reverse.
2. Collisions while reversing.
3. Drivers injured when leaning out of the cab.
4. Collision with pedestrians and vehicles emerging from side roads, particularly on the off-side.
5. Collision with pedestrians and obstructions when entering turnings on the off-side.
6. Workmen caught in pivot point when vehicle articulates.
7. Collision with corners of turnings particularly on the off-side.
8. Drivers and other workmen injured by falling roof or equipment dislodged by load or canopy.
9. Passengers climbing in and out of personnel carriers injured when vehicle moves off.
10. Drivers and other workmen injured by falling roof or equipment dislodged by loaded trailer

Recommendations

Illumination:

- Two headlights should be fitted to the front of the vehicle, preferably one at each corner at least 1m off the ground.

- The headlights should provide a minimum illumination of 10 lux at 20m. The illumination levels should be adapted to the permissible speed limit for the vehicle and the maximum stopping distance at that speed.
- Two white lights with wide angled beams (i.e. 'diffuse lighting') should be mounted to the rear of the canopy and directed to illuminate the trailer cradle arms and anchor points and the top of any load being transported. These should be activated by an independent switch during coupling operations.
- Two white taillights should be fitted to the rear of the vehicle, preferably one at each corner. These should be interlinked with the direction of travel.
- The taillights should provide a minimum illumination of 10 lux at 10m.
- Where the load being transported extends beyond the trailer, the practicality of hooking the taillights (connected to extension leads) on the rear of the loads should be considered.
- At least one red taillight should be provided at the rear of the vehicle.
- The headlights and taillights should be switched automatically to show a white light in the direction of travel and a lower intensity red light at the trailing end.
- A red taillight should be provided on the unit cradle or at the rear of the unit being transported.

Sight lines:

In the acquisition of new MPVs, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved.

- Provision of adjustable-height seats (and canopies) to improve sight lines in all directions.
- Enhancement of the drivers general field of view by modifying the profile of the vehicles by, for example, chamfering the corners of the engine covers and relocating items from the top of the vehicles that obstruct the drivers view.
- Provision of alignment markers on containers to prevent collision damage during attachment.
- Enhancement of the drivers view of the critical areas behind the vehicle through the provision of suitably located mirrors.

- Modification of existing canopies to improve the driver's view of potential overhead obstructions.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment.

- Provision of visual tramming warnings on mobile machines/vehicles
- Provision of two way mirrors at junctions/crossings
- Use of reflective information signs e.g. Road signs, symbolic and other signs

Tractors

A wide range of tractors are used on the mines ranging from small two-wheel-drive units, where the drivers sit low down at the back between the two large drive wheels, to the more substantial four-wheel-drive units where the drivers generally are provided with a higher more central driving position. Tractors are essentially used as a general utility vehicle for towing a variety of sleds and trailers including personnel carriers. The following potential hazards and recommendations were derived from studies on a range of these units employed in typical transport operations.

Tasks considered

- Reversing and coupling onto loads.
- Moving off
- Negotiating bends, junctions and ventilation doors
- Travelling roadways used by pedestrians and approaching areas where pedestrian activities take place.
- Operating in congested areas such as tips, material transfer stations, garages, etc.
- Travelling on roadways where clearances are restricted by the presence of stored materials conveyors, power packs, parked vehicles, pipe ranges, etc.
- Reversing into ‘splits’ to attach or detach loads or to turn the vehicles for travelling in the opposite direction.
- Reversing trailers into ‘parking spaces’ at the side of roadways.

Critical visual requirements

- Workmen and obstacles in front, to the rear and at each side of the vehicle.
- Towing hitch/towbar
- Workmen stooping behind the tractor connecting and disconnecting towbars.
- Workmen standing behind trailers, especially loaded trailers.
- Obstacles in the roadway behind the rear wheels.
- Clearance between the roof and top of the drivers head, tractor and load.

- Workmen and obstacles sufficiently far ahead of the vehicle for them to be detected to avoid collisions.
- Clearance between the four wheels of the vehicle and potential obstacles.
- The corners of turnings: from ground level to a point level with the top of the tractor or trailer whichever is higher.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Loads while being transported.
- Roadway signs.
- Road and ribside conditions.

Potential visual limitations

- Obstructed lines of sight to the front and sides of the smaller vehicles where drivers have low seat positions.
- Lines of sight to the towing hitch, towbars and workmen stooping behind the tractor obstructed by the rear wheel arches and bulkhead behind the driver.
- Forward facing driving position restricts driver's view of load when travelling forward.
- Defective headlights (bulbs expired, mountings damaged), result in misalignment.
- Limited provision of effective visual warnings on moving or parked tractors
- Inadequate illumination from head and taillights.
- Headlight output diminishes at low engine speed.
- Drivers of some vehicles need to leave their seats to see when coupling up to trailers.
- Taillights on some tractors dazzle workmen involved in connecting and disconnecting towbars.
- Restricted illumination levels provided by mine lighting, particularly at crossings.
- Driver's view of passengers boarding and alighting personnel carriers totally obscured.

Potential hazards

1. Workmen trapped between tractor and trailers.
2. Collision with pedestrians and maintenance staff when moving off, particularly in reverse.
3. Collisions while reversing.
4. Drivers strike their heads against the roof or overhead equipment.
5. Drivers and other workmen injured by falling roof or equipment dislodged by load on trailer.
6. Passengers in the act of climbing in and out of personnel carriers injured when vehicle moves off.
7. Workmen in the roadways injured by objects thrown up by the rear wheels when reversing.
8. Collisions with oncoming vehicles where both right-hand and left-hand side driver equipment is used in the same haul/travelroad and a 'keep-left or-right' rule-of-road is enforced.

Recommendations

Illumination:

- Two headlights should be fitted to the front of the vehicle, preferably one at each side to maximise beam spread at least 1m off the ground.
- The headlights should provide a minimum illumination of 10 lux at 20m. The illumination levels should be adapted to the permissible speed limit for the vehicle and the maximum stopping distance at that speed.
- Two white lights should be mounted to the rear of the vehicle and directed downwards to illuminate the ground and coupling arrangements directly behind the tractor. Floodlights are preferred to enhance the peripheral vision of the drivers and their assistants when coupling trailers and minimise the risk of glare. These should be activated by an independent switch during coupling operations.
- Two white taillights should be fitted to the rear of the tractor interlinked with the direction of travel.

- Similar lights should be provided on the rear of trailers. The practicality of hooking the taillights (connected to extension leads) on the rear of the trailers should be considered.
- At least one red taillight should be provided at the rear end of the tractor.
- The headlights and taillights should be switched automatically to show a white light in the direction of travel and a lower intensity red light at the trailing end.

Sight lines:

In the acquisition of new tractors, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved.

- Provision of adjustable height seats to improve sight lines in all directions.
- Enhancement of the driver's general field of view by modifying the profile of the tractors by, for example, chamfering the corners of the engine covers, re-shaping the bulkheads behind the drivers and relocating items from the top of the tractors that obstruct the drivers view.
- Enhancement of the driver's view of the critical areas behind the tractor through the provision of suitably located mirrors.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment:

- Provision of visual tramming warnings on mobile machines/vehicles
- Provision of two-way mirrors at junctions/crossings
- Use of high visibility clothing with reflective strips
- Use of reflective information signs e.g. road signs, symbolic signs, etc.

Chain haulage system (CHS)

The following potential hazards and recommendations were derived from a study of systems that consisted of a series of bridge conveyors interconnected by mobile bridge carriers. A typical CHS includes an inbye Mobile bridge-carrier (MBC) with a hopper for material collection, a bridge conveyor, an intermediate MBC and bridge conveyor and an outbye MBC and bridge conveyor. The outbye bridge conveyor terminates at the section belt or other mine main haulage system. The MBCs are track driven units. A seated forward-facing operator compartment is provided on the right near the back of each unit.

Tasks considered

Tracking the MBCs backwards and forwards in unison with one another and with the heading machine

Critical visual requirements

- Workmen and obstacles ahead of the inbye MBC and behind the outbye bridge conveyor.
- Workmen, obstacles, ventilation ducting, etc. on both sides of the CHS, particularly adjacent to the corners of the MBC and the pivot points in the system.
- Clearances between the sides of the system and sidewalls, particularly between the central areas of the bridge conveyors and the corners of turns.
- Clearances between the sides of the system and the section conveyor.
- Water sprays and discharge of material onto the conveyor ahead of the operators.
- Workmen and ribside alongside and immediately behind the cabs.
- Roof and ribside conditions.

Potential visual Limitations

- No mine lighting provided in working sections.
- High visibility clothing with reflective strips not worn.
- Obstructed lines of sight to the off-side and rear of each MBC.

- Restricted forward vision caused by dust and spray from the continuous miner blown into the face of the leading MBC operator
- Inadequate spread of light from headlights and output impaired by heavy accumulations of dust.
- Output of additional headlights mounted on top of machine obstructed by the spray units.
- Lack of adequate illumination provided to the rear of the units.
- Inadequate illumination to the roof and sight lines obstructed by the canopies.
- Lack of provision of effective visual warnings of reverse movement.
- Defective light units (bulbs expired, mountings damaged, result in misaligned illumination, etc.)
- Restricted illumination provided by mine lighting in designated travelways.

Potential hazards

1. Operators, cable handlers and other workmen trapped between leading MBC and heading machine.
2. Injuries caused by driving over and damaging the supply cable to the continuous miner.
3. Drivers injured by objects entering the workspace.
4. Slipping tripping and falling when crossing over the machine.
5. Trapped between the cable handler and ribside in the section belt travelway.
6. Tripping and falling over spillage and over cables lying on the floor in the section belt travelway.
7. Workmen trapped between the CHS and sidewalls/obstacles, particularly on the off-side.
8. Collision with people and obstructions when reversing.

Recommendations

Illumination:

- Two headlights should be fitted to the front of each MBC.
- The headlights should be mounted on top of the machine, one at each corner.
- The lights should provide wide angled beams and illumination levels of at least 15 lux across the full profile of the heading 5m in front of each MBC.
- The headlights should be located where their beam spreads are not obstructed by the spray systems or any other aspect of the machine.
- A single wide-angled taillight should be mounted centrally on top of each MBC providing illumination levels of at least 10 lux at a distance of 5m.
- Additional illumination to the off-side and near-side of the bridge conveyors would be beneficial for detecting the presence of workmen in these areas and to enable these workmen to identify any tripping hazards. Ideally minimum illumination levels of 10 lux should be provided from ground level up to the height of the machine along the length of the conveyors.
- A pair of taillights should also be provided on the end of the rear bridge belt dolly.
- These taillights should be switched automatically to show a white light when reversing and a lower intensity red light when tramming forward.
- The white lights should provide a similar output characteristic to the front headlights.

Sight lines:

The chain haulage system observed was designed primarily for use in low-seam applications. While the operator's workplace on this equipment satisfies many of the recommendations relevant to the design of low-height cabs, it is inappropriate, from an ergonomics perspective, for use in the thicker seam (2,5 m) headings found in the mine visited. The physical restrictions placed on operators, particularly with regard to their field of view, are unnecessary. Given the apparent market potential for this type of haulage in South Africa, manufacturers should be encouraged to consider the development of a more appropriate design of cab for future versions of this equipment. In any such developments, consideration should be given to the critical visual requirements given above.

Also, European research on track-mounted machines recommends that:

- At the corners of the machine where speed of movement is greatest during slewing, points 0.75m from the machine and 1.0m high should be visible. (The recommendation is based on commonly observed positions of men and their typical worst postures for visual detection).
- At the sides of the machine, where lateral movement is least, points 0.75m from the machine and 1.3m high would be acceptable.

To meet these recommendations and generally improve sight line restrictions on existing systems, where practical,

- seats and canopies should be raised to the highest practical level to minimise sight line constraints
- the profile of the various units in the system should be modified by, for example,
  - ◊ keeping the height of spill plates to the minimum while maintaining operational efficiency,
  - ◊ relocating spray heads and headlights to more advantageous positions where they do not obstruct sight lines,
  - ◊ ensuring that air from the continuous miner dust extraction system is discharged on the opposite side to that of the cab of the MBC,
  - ◊ removing and relocating items from the top of the machines that obstruct the operator's view.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of the equipment, providing additional safety features such as emergency stops etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment.

- The provision of deflector plates on the back of the continuous miners to deflect the air stream away from the leading MBC drivers.

- Emergency stop push buttons should be provided, particularly on the off-side of the MBCs. They should be attention-gaining to enable operators to rapidly identify them. This can be achieved by making them large, mushroom shaped, at least 75mm diameter and brightly coloured (preferably red).
- Emergency stop chains/tripwires should be considered in an arrangement similar to that recommended for shearers. The chains/tripwires would run along the entire length of each bridge conveyor and be linked to switches which operate when the chains are pulled outwards, to the left or to the right by anyone working at the side of the machine.
- Pre-start audible and visual alarms.
- Use of high visibility clothing with reflective strips.
- Restrict work/access on the off side of the CHS to when the machine is switched off and locked out.

Continuous miners (CMs) and roadheaders

Continuous miners and roadheaders are very similar in both design and operation. The illumination and sight line requirements that are considered to be necessary for these two types of machine to be operated safely are also essentially the same. The following potential hazards and recommendations were derived from studies of a number of different machines operating in a range of heading systems and mining activities. Operations studied included conventional CM sections, stooping sections and development work. The following recommendations are applicable to track-driven machines operated from fixed on-board control stations located at either one of the rear corners.

Separate recommendations have been produced for remotely controlled versions of these machines and these are given at the end of the section.

Tasks considered

- Tramming forwards along roadways in production sections and into blind headings.
- Manoeuvring in headings to correctly line up the machines.
- Cutting and loading operations.
- Reversing the machines out of headings and turning.
- Cutting wedges in the ribsides to facilitate turning.
- Pick inspection/replacement.

Critical visual requirements

- Workmen and obstacles in front, to the rear and to the sides of the machines. In particular:
  - ◊ the supply cable and cable handler (second operator) to the rear,
  - ◊ workmen near the four corners of the machine where slewing movement (and, therefore, accident risk) is greatest,
  - ◊ workmen in front of the cutting head attending to the picks.
- Profile of the heading and the sides of the cutting head.

- Discharge conveyor, shuttle cars and hoppers.
- Clearance between the machine and the sides and corners of headings.
- Workmen, obstructions and equipment located in the entrance to turnings.
- Clearances between the roof and the cutting head and discharge conveyor.
- Roof and ribside conditions

Potential visual limitations

- No mine lighting provided in working sections (other than caplamps, machine lights).
- High visibility clothing with reflective strips not worn.
- Mainframe, chain conveyor and boom restrict lines of sight to the off-side of the machine.
- Boom and cutting head restrict lines of sight and illumination of workmen and obstructions in front of the machine.
- Insufficient illumination to clearly see the profile of the heading and the relative position of the cutting head through dust.
- Front and rear lights located where they are prone to damage and concealment by dust.
- The discharge conveyor obstructs the operator's view of an area behind the machine on the off-side and prevents visual communication with shuttlecar drivers.
- Sight line restrictions to the off-side of the machine, combined with the use of dark coloured clothing, restricts the visibility of the 2nd driver when guiding or 'spotting' for the main driver.
- Glare from arrangement of rear lights impairs the view of operators and workmen behind the machine.
- Design of protective canopies restricts operator's view of roof.
- Limited provision of effective visual warnings on moving machines.
- Inadequate illumination to the rear of the machine for the driver and workmen engaged in supportive activities.
- Defective light units not repaired.

Note that the above limitations are more pronounced in low seam headings.

Potential hazards

1. Workmen caught and trapped between the machine and the ribsides or other plant.
2. Spotters trapped by the machine or injured stumbling over obstacles on the ground.
3. Collision of machine with shuttle cars or chain haulage when reversing.
4. Collision with corners of headings.
5. Operators and workmen injured by falling roof - resulting through either failing to detect a potential 'natural' fall or from striking and dislodging material or equipment with machine conveyor or cutting head.
6. Cable handler and other workmen struck by reversing machine or left/right movement of the discharge conveyor.
7. Injuries caused by tracking over and damaging the supply cable.
8. Pick-maintenance crew caught by unexpected movement of machine or activation of cutting head.

Recommendations

Illumination:

- Two forward facing headlights should be provided, one on each side of the machine.
    - They should be positioned to illuminate the sides of the cutting head, wherever it is directed, and their beams should not be obstructed.
    - On roadheaders the lights should be attached to the machine so that the direction of the beams follow the movement of the cutter booms.
- Spotlights should be used in preference to floodlights. They should provide a minimum illumination of 20 lux at the drum/coal interface.
- They should not be positioned closer than 2m from the front of the cutting head to minimise the risk of damage, dust collection and loss of light output.

- Two integrated white/red rear headlights, switched by the track control(s) to show red when the machine is moving forwards or stationary and white when moving backwards, should be provided.
- The lights should be mounted one on each side of the machine. The beams should have sufficiently **wide spread** intensity to provide useful illumination to the rear of the machine when reversing. 10 lux at a distance of 5m from the rear of the machine should be regarded as the minimum.
- A flameproof tubular type light mounted near each rear corner of the machine should also be provided to aid cable handling activities, other workmen involved in ancillary tasks, and shuttlecar drivers.
- These lights should be positioned where they do not create glare and should be adequately protected from damage risk.
- They should provide a minimum illumination of 15 lux 3m from the rear of the machine.
- With the exception of the rear headlights, all machine lights should be interlocked with the main motor such that they are automatically switched on when the machine has been activated.

Sight lines:

In the acquisition of new machines, consideration should be given to the critical visual requirements given above. However, the recommendations below provide suggestions on how existing units can be improved:

- Ideally, the operator should be positioned at the centre of the machine to provide him with the best overall lines of sight around the machine, as well as to avoid obstructions such as force-ventilation ducting.
- European research on track driven machines recommends that, at the corners of the machine where speed of movement is greatest during slewing, points 0.75m from the machine and 1.0m high should be visible. (The recommendation is based on commonly observed positions of men and their typical worst postures for visual detection).
- The same research also recommends that, at the sides of the machine, where lateral movement is least, points 0.75m from the machine and 1.3m high would be acceptable.

- To meet these recommendations and generally improve sight line restrictions, where practical, the following should be considered:
  - ◊ large/tall components should be located away from the machine periphery,
  - ◊ chamfered external edges of components (e.g. cover plates, hydraulic tank etc.) should be located at the machine periphery
  - ◊ raised or adjustable-height seats should be provided where mining work-heights permit.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional way of compensating for limitations in the visual environment.

- Emergency stop push buttons should be provided at each corner of the machine where the risk of being trapped is greatest. The push buttons should be attention-gaining to enable operators to rapidly identify their location. This can be achieved by making them mushroom shaped, at least 75mm diameter and brightly coloured (preferably red).
- Pre start audible alarm. This could be interlinked with a time delay switch to the starter.
- Activating the water sprays for a number of seconds before the cutter motors are started to act as an additional warning.
- Use of highly visible clothing with reflective strips.

Recommendations for remotely controlled continuous miners and roadheaders

The tasks undertaken with remotely controlled continuous miners and roadheaders are essentially the same as those outlined above for similar machines which are operated

from fixed on-board control stations. The critical visual requirements are also essentially the same. However, one of the major advantages resulting from the application of remote control technology is that it gives operators the freedom to adopt a potentially infinite range of operating positions which enables them to overcome many of the visual limitations associated with fixed on-board control stations. This facility however has introduced a number of additional potential hazards. For example:

1. To enhance their view of the face and cutting head, operators may be tempted to work at the side of the machines where they would be at risk from being trapped by the machine against the ribside and exposed to noise, dust and roof and ribside falls.
2. When standing behind the machine, operators may be at risk from being struck by approaching shuttle cars or the movement of other machines, and from tripping over or being caught by the movement of supply cables.
3. While operating on foot there is an increased risk of tripping and falling over obstacles or uneven ground.

The illumination recommendations given above for machines with fixed on-board control stations are also applicable to remotely controlled machines. However, the following further recommendations could be considered as ways of compensating for the additional visual hazards.

- A higher standard of peripheral illumination to be provided in the locations most frequently adopted by the operators.
- Use of high visibility clothing (preferably reflective waistcoats) to improve the visibility of workmen to the operators of shuttle cars and other machines.
- Use of effective audible warnings on shuttle cars and other machines.
- Provision of appropriate visual aids that can be used from a position of relative safety to reduce any temptation operators may develop to work alongside the machines. For example, consideration should be given to the provision of:
  - ◊ inclinometers to display the angle of the boom,
  - ◊ columns of lights to indicate the height of the cutting head.
- High standards of housekeeping should be maintained to eliminate potential trip hazards.

Face drilling machine

The following potential hazards and recommendations were derived from a study of face drilling operations in conventional drill and shot-fire production sections. The recommendations produced are applicable to wheel driven machines operated from a seated forward-facing operating position located on one side of the machine between the front and rear wheels. A feature of this type of machine is the long, fully articulated, drilling boom which projects forward of the front wheels by up to 5m

Tasks considered

- Tramming forwards along roadways within production sections and into blind headings.
- Manoeuvring in headings to set the machines in the required drilling positions.
- Drilling the face which involves articulating the drilling boom to achieve correct drill position and alignment, drilling and retracting the drill.
- Reversing the machines out of headings and turning.

Critical visual requirements

- Drill boom assembly and chalk markings on the face of heading during drilling operations.
- Roof and ribside conditions.
- Clearances between the machine (particularly the tyres and boom assembly) and the sides and corners of heading/roadways.
- Supply cable, water hose and cable/hose handler to the rear.
- Workmen, machines and obstacles in front, to the rear and to the sides.
- Workmen, machines and obstacles in entrances to turns.
- Machine controls.

Potential visual limitations

- No mine lighting provided in working sections other than caplamps and the machine lights.

- High visibility reflective clothing with reflective strips not worn.
- Defective lights (bulbs expired, mountings damaged, etc) results in misaligned illumination.
- Insufficient spread of illumination to clearly identify the marks for drilling and the drill shaft in peripheral areas of the face.
- Limited provision of effective visual warnings on moving or parked machines.
- The boom assembly obstructs sight lines and illumination to much of the roadway ahead on the off-side and to the top row of holes and the drill shaft.
- The canopy and canopy supports obstruct the drivers forward view as well as their view of the roof.
- Beam spread from rear lights restricted by coils of cable/hose on hanger which leaves large areas of dark shadow.
- Inadequate illumination to the rear from machines fitted with single taillights.
- Line of sight restrictions and inadequate illumination combined with fixed forward facing seating arrangements create the need for drivers to adopt adverse driving postures and lean out of the cab when reversing.
- Cable/hose handler and other workmen dazzled by rear lights when tramming forwards and during drilling operations (all lights on the units observed remained switched on during operation).
- Obstructed lines of sight to the off-side and rear of the machine leaves much of the ribside and roadway obscured.
- When tramming forward workmen in front of the machine are dazzled by the headlights and are unable to see the protruding/leading end of the drill boom.

Potential hazards

1. Workmen trapped between the machine and the ribsides on the off-side.
2. Collision with workmen, machines and obstacles when tramming forwards and in reverse.
3. Workmen walk into end of boom of parked machine.
4. Other machines collide with boom of parked machine.

5. Collision with corners of headings.
6. Operators and workmen injured by falling roof or ribsides.
7. Injuries caused by driving over and damaging the supply cable.
8. Workmen caught by swivelling drilling boom when machine turns.
9. Cable handlers dazzled by the rear lights trip and fall over cable and other unseen obstacles behind machine.

Recommendations

Illumination

- Two or more forward facing light sources should be provided to ensure sufficient illumination over the range of movement of the drill carriage to facilitate positioning and clearance estimation.
- Floodlights are preferred to spot lights and they should be fairly well separated to provide a uniform distribution of light to minimise shadowing and transient adaptation effects.
- Mountings for the lights should be easily adjustable to be tailored to local requirements, but should not move or loosen under normal operation.
- Integrated white/red rear lights with a sufficiently wide distribution to cover all the critical requirements to the rear of the machine should be provided.
- The rear lights should be switched by the tramming control(s) showing red when the machine is stationary or moving forwards and white when reversing. White floodlights are preferred to provide a uniform distribution across the roadway and minimise glare effects.
- All lights should be located where, as much as possible, the beams are generally unobstructed by machine components.
- Illumination levels of at least 5 lux should be provided to detect the presence of personnel at the sides of the machine. Reflection of the front and rear lights should be sufficient provided that the minimum illumination produced by the lights is maintained.

Sight lines:

In the acquisition of new machines, consideration should be given to the critical visual requirements given above. However, design constraints on face drilling machines limit the extent to which improvements can be made to sight lines. Therefore, alternative methods of controlling the visual hazards may need to be identified, such as changing working practices or enhancing worker awareness of the machine through, for example, the provision of audible and visual pre-start and tramming alarm systems.

Additional Consideration

- High standard of housekeeping to be maintained to eliminate potential trip hazards.
- High visibility clothing with reflective strips to be worn.
- Provision of audible alarm system when machine is in travelling mode.

Loading machines

The following potential hazards and recommendations were derived from a study of loading operations in conventional drill and shot-fire production sections. The recommendations are applicable to pedestrian operated, track driven and gathering-arm loaders working in conjunction with shuttlecars. The machines stand approximately 1m high and the gathering arm units are mounted on a boom which can be swivelled to the left and right independently of the main body of the machine. The control stations are located mid-way along the right side of the machines approximately 4m from the end of the gathering arms. The operators have to stand or walk alongside the machines in this position when controlling the tramming and loading operations. A typical loading team consists of three men - the machine operator, a cable handler and a general assistant whose main duty involves standing at the side of the operator and watering down the product with a hose pipe.

Tasks considered

- Tracking forward along roadways within production sections and into blind headings.
- Manoeuvring in headings to initially set the machines at the required attitude and loading positions.
- Loading which involves operating the gathering arm unit and conveyor while the machine is traversed laterally across the face with a combination of forward and reverse slewing movements.
- Reversing the machines out of headings and turnings.
- Parking the machine.

Critical visual requirements

- Gathering arm and boom assemblies, coal pile and face of the heading.
- Workmen and obstacles in front, to the rear and sides of the machines. In particular,
  - ◊ the supply cable and cable handler to the rear,
  - ◊ shuttlecars,

- ◊ workmen near the four corners of the machine where slewing movement (and, therefore, accident risk) is greatest,
- ◊ assistant at the side of the machine hosing down the coal pile

- Roof, ribside and floor conditions.
- Clearances between the machine and the sides and corners of headings/roadways.
- Machine controls.
- Workmen, machines and obstacles in entrances to turns.
- Obstacles on floor at operator position.

Potential visual limitations

- No mine lighting provided at working sections.
- High visibility clothing with reflective strips not worn.
- Defective lights (bulbs expired, mountings damaged, resulting in misalignment of lights, etc.)
- Line of sight restrictions to the off-side leading corner of the spade create the need for drivers to stand on the machine to improve visibility.
- Insufficient levels of illumination at the sides of the machine, particularly the right side, where the driver needs to see the controls, any stumbling hazards and his assistant.
- The discharge conveyor obstructs the operator's view to the rear of the machine. This prevents visual communication with shuttlecar drivers and restricts the operator's view of people working behind the machine.
- Single rear taillights further restrict rearward visibility.
- Cable handlers, shuttlecar drivers and other workmen dazzled by glare from rear spot light when tracking forward and during loading operations (this light remained on irrespective of direction of travel).
- Limited provision of effective visual warnings on moving or parked machines.
- Insufficient spread of illumination to clearly identify fault lines and misfires.

- The difficulties involved in controlling tracking operations while walking at the side of the machine diverts the operator's visual attention from potentially hazardous events such as tripping over obstacles and being trapped against the ribside.

Potential hazards

1. Injuries caused by tracking over and damaging the supply cable.
2. Operators track the machine over their feet.
3. Operator on foot injured by unseen items turned up by wheels and tracks.
4. Cable handlers trip and fall over obstacles behind the machine.
5. Cable handlers and other workmen trapped between the machine and shuttle cars or the ribsides.
6. Collision with corners of the heading.
7. Collision with workmen, machines and obstacles when tracking in reverse.
8. Operators stumble over obstacles and are trapped between the machine and the ribside.
9. Operators fall from machine when standing up on the machine to improve their view.

Recommendations

Illumination:

- Two or more forward facing light sources should be provided to ensure a sufficient spread of illumination over the range of movement of the gathering head and face area to identify potential hazards.
- Floodlights are preferred to spot lights and they should be fairly well separated to provide a uniform distribution of light to minimise shadowing effects.
- The lights should be mounted on top of the machine, one at each side, in a position where they do not obstruct the operator's lines of sight and where the light beams are not obstructed by the forward profile of the machine.
- Integrated red/white rear facing lights with a sufficiently wide distribution to cover all the critical requirements to the rear of the machine should be provided. They should be mounted on top of the machine, one on either side of the conveyor unit.

- The rear lights should be switched by the tramming control(s) showing red when the machine is stationary or moving forwards and white when reversing.
- White floodlights are preferred to provide a uniform distribution across the roadway and minimise glare effects.
- Illumination levels of at least 5 lux should be provided to detect the presence of personnel at the sides of the machine. Reflection of the front and rear lights should be sufficient, provided that the minimum illumination produced by the lights is maintained.
- A side light (ideally floodlight) should be fitted below the control panel to illuminate the floor/work area of the operator. The light should be directed downward (to prevent glare/dazzle) and illuminate a 2 m zone centred on the controls to a minimum of 5 lux.

Sight lines:

In the acquisition of new loaders, consideration should be given to the critical visual requirements given above.

Also, European research on track mounted machines recommends that:

- At the corners of the machine where speed of movement is greatest during slewing, points 0.75m from the machine and 1.0m high should be visible.
- At the sides of the machine, where lateral movement is least, points 0.75m from the machine and 1.3m high would be acceptable.

These recommendations are based on commonly observed positions of men and their typical worst postures for visual detection.

Except for the operator's view of the rear off-side corner, all the loaders evaluated complied with these recommendations.

Additional considerations

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment.

- The provision on the machine of a seated operator compartment would considerably reduce the risk of operators tracking the machine over their feet and people being trapped between the machine and the ribsides.

- Emergency stop push-buttons to be provided at each corner of the machine, particularly the off-side corner where the risk of being trapped is greatest. The push buttons should be attention-gaining to enable operators to rapidly identify their location. This can be achieved by making them mushroom shaped, at least 75mm diameter and brightly coloured (preferably red).

- Enhancing section worker awareness by providing the machine with a pre-start audible alarm (or flashing light signal).
- Maintain high standard of housekeeping to eliminate potential tripping hazards.

Coal cutting machines

The following potential hazards and recommendations were derived from a study of typical face cutting operations in conventional drill and shot-fire production sections. The recommendations produced are applicable to wheel propelled machines that are controlled by forward-facing seated operators. The cutter bars are located to a boom. They can be swivelled to the left and right independently of the boom and, together with the booms, they can be inclined and rotated. The machines stand approximately 1m high and typically, an operator's eye height would be 1.5m off the ground. The control position is located centrally on the machines directly behind the boom, about 4m from the tip of the cutter bar. A typical loading team consists of three men - the machine operator; a cable handler and a general assistant whose main duty involves standing at the side of the operator and watering down the product with a hose pipe and clearing loose material from the slot.

Tasks considered

- Travelling forward along roadways within production sections and into blind headings.
- Manoeuvring in headings to initially set the machine at the required attitude and cutting position.
- Cutting, which involves simultaneously operating the cutter bar and boom swivel/rotate functions and traversing the machine laterally across the face with a combination of forward and reverse movements with full left or right steering lock applied.
- Reversing the machines out of headings and turnings.
- Parking the machine.

Critical visual requirements

- Cutter bar, boom assembly and face of the heading during cutting operations.
- Roof and ribside conditions.
- Clearances between the machine (particularly the tyres and cutter bar) and the sides and corners of headings/roadways.
- Workmen attending to the picks on the cutter bar.

- Machine controls
- Supply cable, cable handler and assistant to the sides and rear.
- Workmen, machines and obstacles in front, to the rear and to the sides.
- Workmen, machines and obstacles in entrances to turns.

Potential visual limitations

- No mine lighting provided at working sections other than caplamps and machine lights.
- High visibility clothing with reflective strips not worn.
- Defective lights (bulbs expired, mountings damaged, etc) result in misalignment of lights.
- Cable handlers, other machine operators and workmen operating behind the machine dazzled by glare from the rear spot light, which remained on, when tracking forward and during cutting operations.
- Limited provision of effective visual warnings on moving or parked machines.
- Inadequate illumination to the rear from machines fitted with single taillights.
- Insufficient spread of illumination to clearly identify socket holes on the face to detect misfired holes.
- Limited illumination along both sides of the machine.
- Cutter bar, when raised for tracking, obstructs sight lines and illumination ahead of the machine.
- When tramming forward, workmen in front of the machine are dazzled by the headlights and are unable to see the leading end of the cutter bar.

Potential hazards

1. Injuries caused by tracking over and damaging supply cable.
2. Cable handlers trip and fall over obstacles behind machine.
3. Collision with workmen, machines and obstacles when tramming forward and in reverse.
4. Workmen trip over cutter bar of parked machine.

5. Assistant trapped between machine and ribsides.
6. Other machines collide with cutter bar of parked machine.

Recommendations

Illumination:

- Two or more forward facing light sources should be provided to ensure a sufficient spread of illumination over the range of movement of the cutter bar and face area to identify potential hazards.
- Floodlights are preferred to spot lights and they should be fairly well separated to provide a uniform distribution of light to minimise shadowing effects.
- The lights should be mounted on top of the machine, one at each side, in a position where they do not obstruct the operator's lines of sight and where the light beams are not obstructed by the forward profile of the machine.
- Integrated white/red rear lights with a sufficiently wide distribution to cover all the critical requirements to the rear of the machine should be provided. They should be mounted on top of the machine, one at each corner.
- The rear lights should be switched by the tramming control(s) showing red when the machine is stationary or moving forwards and white when reversing.
- White floodlights are preferred to provide a uniform distribution across the roadway and minimise glare effects.
- Illumination levels of at least 5 lux should be provided to detect the presence of personnel at the sides of the machine. Reflection of the front and rear lights should be sufficient, provided that the minimum illumination produced by the lights is maintained.

Sight lines:

In the acquisition of new coal cutters, consideration should be given to the critical visual requirements given above. However, based on the sample of machines evaluated, sight line provision on coal cutters is satisfactory.

The following additional recommendations should however be considered:

- Emergency stop push buttons provided at each corner of the machine, particularly the off-side corner where the risk of being trapped is greatest. The push buttons

should be attention-gaining to enable operators to rapidly identify their location. This can be achieved by making them mushroom shaped, at least 75mm diameter and brightly coloured (preferably red).

- Enhancing section worker awareness by providing the machine with a pre-start audible alarm or flashing light warning system.
- Use of high visibility clothing with reflective strips.
- Maintain a high level of housekeeping to eliminate potential trip hazards in the operating area.

Roofbolting machines

The following potential hazards and recommendations were derived by studying a number of different roofbolting machines operating in a range of heading systems and mining activities. Operations included conventional CM sections, stooping sections, conventional drill and shot-fire sections and development work. The recommendations produced are applicable to:

- Track driven or wheel propelled machines
- Machines operated from seated forward-facing operating positions located at one of the rear corners.
- Machines operated from control stations located mid-way along one side which require the operators to stand or walk alongside the machines in this position when controlling the tramming or bolting operations.
- The installation of mechanical bolts and resin set bolts.

A typical bolting team consists of the machine operator and an assistant who acts as cable handler and feeds the bolts into the drill rig.

Tasks considered

- Tramming forward along roadways within production sections and into headings.
- Manoeuvring in headings to set the machine in the required drilling positions.
- Drilling and bolting,
- Reversing the machine out of the headings or turning it round in the heading and driving out forwards.
- Parking the machine.

Critical visual requirements

- Drilling rig assembly and chalk markings on the roof of the heading.
- Clearances between the machine and the sides and corners of headings/roadways.
- Supply cable, water hose and cable/hose handler to the rear.
- Workmen, machines and obstacles in front, to the rear and to the sides.

- Anyone standing close to the corners of the machine where slewing and turning movements (and, therefore, accident risk) are high.
- Assistant operator working on top of the machine, at the side of the drill rig and behind the machine.
- Roof and ribside conditions.
- Workmen, machines and obstacles in entrances to turns.
- Machine controls.

Potential visual limitations

- No mine lighting provided at working sections except caplamps and machine lights.
- High visibility clothing with reflective strips not worn.
- Defective lights (bulbs expired, mountings damaged etc) result in misaligned lights.
- Inadequate illumination from headlights.
- Insufficient illumination to clearly identify the marks for drilling and the drill shaft and any deterioration in roof conditions when drilling.
- Insufficient illumination in areas where potential hand traps exist.
- Limited provision of effective visual warnings on moving or parked machines.
- The drilling rig obstructs sight lines and illumination to the roadway ahead.
- The canopies and canopy supports obstruct the operators rear view and their view of the roof.
- Beam spread from rear lights restricted by coils of cable/hose on hanger which leaves large areas of dark shadow.
- Inadequate illumination to the rear from machines fitted with single taillights.
- Line of sight restrictions, inadequate illumination combined with fixed forward facing seating arrangements create the need for drivers to adopt adverse driving postures and lean out of the cab when reversing.
- Assistant, other workmen and machine operators dazzled by rear lights which remain on when tramming forwards and during bolting operations.

- The difficulties involved in controlling tramming operations while walking at the side of the machine diverts the operator's attention from potentially hazardous events such as tripping over obstacles, being trapped against the ribsides and being struck by unseen objects turned up by the tracks or wheels.

Potential hazards

1. Injuries caused by tramming over and damaging the supply cable
2. Operators on foot track the machine over their feet.
3. Operator on foot injured by unseen items turned up by wheels and tracks.
4. Cable handlers trip and fall over cable and other unseen obstacles behind the machine.
5. Assistant and other workmen trapped between the machine and the ribside.
6. Collision with workmen, machines and obstacles when tramming forwards and in reverse.
7. Operators on foot stumble over obstacles and are trapped between the machine and the ribside.
8. Assistant trips over obstacles on machine deck and falls from machine.
9. Assistant gets caught up or trapped in drilling rig.
10. Assistants injured by falling roof or ribside.

Recommendations

Illumination:

- Two forward facing light sources to provide sufficient illumination for safe tramming in the forward direction should be fitted.
- Spot lights mounted on top of the machine are preferred and they should be fairly well separated to shine round either side of the drilling rig.
- The lights should provide a minimum illumination of 10 lux across the heading/roadway 20m ahead of the machine.
- Two more light sources which provide sufficient illumination over the range of movement of the drill rig and the activities of the assistant involved in bolting

operations should be fitted. Flood lights are preferred to spot lights and these should be mounted and directed so that one illuminates the roof and drill rig and the other illuminates the top and sides of the machine.

- Mountings for these lights should be easily adjustable to be tailored to local requirements, but should not move or loosen under normal operation.
- Two integrated white/red rear lights with a sufficiently wide distribution to cover all the critical requirements to the rear of the machine should be provided. They should be mounted on top and near the corners of the machine.
- The rear lights should be switched by the tramming control(s) showing red when the machine is stationary or moving forwards and white when reversing.
- White floodlights are preferred to provide a uniform distribution across the roadway and minimise glare effects. They should provide a minimum of 15 lux across the heading at a distance of 5m from the rear of the machine.
- All lights should be located where, as much as possible, the beams are generally unobstructed by machine components.
- Illumination levels of at least 5 lux should be provided to detect the presence of personnel at the sides of the machine. Reflection of the forward facing and rear lights should be sufficient, provided that the illumination produced by the lights is maintained.
- For machines not fitted with operator platforms/compartments, a side light (ideally floodlight) should be fitted below the control panel to illuminate to floor/work area of the operator. The light should be directed downward(to prevent glare/dazzle) and a 2nd zone centred on the control to a minimum of 5 lux.

Sight Lines:

In the acquisition of new machines, consideration should be given to the critical visual requirements given above.

Also, European research on track mounted machines recommends that:

- At the corners of the machine where speed of movement is greatest during slewing, points 0.75m from the machine and 1.0m high should be visible.
- At the sides of the machine, where lateral movement is least, points 0.75m from the machine and 1.3m high would be acceptable.

These recommendations are based on commonly observed positions of men and their typical worst postures for visual detection. Due to small turning circles achievable on the wheel propelled roofbolters provided by their twin steering axles, the recommendations can be regarded as being applicable to both classes of machine.

Operator's sight lines to these and other important areas can be enhanced by:

- The provision of higher seats where normal mining seam heights allow
- Modification of canopies and canopy supports
- Modifying the profile of the machines by, for example, chamfering off unnecessary corners and relocating items from the top of the machines that obstruct the driver's view.
- Relocating cable storage reel to a position where it would not interfere with or impair illumination sources provided on the machine.

Additional considerations

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional way of compensating for limitations in the visual environment:

- The provision of visual tramming warnings
- Provision of horns/audible systems for use when the machine is being moved to a new location
- Enhancing worker awareness by providing the machine with a pre-start audible alarm or flashing light system.
- The provision on the machine of a seated operator compartment would considerably reduce the risk of operators tracking the machine over their feet, people being trapped between the machine and the ribsides and operators being injured by unseen items turned up by the wheels or tracks..

- Provision of water tanks on the machine to eliminate the hazards associated with handling trailing water hoses.
- Emergency stop push buttons provided at each corner of the machine, particularly where there are sight line restrictions and the risk of being trapped is high. Such push buttons should be attention-gaining to enable operators to rapidly identify their location. This can be achieved by making them mushroom shaped, at least 75mm diameter and brightly coloured, preferably red.
- Maintain high housekeeping standards to prevent tripping – for machines without operator compartments.

Shuttlecars

A number of different types of shuttlecar are used on the mines ranging from low to high profile units. The systems of mining within which they are employed also differ. The following potential hazards and recommendations were derived by studying a number of different units working in conjunction with continuous miners, roadheaders and loaders in CM sections, stooping sections and conventional drill and shot-fire sections.

Shuttle cars are provided with a single operator cab, which may be located on either side of the unit. The cabs are fitted with dual seating arrangements, which enable the operators to face either direction of travel. The cabs are located 2m-3m from the inbye loading end of the units. The recommendations are applicable to all types of units.

Tasks considered

- Manoeuvring up to and maintaining station with a CM, roadheader, or loader discharge conveyor while loading is undertaken.
- Manoeuvring up to feeder breakers or tips and discharging the load.
- Travelling through sections which involves negotiating:
  - ◊ left and right turns;
  - ◊ roadways used by pedestrians and areas where pedestrian activities take place; and
  - ◊ areas where other machines or vehicles may be in use.
- Queuing to load and discharge at the inbye and outbye ends of a section. (It is normal to employ two or three shuttlecars in a section. To minimise the risk of them colliding with one another, each is allocated an individual route through the section. However, at each end of the section the routes converge and the shuttlecars have to queue and integrate their loading and discharging activities.)

Critical visual requirements

- Workmen directly ahead and to the sides when manoeuvring in areas of pedestrian activity, particularly at each end of the section e.g. CM cable handlers and tip attendants.
- Discharge conveyor and visual signals from operators of heading machines.

- Ends of the shuttlecar discharge conveyors and receiving hoppers at the outbye tipping points.
- Other shuttlecars and machines emerging from side roads.
- Workmen and obstacles sufficiently far enough ahead for them to be detected to avoid collisions.
- Clearances between the shuttlecars and the corners of turnings.
- Workmen and vehicles in the entrances to turnings.
- Leading corners of the shuttlecar.

Potential visual limitations

- Obstructed lines of sight to the front, particularly the front off-side of the shuttle car in both directions.
- Sight lines to cable handlers and other workmen operating behind the heading machine (CM or roadheader) are obscured when shuttlecars are used which have cabs located on the off side.
- Similarly, sight lines to feeder breaker/tip attendants and the discharge points are obscured when shuttle cars are used which have cabs located on the off side.
- Obstructed lines of sight extend along the complete off-side of the vehicle
- Restricted illumination levels provided by mine lighting at tips and feeder breakers.
- No mine lighting provided elsewhere in working section
- High visibility clothing with reflective strips not worn.
- Defective light units e.g. bulbs expired, mountings damaged, lights obscured by mud/dust, lights misaligned.
- Headlights vulnerable to contamination when working in dusty or muddy conditions.
- Narrow spread of headlight beams leave an area of dark shadow directly in front of shuttle cars.
- Line of sight and headlight restrictions create the temptation for drivers to stand up or lean out of the cab to improve their vision.
- Lines of site and illumination to the corners of junctions and the potential collision points on the vehicles obstructed.

- Limited provision of effective visual warnings on parked or moving vehicles.
- Light reflected from brightly painted cab interiors create glare problems for the drivers.
- On some vehicles light output diminishes when accelerator pedals are released.

Potential hazards

1. Cable handlers and other workmen trapped between the mining machine and shuttlecar.
2. Workmen trapped between the shuttlecar and tip or feeder breaker.
3. Collision with people and other objects in the path of the vehicle.
4. Collision with other shuttlecars and machines at junctions
5. Injuries caused by driving over and damaging supply cables.
6. Collision into the back of heading machines and into feeder breakers.
7. Operators fall from machine or strike objects in the roof when standing to improve their view.
8. Operators injured through contact with unseen objects fixed to the sides of roadways, particularly at corners.
9. Workmen trapped between shuttlecars and the ribside.
10. Drivers injured leaning out of cabs to improve their vision.

Recommendations

Illumination:

- At least two integrated white/red headlights should be fitted to each end of the shuttle car as close a possible to the corners facing in the direction of travel.
- The lights should be switched automatically to show a bright white light in the direction of travel and a lower intensity red light at the trailing end.
- Assuming a 20 km/h top speed and/or mine speed limit, headlight illumination in the direction of travel should provide 10 lux at 20m.

- The positioning of lights, light separation, depth and size of the recess within which they are mounted and beam angle should be designed to minimise any dark areas in front of the shuttle car.
- Provision of visual tramming warnings
- Cab interiors should be painted a dark matt colour to minimise reflections.

Sight lines:

In the acquisition of new machines, consideration should be given to the critical visual requirements given above.

The inherent design of shuttle cars and the operational conditions within which they work constrain design initiatives to improve sight lines. It is possible that in some cases marginal improvements could be achieved by increasing seat height, however, alternative methods of controlling the visual hazards, such as changing working practices, are likely to be more productive. The following ideas could be considered.

- The provision of small ramps or buffers at feeder breakers to prevent collision.
- The use of an effective signalling system at queuing points to control shuttle car movement.
- Using shuttle cars with cabs located on the same side as those provided on the heading machines.
- Audible tramming alarms
- Provision of two-way mirrors at critical junctions e.g. feeder breaker.
- Consideration should be given towards mounting automatically rechargeable battery powered parking light on a prominent position on all mobile equipment operating inside the section to enable the shuttlecar operator to avoid collisions with parked vehicles.

Additional considerations:

Where design constraints prevent improvements to illumination and sight lines, alternative means of controlling the visual hazards need to be identified such as, for example, changing working practices, enhancing pedestrian awareness of the presence

of vehicles and machines, providing additional safety features such as emergency stops, etc.

The following recommendations would not improve sight lines or lighting standards but could be considered as additional ways of compensating for limitations in the visual environment.

- Operators to frequently check and clean light lenses.
- Provision of visual tramming warnings

Measuring sight lines on mobile machines

Considerations in the measurement of light lines

One of the major ergonomic limitations governing the safe and efficient use of mining machinery is poor visibility from the operating position. Visibility is characteristically poor on mobile machines and is particularly poor on the free steering range of trackless vehicles such as LHDs, shuttle cars, continuous miners etc.

In order to provide machines with satisfactory operator visibility, it is essential first to know the important areas that the operators will be required to see to enable them to work safely. Secondly it is important to have a means of assessing the sight lines provided by the machines against these visual targets. Assessing vehicle sight lines in this way provides a method of focusing attention on a number of issues. These are

- design or retrofit changes
- selection decisions i.e. comparing one machine against another
- mine operational considerations such as the provision of driver training aids, determining the preferred direction of travel or the best position to place a load for particular operations or, ultimately, in influencing the design and layout of roadways or mine infrastructure.

Central to an assessment of the individual machines against the operator's minimum visual requirements is the ability to measure the operator's sight lines.

In order to determine a suitable method of measuring and recording operators sight lines for the study and for further general use within the industry, a review of applicable sight line assessment procedures was undertaken. The sight line assessment procedures considered ranged from relatively straight-forward shadow graph, photographic and line-of-sight techniques to more complex computer based three-dimensional modelling techniques. All the techniques have, at some time, been applied with varying degrees of success in mining.

The suitability of any sight line measuring technique will depend on the type and circumstances of the investigation required. A technique used, for example, to assess the implications of sight lines in an accident investigation will probably not be effective if

used in the design process to predict the benefits to sight lines from locating a workplace at different locations on a machine. Similarly, the techniques which can be used will also be affected by the location of the machine i.e. in use underground; in a surface simulation, on open ground on the surface; or whether only design drawings or scale models are available for the assessment.

The type of machine requiring assessment also needs to be taken into consideration when determining a suitable sight line measuring technique. For example, the visibility requirements for drivers of locomotives concern, primarily, forward vision which does not require any specially developed techniques to measure. In contrast, the visibility requirements for drivers of LHDs are more complex. They need to see equally well in either direction and they also need to see the whole perimeter of the vehicles so that they can successfully manoeuvre them around corners. LHDs would therefore require a correspondingly more detailed and accurate method of assessment.

Basic requirements for an appropriate sight line measuring technique

The basic requirements for a sight line assessment procedure that would be appropriate to meet the requirements of the majority of mines are:

1. A standard method of assessing the wide range of machines used in an underground environment where there are likely to be spatial constraints.
2. A simple but effective and repeatable method of assessing the machines in their existing working surroundings thereby avoiding the need to create special test environments and minimising any unnecessary intrusion on machine availability.
3. A means of enabling attention to be focused on the areas where significant visually related hazard potential has been identified i.e. the critical visual attention areas.
4. A system which would not require the use of expensive or sophisticated scientific apparatus or equipment which would require special certification for underground use.
5. A straight forward practical approach that could be adopted subsequently by the mines for their own purposes, for example, for use in risk assessments, making selection decisions, identifying potential design retrofit improvements, identifying improvements to the operational system and the environment in which the machines are used etc.

From the review of applicable sight line assessment procedures it was possible to identify a technique which met the above basic requirements. This was the simple ranging pole technique described below.

A sight line assessments using a ranging pole

Equipment required

The equipment required is very simple comprising:

A 15 m tape measure

A small 2 m tape measure

A 2m-long graduated ranging pole

A notebook or notepad to record the measurements

Eye-height poles of lengths corresponding to the sitting and standing eye-heights of the 5th and 97,5th percentile miners may also be necessary.

Method

The basic procedure that should be adopted is as follows:

1. The machine should be positioned on a flat surface with at least 1 m clearance all round it.
2. On one side of the machine, a distance of 0,5 m or 1 m should be measured from the machine at two points and marked with small pieces of stone.
3. The 15m tape measure should be run across these stones extending 0,5 m or 1 m beyond each end of the machine depending on whether the tape measure has been placed 0,5 m, or 1 m from the side of the machine.
4. The 15 m tape should be fixed down on the floor with more stones.
5. The ranging pole should be positioned on one end of the tape and at 0,5 m intervals the areas on the ranging pole which are visible to the driver when he is located in his normal driving position should be recorded. When assessing the driver's visual target areas the 0,5 m intervals can be increased or reduced to whatever is deemed to be a more appropriate increment, for example, every 20 cm.
6. The procedure should be repeated for the other three sides of the machine.
7. The following additional measurements should also be taken:

The drivers eye position from the ground.

The distance of the driver's eye position from the front and back of the machine i.e. measurements taken from the eye position along the longitudinal axis of the machine.

The distance of the driver's eye position from the two sides of the machine i.e. measurements taken from the eye position along the lateral axis of the machine.

Two people are required to apply the technique. One person should act as the 'observer' by adopting the normal driving or operating position on the machine and sighting the ranging pole in its various positions. The other person should be responsible for placing the pole in the various assessment positions and, for each position, recording the regions of the pole that can and that can not be seen by the observer.

If the assessment is being undertaken with the intention of subsequently modifying a machine to improve the operator's field of vision, the features of the machine which obstruct the observer's view of the ranging poles should also be recorded.

The basic procedure outlined above can be extended or refined to accommodate more in-depth assessments. For example, in zones where line of site restrictions are critical, it may be necessary for the assessment to consider the different eye heights associated with drivers of different stature and the range of seating adjustment, the range of available head and body movement or the different operational conditions of a machine. Modifications to the basic procedure to take account of such conditional changes are outlined below.

Different eye heights: Machines should be designed to provide adequate lines of sight for both short and tall drivers. This provision can be examined in the assessment by the observer simulating the 5th and 97,5th percentile eye heights respectively using the recommended eye-height poles. In the majority of cases, however, it would be unnecessarily time consuming and of little practical value to routinely undertake a very detailed all-round assessment of a machine from both the 5th and 97,5th percentile eye heights. It would be more appropriate to focus the assessment of certain features or areas of the machine from either the 5th percentile eye height or the 95th percentile eye height. For example, when the downward field of view is likely to be obstructed by, for instance, engine housings, buckets, aprons, etc., it would be more appropriate to adopt the 5th percentile eye height position as the worst case condition in the assessment. Conversely, when the upward field of view is likely to be obstructed by an overhead

canopy or the top of a windscreen, it would be more appropriate to adopt the 97,5th percentile eye height position as the worst case condition in the assessment. Before a sight line assessment is undertaken a preliminary examination should therefore be made of the machine to determine an assessment strategy that provides meaningful results and at the same time avoids unnecessary duplication of effort.

For the South African mining industry eye heights for the 'observer' should be set at:-

5th% seated = 674 mm from the upper surface of the compressed seat

5th% standing = 1486 mm from the floor of the driving compartment

97.5% seated = 795 mm from the upper surface of the compressed seat

97.5% standing = 1700 mm from the floor of the driving compartment

Seat adjustment: Seats can be provided with lateral and vertical adjustment. However, unless a special investigation is undertaken to examine the influence of seat position on line of sight provision, it is recommended that sight line assessments be carried out with the seats set in their mid-point positions. Attempting to examine the combined influence of various combinations in both seat adjustment and seated eye height can create unnecessarily complex and often meaningless results.

Varying head movement: When assessing sight lines, head and body movement should be restrained within comfortable postural limits and within the confines of the cab.

Different machine conditions: A feature of many types of mining machine is that they have large sections or components that are moveable relative to the main body of the machines, for example, ranging arms and booms, buckets, drilling rigs, etc. The operating positions of these movable elements can have an important influence on driver sight lines and may need to be taken into account by the assessment. In contrast to many of the available sight line assessment techniques, the system outlined above can be used to assess machines with the movable elements orientated in their different operating configurations.

Data presentation and analysis

There are essentially two methods of presenting and analysing the recorded data. These are side plots and polar plots.

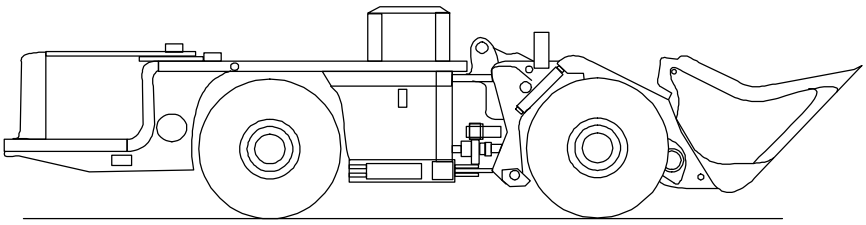
Side plots

These are the most straight forward method of presenting and analysing the data. They also constitute the most meaningful method for dealing with the majority of mobile machines used in underground coal mining operations. The basic procedure that should be adopted is as follows:

1. A scale plan elevation of the machine should be drawn with the operators eye position shown.
2. Lines representing the positions of the 15 m tape around the machine should be drawn on the plan.
3. The points at which each ranging pole measurement was taken should be superimposed on each tape line.
4. The lines representing the tape form the bases of four graphs on which should be plotted the points recorded in the assessment for each position of the ranging pole.
5. The areas on the completed plots which represent regions on the ranging pole that the 'observer' was unable to see should be shaded to represent them as 'blind spots' i.e. those areas close to the machine that operators would be unable to see without, for example, leaving their seat, leaning out of the cab, adopting adverse working postures etc.

Two examples of a sight line assessment using this method of analysis are given below.

Example 1. Sight line assessment of an LHD



Side plots for this machine are shown in Figure 1. The measurements were taken 1.0 m from the sides of the machine. Since it was the operator's downward field of vision that was most restricted the assessment was undertaken from the 5th percentile eye height position. From such a plot it is possible to assess whether the operators critical visual requirements detailed in the previous section of the recommendations are accommodated. For instance, the first critical visual requirement listed for LHDs is:

> "Workmen and obstacles to the front, to the rear, in close proximity to the pivot point of the vehicle and at each side of the bucket or load"

To examine the provision of this requirement in relation to the presence of workmen, lines have been superimposed on the plots which represent the height of a South African mine worker of 5th percentile stature adopting both stooped and erect postures. The plots clearly show the regions where small operators would experience difficulties in detecting the presence of such workers who adopt these postures.

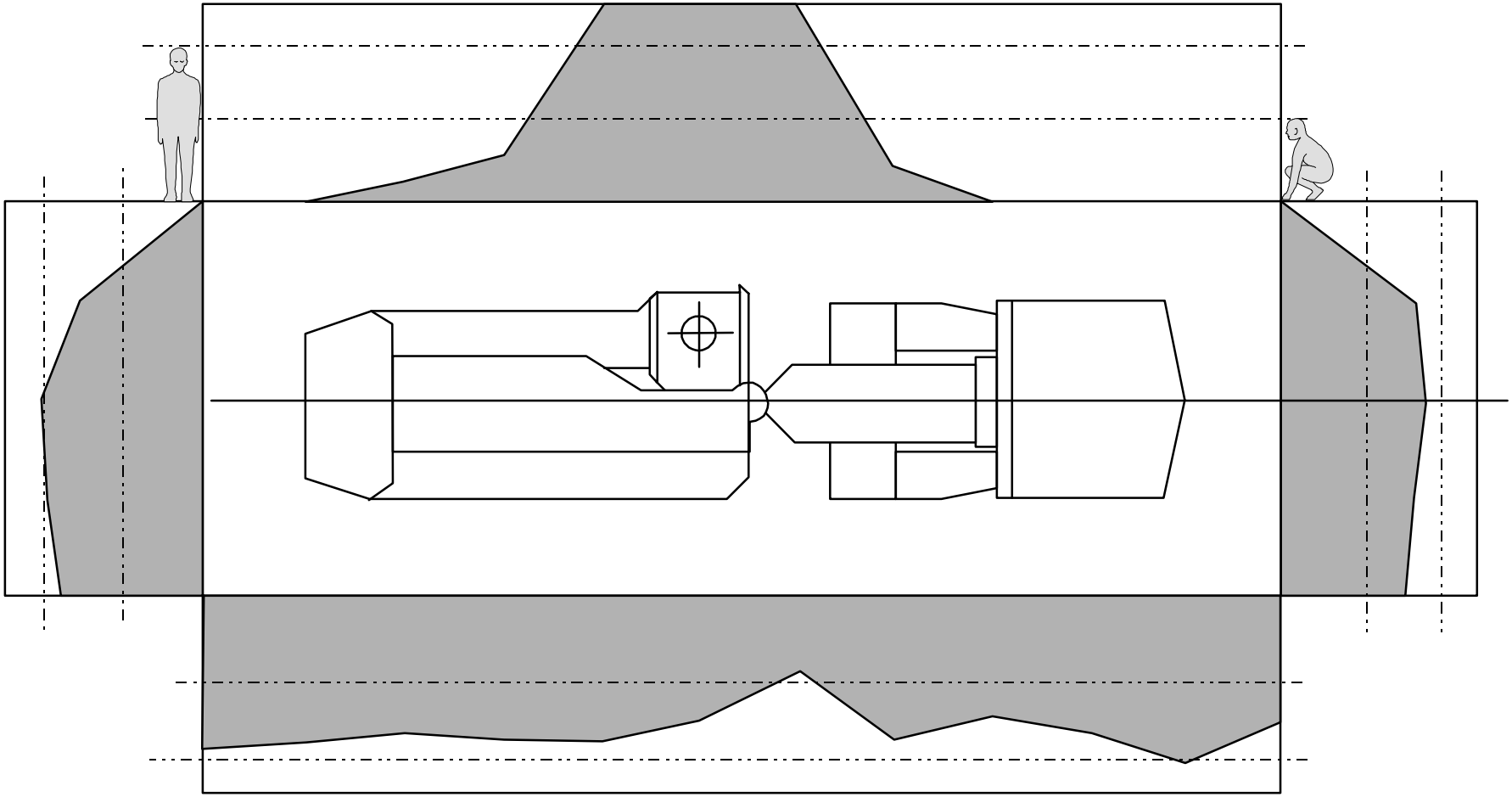
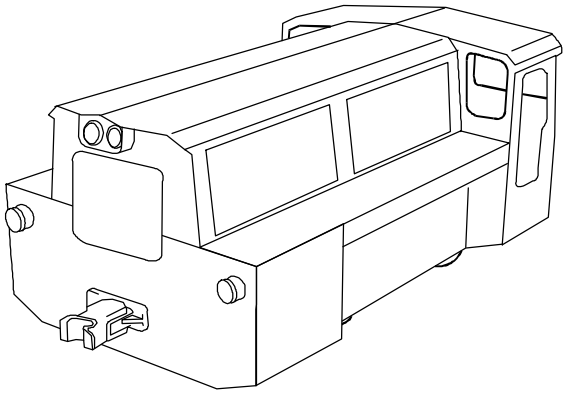


Figure 1. Sight line assessment of an LHD using side plots

Example 2. Sight line assessment of a locomotive



Side plots for this machine are shown in Figures 2 and 3. This type of loco was provided with a single two-man cab at one end wherein the drivers had a swivelling seat which enabled them to always face the direction of travel. It was necessary therefore to carry out two sight line assessments, one for each direction of travel. Figure 2. shows side plots for an assessment carried out with the engine trailing and Figure 3. is the corresponding assessment undertaken with the engine leading. Again, lines representing the a 5th percentile stooping and erect mine worker have been superimposed on the plots to provide a means of examining the machine in relation to the operators critical visual requirements.

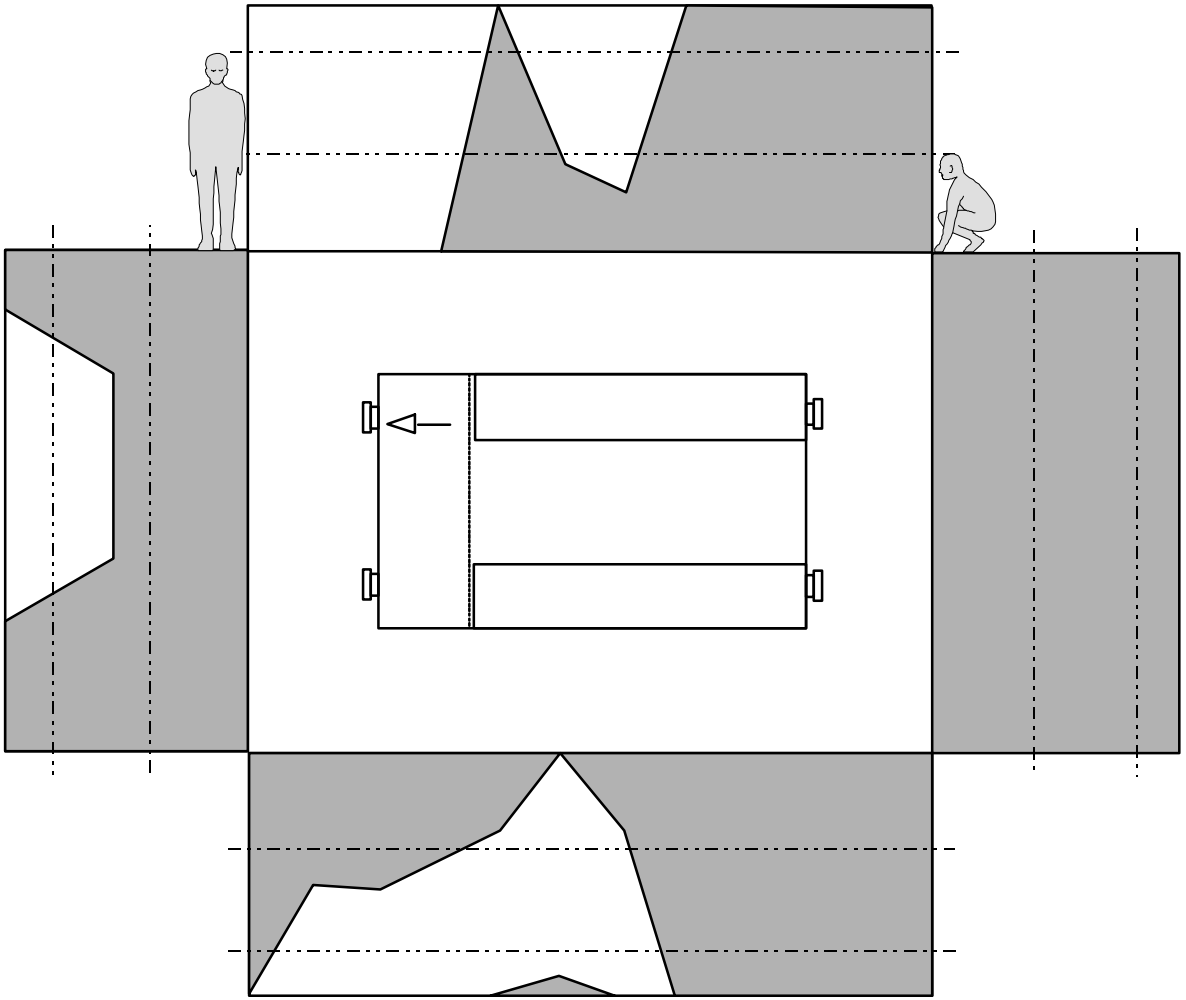


Figure 2. Sight line assessment of a locomotive using side plots (Engine trailing)

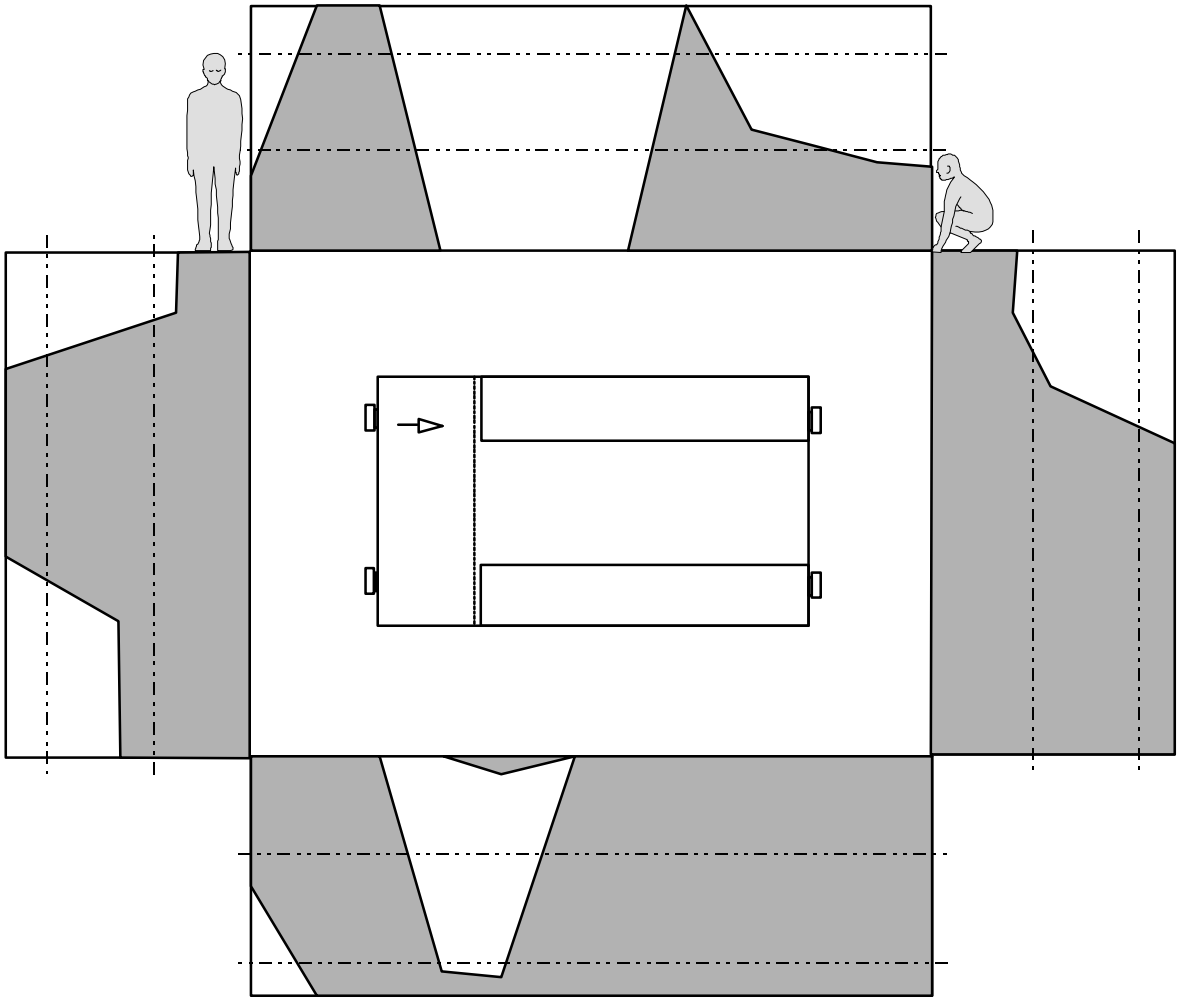


Figure 3. Sight Line Assessment of a locomotive using Side Plots (Engine Leading)

Polar Plots

These are less straight forward to produce than side plots and are more appropriate for assessing mobile machines employed in surface mining activities which potentially can be turned and driven off in any direction. For this reason sight line assessments need to take account of the drivers wider field of vision all round the machine, The basic procedure that should be adopted is as follows:

1. A scale plan elevation of the machine should be drawn with the operators eye position shown.
2. The position of the 15m tape around the machine should be drawn on the plan.
3. The points at which each ranging pole measurement was taken should be superimposed on each tape line.
4. The horizontal distances between each ranging pole position and the eye position should be scaled from the drawing.
5. The distance L at which the ground, stooping height, erect standing height or any other relevant height can be seen should then be calculated using similar triangles.

The formula for calculating the distance at which the ground can be seen is:

$$L=ED/(E-R)$$

Where: D is the horizontal distance between each ranging pole position and the eye position

E is the height from the ground, stooping height, erect standing height or any other relevant height to the operators eye position.

R is the height from the ground, stooping height, erect standing height or any other relevant height to the measurement recorded on the ranging pole.

Appropriate modifications will have to be made to the values of E and R to calculate the distances at which stooping height, erect standing height or any other relevant height can be seen.

6. The resulting distances should be used to construct a polar plot on the drawing.

An example of a polar plot produced for a road heading machine is shown below in Figure 4.

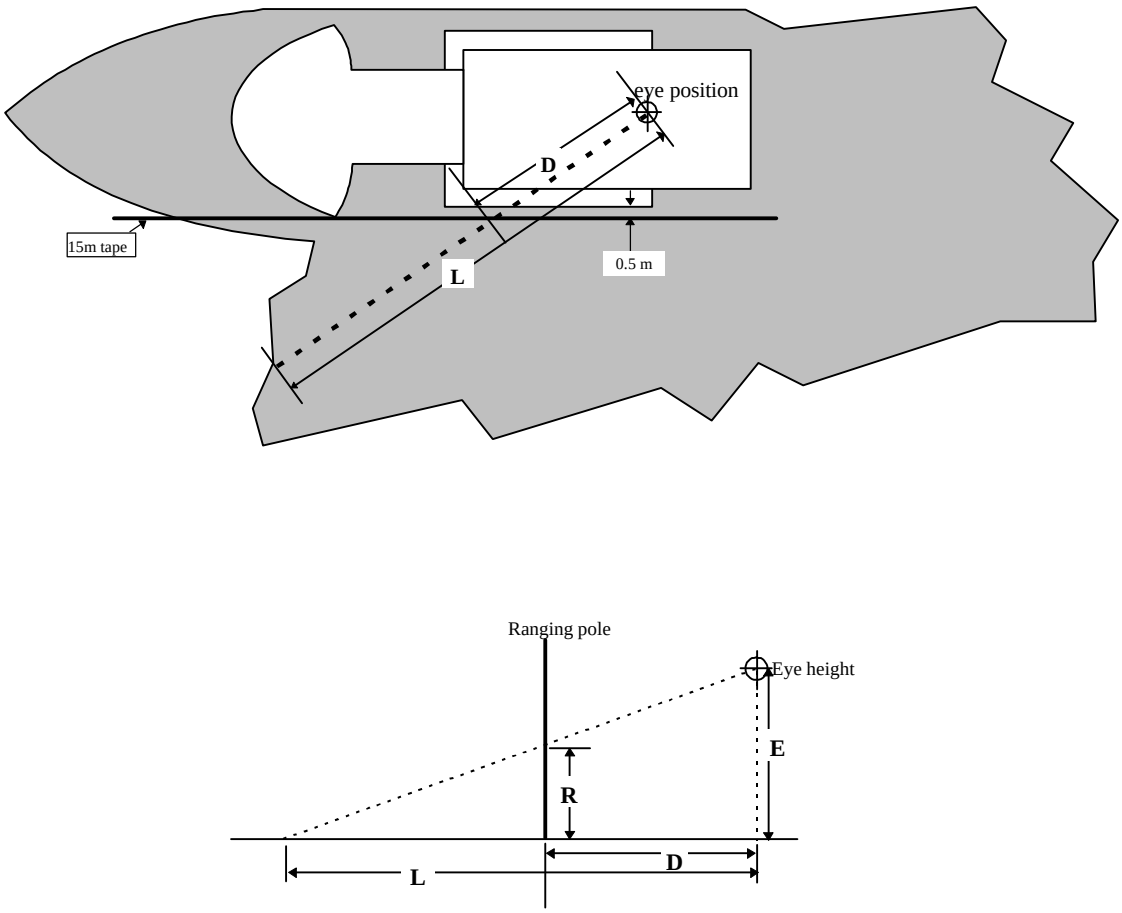


Figure 4 Sight line assessment of a roadheader using a polar plot